BNSF Railway Company

Remedial Investigation Work Plan

Time Oil Bulk Terminal – BNSF Property

Agreed Order No. DE 18042

Facility Site Identification No. 75486194

Cleanup Site Identification No. 14604

June 26, 2023

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Acronyms and Abbreviations

AOC	area of concern
Arcadis	Arcadis U.S., Inc.
AST	aboveground storage tank
bgs	below ground surface
BNSF	BNSF Railway Company
BTEX	benzene, toluene, ethylbenzene, and xylene
CAP	Cleanup Action Plan
CSM	conceptual site model
CVOC	chlorinated volatile organic compound
cis-1,2-DCE	cis-1,2-dichloroethene
DNR	Department of Natural Resources
DRO	diesel range organics
DQI	data quality indicator
Ecology	State of Washington Department of Ecology
EDR	Engineering Design Report
EIMS	Ecology Environmental Information Management System
GRO	gasoline range organics
HO	heavy oil
IDW	Investigation-derived waste
ISS	In situ solidification and stabilization
LNAPL	light non-aqueous-phase liquid
mg/kg	milligrams per kilogram
MTCA	Ecology Model Toxics Control Act
NAVD88	North American Vertical Datum of 1988
Pace	Pace National Center for Testing and Innovation of Mt. Juliet, Tennessee
PCP	pentachlorophenol
PRB	permeable reactive barrier
PVC	polyvinyl chloride
QA	quality assurance

QAPP	Quality Assurance Project Plan
QC	quality control
RIWP	Remedial Investigation Work Plan
SAP	Sampling and Analysis Plan
SES	SoundEarth Strategies, Inc.
SHA	site hazard assessment
TCE	trichloroethylene
TEE	terrestrial ecological evaluation
TGI	Technical Guidance Instruction
TOCST	TOC Seattle Terminal 1, LLC
TPH	total petroleum hydrocarbons
µg/L	micrograms per liter
VC	vinyl chloride
WBZ	water bearing zone

1 Introduction

On behalf of BNSF Railway Company (BNSF), Arcadis U.S., Inc. (Arcadis) has prepared this Remedial Investigation Work Plan (RIWP) for the BNSF Property within the Time Oil Bulk Terminal Site, located in Seattle, Washington (Figures 1 and 2). This RIWP describes the activities to be undertaken to evaluate the nature and extent of releases within the BNSF Property to determine whether any interim actions are necessary and to inform selection of final remedial actions, as described in the Agreed Order No. DE 18042 (State of Washington Department of Ecology [Ecology] 2021).

1.1 Purpose

This RIWP presents BNSF Property-specific information, including, but not limited to, historical operations, previous investigations, and characteristics of the BNSF Property. Existing environmental data from previous investigations were evaluated to identify data gaps that will be the basis for the investigatory activities described herein. The purpose of this RIWP is to define the activities that will be completed to fill data gaps in site characterization, specifically confirming the vertical and horizontal extent of contamination in soil and groundwater.

This RIWP includes a Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) as Appendix A that describes the organization, objectives, and specific quality assurance (QA) and quality control (QC) procedures for field and laboratory activities associated with sample collection proposed for remedial investigation data collection and analyses.

1.2 Key Project Personnel

Contact information for the property owner's representative, Ecology project coordinator, environmental consultant, and supervising geologist are listed below:

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2 Site History and Background

2.1 General Site Information

The BNSF Property is part of the Time Oil Bulk Terminal Site, located in the Magnolia neighborhood of Seattle, Washington. The Time Oil Bulk Terminal Site is located within the Ballard Interbay North Manufacturing Industrial Center, with a portion located along the waterfront area of Salmon Bay (City of Seattle 2022a and 2022b). The Time Oil Bulk Terminal Site consists of multiple properties, collectively referred to as the "Time Oil Properties," in addition to the BNSF Property, a portion of the West Commodore Way right-of-way, and portions of Salmon Bay. The Time Oil Properties include two upland properties adjacent to the BNSF Property, known as the Bulk Terminal Parcel (4.08 acres) and the ASKO Hydraulic Parcel (1.59 acres), and two waterfront properties, known as the East Waterfront Property (3.05 acres) and West Waterfront Property (1.69 acres) (Floyd Snider 2019). A property diagram showing the four Time Oil Properties and the BNSF Property is included as Figure 2.

The Time Oil Properties were owned by the TOC Holdings Co. until 2017, when the company filed for bankruptcy (Ecology 2021a). The Time Oil Properties are currently owned (as of November 2020) by TOC Seattle Terminal 1, LLC (TOCST) (City of Seattle 2022b). In conjunction with the 2020 property transaction, TOCST entered into a Prospective Purchaser Consent Decree with Ecology to clean up the Time Oil Properties (PPCD No. 20-2-15215-3 SEA).

The BNSF Property was previously owned by the Great Northern Railway Company and is currently owned by BNSF. The BNSF Property contained five rail spurs that delivered rail cars to the Time Oil Properties to load and unload petroleum products. While BNSF parcel number 423790-0240 is approximately 5.6 acres (Ecology 2021a), the area where known contamination is present on the BNSF Property, the BNSF area of concern (AOC), is approximately 0.4 acre (Ecology 2020c). The ground surface in the BNSF AOC is generally flat at an elevation of approximately 59 feet relative to the North American Vertical Datum of 1988 (NAVD 88). To the southwest, the ground slopes steeply downward to active main-line track corridors running through the BNSF Property. The BNSF AOC is located south of the ASKO Hydraulic Parcel and the area of four former rail spurs (Figure 2). The activities proposed in this RIWP are intended to address characterization data gaps associated with the BNSF AOC.

2.2 Site Use History

The Time Oil Bulk Terminal operated between 1941 and 2001. Operations included the distribution of petroleum products by ships, rail, and trucks and the bulk storage of petroleum in aboveground storage tanks (ASTs, Floyd Snider 2019). There were 14 ASTs, a barreling shed, barrel inclines, overhead loading racks, and an underground pipeline. Bulk Terminal operations began in support of the Second World War efforts, and the Time Oil Bulk Terminal was a main distributor of fuel to the military in Alaska (Floyd Snider 2019). The Time Oil Bulk Terminal Parcel was first developed by the Jobbers Petroleum Company and was then acquired by TOC Holdings Co. in 1941, which continued to develop the site for bulk petroleum storage facility operations. After operations ended in 2001, the ASTs and associated infrastructure were removed from the Bulk Terminal Parcel. The ASKO Hydraulic Parcel was acquired by TOC Holdings Co. between 1946 and 1950 to support the bulk storage operations (Floyd Snider 2019). The ASKO Hydraulic Parcel included drum storage, a barreling shed and several ASTs. The ASKO

Parcel was also used for truck storage and as parking lot for the Bulk Terminal Parcel. In 1976, TOC Holdings Co. leased the warehouse on the ASKO Hydraulic Parcel for use as a marine and engine repair facility. From 1989 to between 2015 and 2017, the warehouse was used as a hydraulic repair and machine shop (Floyd Snider 2019).

Between 1936 and 1944, five rail spurs were constructed to connect the main railroad line with the ASKO Hydraulic and Bulk Terminal Parcels (Ecology 2021a). The Great Northern Railway Company owned the rail spurs in accordance with a spur track agreement between the Great Northern Railway Company and the TOC Holdings Co. (Floyd Snider 2019). Three spurs ran near the barreling sheds on the Bulk Terminal Parcel and were connected to distribution piping to unload and load petroleum products from the rail cars, and one spur extended toward the ASTs to facilitate the transfer of petroleum from the rail cars to the ASTs via hoses. A final spur ran parallel to the main rail line and was used for extra storage of tanker cars (Figure 3). Based on review of historical aerial photographs, rail spurs were no longer visible on the BNSF Property in 1985 (SoundEarth Strategies, Inc. [SES] 2014).

2.3 Previous Investigations

Numerous environmental investigations were completed at the Time Oil Bulk Terminal Site between 1991 and 2019 (Floyd Snider 2020). Initial investigations were completed from 1991 to 2005. From 2006 to 2014, focused remedial investigations were completed at the Bulk Terminal Parcel, ASKO Hydraulic Parcel, and East Waterfront Property (SES 2014a, 2014b, 2014c). Additional soil investigations (SES 2015a, 2015b), vapor intrusion assessments (SES 2016a, 2016b), and groundwater monitoring events (SES 2016c, 2016d, 2016e) have been conducted since 2014. As part of the Supplemental Upland Remedial Investigation and Feasibility Study performed in conjunction with TOCST's purchase of the Time Oil Properties, additional soil and groundwater sampling was conducted in 2019 (Floyd Snider 2020). Investigations that included data collection from the BNSF Property are summarized below.

2.3.1 Previous Soil Investigations

Ten soil borings were advanced within the BNSF Property, and seven of the 10 soil borings were converted to permanent groundwater monitoring wells (Figure 3). These locations were advanced at the property during three investigations in 2001, 2012, and 2013. In addition, 10 borings were advanced adjacent to the BNSF Property on the Time Oil Properties. These locations were advanced at the Time Oil Properties during five investigations in 2001, 2008, 2009, 2010, and 2011. Well construction details for the BNSF Property are included in Table 1. The 2001, 2008, 2009, 2010, 2011, 2012, and 2013 soil investigations are described below:

- **2001 Soil Investigation** – Three soil borings (SB-07 through SB-09) were advanced within the BNSF Property within the former rail spur area, and two soil borings (SB-06 and SB-10) were advanced on the adjacent Time Oil Properties (SES 2014a). Soil samples collected from borings SB-06, SB-07, and SB-08 were analyzed for pentachlorophenol (PCP); TPH; benzene, toluene, ethylbenzene, and total xylenes (BTEX, collectively); and lead during the investigation. Concentrations of PCP ranged from non-detect to 0.057 milligrams per kilogram (mg/kg) at depths between 5 and 15 feet below ground surface (bgs). Gasoline range organics (GRO) ranged from non-detect to 1,240 mg/kg (SB-07 at 5 feet bgs) and diesel range organics plus heavy oil (DRO+HO) ranged from ND to 1,973 mg/kg. BTEX ranged from non-detect to 18.2 mg/kg (total xylenes at SB-07). Lead concentrations were consistent with background and ranged from 3.58 to 9.81 mg/kg.

- **2008 Soil Boring/Monitoring Well Installation –** Four soil borings (B83 through B86) were advanced and converted to groundwater monitoring wells (01MW60 through 01MW63). Monitoring wells 01MW60 through 01MW62 were installed to further characterize total petroleum hydrocarbons (TPH) and trichloroethylene (TCE) along the property boundary of the ASKO Hydraulic Parcel and the BNSF Property (SES 2014a). Soil samples were collected at varying intervals (5 to 37.5 feet bgs) and analyzed for TPH; BTEX; and chlorinated volatile organic compounds (CVOCs). Concentrations of TCE ranged from non-detect to 66 mg/kg, cis-1,2-dichlorethane (DCE) ranged from non-detect to 0.14 mg/kg, BTEX ranged from non-detect to 19 mg/kg (total xylenes), GRO ranged from non-detect to 1,600 mg/kg, and DRO+HO ranged from non-detect to 3,200 mg/kg. Vertical delineation was not achieved for TCE at 01MW62 or TPH at 01MW60.
- **2009 Soil Boring/Monitoring Well Installation** – Two borings (B102 and B103) were advanced and converted to monitoring wells (01MW64 and 01MW65). Monitoring well 01MW64 was installed at the ASKO Hydraulic Parcel near the former rail spurs to evaluate the lateral extent of TPH and CVOCs in the Shallow Water Bearing Zone (WBZ; SES 2014a). Soil samples were collected at varying intervals (2.5 to 20 feet bgs). Concentrations of BTEX and CVOCs were non-detect at 01MW64. TPH ranged from non-detect to 670 (DRO+HO) and was vertically delineated.
- **2009 Soil Investigation** – Thirteen soil borings (B104 through B116) were advanced on the ASKO Hydraulic Parcel. Soil boring B116 was advanced along the property boundary of the ASKO Hydraulic Parcel and the BNSF Property to further evaluate TCE concentrations downgradient of the Former Barreling Shed #3 (SES 2014a). Soil samples were collected at varying intervals (3 to 16 feet bgs). Concentrations of TPH were detected only in the 3 feet bgs sample and ranged from non-detect to 4,100 mg/kg (DRO+HO). The only detection of TCE (0.21 mg/kg) was at 3 feet bgs, and the only detection of cis-1,2-DCE was at 16 feet bgs (0.20 mg/kg). Cis-1,2-DCE was not vertically delineated.
- **2010 Soil Boring/Monitoring Well Installation** – Two soil borings (B133 and B134) were advanced and converted to dual-use perched zone monitoring wells and soil vapor extraction wells (01MW70/01SVE02 and 01MW71/01SVE03) on the ASKO Hydraulic Parcel (SES 2014a). The purpose of the borings was to assess the extent of TPH and TCE in soil and groundwater along the boundary with the BNSF Property and for use during a soil vapor extraction pilot test. Soil samples were collected at varying intervals (2.5 to 20 feet bgs). TPH and BTEX were non-detect in all samples. Concentrations of TCE ranged from 0.033 mg/kg to 120 mg/kg, cis-1,2-DCE ranged from non-detect to 0.34 mg/kg, and trans-1,2-DCE ranged from non-detect to 0.15 mg/kg. TCE and cis-1,2-DCE were not vertically delineated.
- **2011 Soil Boring/Monitoring Well Installation –** Five soil borings (B171 through B175) were advanced and four were converted to monitoring wells (01MW76 through 01MW79) to create well pairs (SES 2014a). Monitoring well 01MW78 was installed in the Intermediate WBZ adjacent to the BNSF Property boundary as a well pairing with Shallow WBZ well 01MW62. Soil boring B175 was not converted to a monitoring well because perched water was not encountered during advancement. Soil samples were collected at varying intervals (7.5 to 27.5 feet bgs). TPH concentrations at 01MW78 were non-detect, except for GRO, which ranged from 3.8 to 4.4 mg/kg. CVOCs were non-detect, except one detection of cis-1,2-DCE (0.065 mg/kg) at 7.5 bgs and detections of TCE ranging from 5.3 to 47 mg/kg. Vertical delineation of GRO and CVOCs was achieved at 01MW78, except for TCE.

- **2012 Soil Boring/Monitoring Well Installation** – Four soil borings (B258 through B261) were advanced and converted to groundwater monitoring wells (01MW92 through 01MW95) to further characterize the BNSF Property (SES 2014a). Soil samples were collected at varying intervals (0.5 to 22.5 feet bgs) and analyzed for TPH, BTEX, and CVOCs. Concentrations of TCE ranged from non-detect to 0.39 mg/kg, GRO ranged from non-detect to 240 mg/kg, and DRO ranged from non-detect to 3,000 mg/kg at depths between 2.5 and 10 feet bgs. BTEX concentrations were detected in one sample at 01MW95, ranging from 0.046 to 4.3 mg/kg. Vertical delineation of TPH, BTEX, and CVOCs was achieved at all locations.
- **2013 Soil Boring/Monitoring Well Installation** – Three soil borings (B264 through B266) were advanced and converted to groundwater monitoring wells (01MW96 through 01MW98) (SES 2014a). Soil samples were collected and analyzed at varying depth intervals from 2.5 to 16 feet bgs. Samples were analyzed for TPH, BTEX, and CVOCs. GRO, DRO, and TCE were detected at concentrations ranging from non-detect to 130, 4,100, and 7.9 mg/kg, respectively, at depths between 3 and 11 feet bgs. All other CVOCs were non-detect, except for cis-1,2-DCE, with one detection (0.071 mg/kg) at 11 feet bgs. BTEX concentrations were detected in one sample at 01MW98, ranging from 0.33 to 0.56 mg/kg. Vertical delineation was achieved at all locations.

Soil analytical results from the investigations summarized above are presented in Table 2 and on Figures 4 through 7.

2.3.2 Previous Groundwater Investigations

Seven groundwater monitoring wells were installed within the BNSF Property between 2012 and 2013, as described in Section 2.3.1. Four of the monitoring wells (01MW92 and 01MW96 through 01MW98) are screened between five and 16 feet bgs in the shallowest WBZ, referred to as the Perched WBZ. Three of the monitoring wells (01MW93 through 01MW95) are screened between 23.5 and 40 feet bgs, in the underlying WBZ, referred to as the Shallow WBZ. There are no wells screened below the Shallow WBZ within the BNSF Property.

Seven groundwater monitoring wells were installed on the ASKO Hydraulic Parcel along the property boundary with the BNSF Property, as described in Section 2.3.1 (Figure 3). Two of the monitoring wells (01MW70 and 01MW71) are screened in the Perched WBZ, four monitoring wells (01MW60 through 01MW62, and 01MW64) are screened in the Shallow WBZ, and one monitoring well (01MW78) is screened in the Intermediate WBZ.

Groundwater monitoring events conducted within the BNSF Property and at the monitoring wells on the ASKO Hydraulic Parcel adjacent to the BNSF Property boundary are summarized below:

- **2009 Groundwater Monitoring** – 01MW60 through 01MW62 were gauged and sampled in January, April, and July 2009, and 01MW64 was gauged and sampled in April and July 2009. Groundwater samples were analyzed for TPH, BTEX, and CVOCs. Groundwater samples collected from the Shallow WBZ contained detected TPH concentrations ranging from 58 to 520 micrograms per liter (µg/L) of DRO+HO. The only detections of BTEX (1.2 µg/L for benzene and ethylbenzene) were in a sample collected from 01MW60 in January 2009. Concentrations of TCE ranged from 6.3 to 1,300 µg/L, and concentrations of vinyl chloride (VC) ranged from 0.23 to 0.37 µg/L.
- **2010 Groundwater Monitoring –** Shallow WBZ wells 01MW60 through 01MW62 and 01MW64 were gauged and sampled in January, April, and July 2010. Perched WBZ wells 01MW70 and 01MW71 were gauged and sampled in April and July 2010. The highest TPH concentration in the Shallow WBZ wells was 540 µg/L of GRO in 01MW62. GRO was also detected in the Perched WBZ at a maximum concentration of 450 µg/L.

DRO and HO were not detected in the Shallow or Perched WBZs, except DRO at 01MW64 (180 µg/L) in January 2010. BTEX detections were limited to two locations adjacent to the BNSF Property boundary. Benzene was detected at a maximum concentration of 3.2 µg/L in 01MW62. Detected TCE concentrations ranged from 8.9 µg/L (01MW60) to 1,200 µg/L (01MW62) in the Shallow WBZ wells and 290 µg/L (01MW70) to 1,100 µg/L (01MW71) in the Perched WBZ wells. Detected concentrations of VC ranged from 0.30 µg/L (01MW60) to 0.50 µg/L at 01MW62 in the Shallow WBZ wells and from 0.46 µg/L (01MW70) to 6.7 µg/L (01MW71) in the Perched WBZ wells. Other detected CVOC concentrations ranged from 4.5 µg/L to 10 µg/L (01MW62) in the Shallow WBZ and from 2.1 µg/L to 99 µg/L (01MW71) in the Perched WBZ.

- **2011 Groundwater Monitoring –** All Shallow WBZ and Perched WBZ wells adjacent to the BNSF Property, as mentioned above, were gauged and sampled in January, April, August, and December 2011. One Intermediate WBZ well (01MW78) was gauged and sampled in March, April, August, and December 2011. Detected TPH concentrations ranged from 60 µg/L (01MW60) and 170 µg/L (01MW70) to 520 µg/L of GRO and 2,130 µg/L of DRO+HO at 01MW62 and 01MW71, respectively. All BTEX concentrations were non-detect, except for one detection of toluene (1.4 µg/L) at 01MW71 in April 2011. Detected TCE concentrations ranged from 1.1 µg/L (01MW64) to 2,500 µg/L (01MW62) in the Shallow WBZ wells and 330 µg/L (01MW70) to 1,700 µg/L (01MW71) in the Perched WBZ wells. VC was detected at concentrations ranging from 0.28 µg/L to 0.53 µg/L in the Shallow WBZ wells during two events at 01MW62. Detected concentrations of VC ranged from 0.93 µg/L (01MW70) to 7.0 µg/L (01MW71) in the Perched WBZ. Other CVOC concentrations in the Shallow WBZ ranged from 1.8 µg/L to 6.1 µg/L (cis-1,2-DCE) at 01MW62. Other CVOC concentrations in the Perched WBZ ranged from 1.9 (1,1-DCE) at 01MW70 and 180 µg/L (trans-1,2-DCE) at 01MW71. Detections in the Intermediate WBZ were limited to cis-1,2-DCE and TCE, ranging from 1.1 µg/L to 16 µg/L (01MW78).
- **2012 Groundwater Monitoring** – Shallow WBZ wells 01MW60 through 01MW62, 01MW64, and 01MW93 through 01MW95 were gauged and sampled in April, August, and October 2012. Perched WBZ wells 01MW70, 01MW71, and 01MW92 were gauged and sampled in April, August, and October 2012. Intermediate WBZ well 01MW78 was gauged and sampled in April and October 2012. Detected TPH concentrations in the Perched WBZ ranged from 120 µg/L of GRO at 01MW70 to 3,100 µg/L of DRO at 01MW92. Detected TPH concentrations in the Shallow WBZ ranged from 50 µg/L of DRO at 01MW64 to 260 µg/L of GRO at 01MW62. All BTEX concentrations in the Perched WBZ and Shallow WBZ were non-detect, except for a detection of toluene (1.5 µg/L) and ethylbenzene (1.1 µg/L) in 01MW70 and 01MW71, respectively. TCE concentrations ranged from 1.5 µg/L (01MW94) to 390 µg/L (01MW62) in the Shallow WBZ wells and 110 µg/L (01MW92) to 3,600 µg/L (01MW71) in the Perched WBZ wells. VC concentrations were non-detect in the Shallow WBZ wells and ranged from 0.81 µg/L (01MW70) to 9.4 µg/L (01MW92) in the Perched WBZ wells. Other CVOC concentrations ranged from 32 µg/L to 120 µg/L (cis-1,2-DCE) and 2.2 µg/L to 140 µg/L (trans-1,2-DCE) at 01MW92 and 01MW70, respectively. Detections in the Intermediate WBZ were limited to cis-1,2-DCE and TCE, ranging from 1.2 to 1.6 µg/L.
- **2013 Groundwater Monitoring** – Shallow WBZ wells 01MW60 through 01MW62, 01MW64, and 01MW93 through 01MW95 were gauged and sampled in April, May, and November 2013. Perched WBZ wells 01MW70, 01MW71, 01MW92, and 01MW96 through 01MW98 were gauged and sampled in April, May, and November 2013. Intermediate well 01MW78 was gauged and sampled in April and November 2013. Detected TPH concentrations in the Perched WBZ ranged from 150 µg/L of GRO to 4,000 µg/L of DRO at 01MW70 and 01MW98, respectively. Detected TPH concentrations in the Shallow WBZ ranged from 56 µg/L of DRO to 290 µg/L of GRO at 01MW94 and 01MW62, respectively. All BTEX concentrations were non-detect, except

for one detection of toluene at 01MW62 in April 2013. TCE concentrations ranged from 2.7 µg/L (01MW60) to 890 µg/L (01MW61) in the Shallow WBZ wells and from 190 µg/L to 6,700 µg/L (01MW92) in the Perched WBZ wells. Vinyl chloride concentrations were non-detect in the Shallow WBZ wells and ranged from 0.80 µg/L to 9.7 µg/L (01MW71) in the Perched WBZ wells. Other CVOC concentrations ranged from non-detect to 420 µg/L (cis-1,2-DCE) and 43 µg/L (trans-1,2-DCE) at 01MW92. Detections in the Intermediate WBZ were limited to cis-1,2-DCE and TCE, ranging from non-detect to 3.5 µg/L.

- **2014 Groundwater Monitoring –** Shallow WBZ wells 01MW60 through 01MW62, 01MW64, and 01MW93 through 01MW95 were gauged and sampled in April 2014. Perched WBZ wells 01MW70, 01MW71, 01MW92, and 01MW96 through 01MW98 were gauged and sampled in April 2014. Intermediate well 01MW78 was gauged and sampled in April 2014. TPH concentrations ranged from non-detect to 1,500 µg/L of GRO and 6,400 µg/L of DRO at 01MW92 in the Perched WBZ. All BTEX concentrations were non-detect, except for one detection of toluene at 01MW92 (1.7 µg/L). TCE concentrations ranged from non-detect to 950 µg/L (01MW62) in the Shallow WBZ wells and from non-detect to 7,800 µg/L (01MW92) in the Perched WBZ wells. Vinyl chloride concentrations were non-detect in the Shallow WBZ wells and ranged from non-detect to 7.1 µg/L (01MW71) in the Perched WBZ wells. Other CVOC concentrations ranged from non-detect to 640 µg/L (cis-1,2-DCE) and 35 µg/L (trans-1,2-DCE) at 01MW92. Detections in the Intermediate WBZ were limited to cis-1,2-DCE and TCE, ranging from 1.3 to 4.4 µg/L, respectively.
- **2015 Groundwater Monitoring –** Shallow WBZ wells 01MW60 through 01MW62 and 01MW64 were gauged and sampled in May 2015. Perched WBZ wells 01MW70 and 01MW71 were gauged and sampled in May 2015. Intermediate WBZ well 01MW78 was gauged and sampled in May 2015. TPH concentrations ranged from non-detect to 1,500 µg/L of GRO and 2,100µg/L of HO at 01MW71. All BTEX concentrations were non-detect, except for one detection of toluene and one detection of ethylbenzene at 01MW71. TCE concentrations ranged from non-detect to 1,700 µg/L (01MW62) in the Shallow WBZ wells and from 450 to 2,600 µg/L (01MW71) in the Perched WBZ wells. Vinyl chloride concentrations were non-detect in the Shallow WBZ wells and ranged from non-detect to 12 µg/L (01MW71) in the Perched WBZ wells. Other CVOC concentrations ranged from non-detect to 120 µg/L (cis-1,2-DCE) and 40 µg/L (trans-1,2-DCE) at 01MW71 and 01MW70, respectively. Detections in the Intermediate WBZ were limited to TCE, with a detection of 5.2 µg/L.
- **2016 Groundwater Monitoring –** Shallow WBZ wells 01MW60 through 01MW62 and 01MW64 were gauged and sampled in May 2016. Perched WBZ wells 01MW70 and 01MW71 were gauged and sampled in May 2016. Intermediate WBZ well 01MW78 was gauged and sampled in May 2016. TPH concentrations in the Perched WBZ ranged from 210 µg/L to 930 µg/L of GRO and 1,700 µg/L of DRO at 01MW71. All BTEX concentrations were non-detect, except for one detection of toluene at 01MW71. TCE concentrations ranged from non-detect to 630 µg/L (01MW62) in the Shallow WBZ wells and from 430 to 2,200 µg/L (01MW71) in the Perched WBZ wells. Vinyl chloride concentrations were non-detect in the Shallow WBZ wells and ranged from 0.87 to 12 µg/L (01MW71) in the Perched WBZ wells. Other CVOC concentrations ranged from non-detect to 110 µg/L (cis-1,2-DCE) and 10 µg/L (trans-1,2-DCE) at 01MW71. Detections in the intermediate WBZ were limited to TCE, with a detection of 4.0 µg/L.
- **2019 Groundwater Monitoring** – Shallow WBZ wells 01MW60, 01MW62, 01MW64, and 01MW93 through 01MW95 were gauged and sampled in May 2019. Perched WBZ wells 01MW70, 01MW71, 01MW92, and 01MW96 through 01MW98 were gauged and sampled in May 2019. Intermediate WBZ well 01MW78 was gauged and sampled in May 2019. TPH concentrations in the Perched WBZ ranged from non-detect to 1,500

µg/L of GRO and 4,600 of DRO at 01MW92. All BTEX concentrations were non-detect, except for one detection of benzene at 01MW96. TCE concentrations ranged from non-detect to 850 µg/L (01MW62) in the Shallow WBZ wells and from 1.5 to 5,200 µg/L (01MW92) in the Perched WBZ wells. Vinyl chloride concentrations were non-detect in the Shallow WBZ wells and ranged from non-detect to 7.9 µg/L (01MW71) in the Perched WBZ wells. Other CVOC concentrations ranged from non-detect to 570 µg/L (cis-1,2-DCE) and 71 µg/L (trans-1,2-DCE) at 01MW71 and 01MW70, respectively. Detections in the intermediate WBZ were limited to cis-1,2-DCE and TCE, ranging from 1.2 µg/L to 5.5 µg/L.

Historical groundwater elevations for monitoring wells located on the BNSF Property are provided in Table 3. Historical depth to groundwater in the Perched WBZ ranged from approximately 6.5 to 11 feet bgs (47.8 to 51.2 feet North American Vertical Datum of 1988 [NAVD 88]). Depth to groundwater in the Shallow WBZ ranged from approximately 29 to 31 feet bgs (27.1 to 29.8 feet NAVD 88).

Historical groundwater analytical results for monitoring wells on the BNSF Property and along the property boundary on the ASKO Hydraulic Parcel are presented in Table 4. Groundwater analytical results collected from Perched WBZ monitoring wells in 2019 are included on Figures 8 and 9, and groundwater analytical results collected from Shallow WBZ monitoring wells in 2019 are included on Figures 10 and 11.

2.4 Time Oil Properties Remedial Actions

Multiple interim remedial actions have been completed at the adjacent Time Oil Properties since 1991. Most of the remedial actions completed prior to 2017 occurred within the Bulk Terminal Parcel and East Waterfront Property (Floyd Snider 2020). These remedial actions included:

- AST and underground storage tank removals;
- Excavation of soils containing PCP, TPH and dioxin/furans;
- Removal of a petroleum pipeline and related TPH-contaminated soil from within West Commodore Way;
- Chemical oxidation and thermal treatment via electrical resistance heating; and
- Groundwater and light non-aqueous-phase liquid (LNAPL) recovery system operations.

Additional details regarding the interim remedial actions above are included in the Bulk Terminal Property Remedial Investigation Report (SES 2014c), East Waterfront Property Remedial Investigation Report (SES 2014b), and Supplemental Upland Remedial Investigation and Feasibility Study (Floyd Snider 2020).

On June 29, 2021, the Engineering Design Report (EDR) for the Time Oil Properties was approved by Ecology (Ecology 2021b). The EDR (Crete Consulting, Inc. 2021) described the process by which the remedial actions included in the Cleanup Action Plan (CAP; Ecology 2020c) would be implemented. Remedial actions conducted in accordance with the CAP include:

- Soil excavation with offsite disposal;
- LNAPL removal;
- In situ solidification and stabilization (ISS) of soil to the upper portion of the Shallow WBZ (Figures 8 through 11);

- In situ groundwater treatment;
- Installation of a Perched WBZ interceptor trench with permeable reactive barrier (PRB) along the property line for the ASKO Hydraulic Parcel and BNSF Property (Figures 8 through 11); and
- Capping and institutional controls.

The EDR details each of the remedial actions presented above. The interceptor trench and ISS monolith are located on ASKO Hydraulic Parcel, directly adjacent to the BNSF Property. Based on groundwater modeling included in the EDR, Perched Zone groundwater on the BNSF Property is expected to flow towards the interceptor trench, which will then channel it to the PRB for treatment (Crete Consulting, Inc. 2021).

All planned remedial actions on the non-BNSF Property portion of Time Oil Bulk Terminal Site were completed by December 2021, with the exception of the final capping and institutional controls. Final capping and institutional controls on the upland parcels will be implemented in conjunction with the planned redevelopment of those parcels.

2.5 Site Hazard Assessment

In August 2019, Ecology informed BNSF and other responsible parties that a site hazard assessment (SHA) was being conducted at the Time Oil Bulk Terminal Site (Ecology 2019) to evaluate the threat to human health and the environment. The SHA focused on the Time Oil Properties, but also included the BNSF Property, the Department of Natural Resources (DNR) Aquatic Waterway Use parcel[1], and the sediments within Salmon Bay (Ecology 2020a). Media evaluated as part of the SHA included groundwater, soil, and air. Model Toxics Control Act (MTCA) Method A and B cleanup levels were used as the screening levels during the SHA, and the overall numerical rank of the SHA was 1, which represents the highest level of concern (Ecology 2020b).

The SHA concluded that the Time Oil Bulk Terminal Site was contaminated with TPH (GRO, DRO, and HO), PCP, TCE, VC, and arsenic (Ecology 2020b). Sources of the contamination identified in the SHA include a portion of the BNSF Property (the BNSF AOC) and the former maintenance shop within the ASKO Hydraulic Parcel (Ecology 2020a). The groundwater impacts found within the ASKO Hydraulic Parcel and BNSF Property were limited to the Perched and Shallow WBZs, except for TCE, which was found in the Intermediate WBZ on the ASKO Hydraulic Parcel. The vapor intrusion exposure pathway was evaluated through soil vapor and indoor air sampling completed in 2015. Results of the 2015 study indicated that VOCs were below their respective MTCA Method B screening levels in soil vapor samples collected from the Time Oil Bulk Terminal Parcel. Benzene, VC, and cis-1,2-DCE were present above Method B screening levels in soil vapor samples collected from the ASKO Hydraulic Parcel. However, subsequent indoor air sample results demonstrated that vapor intrusion was not occurring in the sampled buildings (Ecology 2020a).

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[1] In accordance with the Prospective Purchaser Consent Decree, TOCST assumed the DNR Aquatic Waterway Use Authorization (lease) associated with that parcel from TOC's bankruptcy trust when they purchased the Time Oil Properties. That parcel is north-adjacent to the East Waterfront Property and includes a portion of the dock that connects to the East Waterfront Property (Figure 2).

3 Conceptual Site Model

Multiple conceptual site models (CSMs) have been prepared for the Time Oil Bulk Terminal Site, the most recent as part of the 2020 CAP (Ecology 2020c). The following sections summarize information presented in previous reports that informs the CSM, with a focus on conditions present within the BNSF Property.

3.1 Site Geology

The surficial geology within the BNSF Property is characterized as pre-Fraser glaciation deposits (Troost and Booth 2008). The deposits include interbedded sand, gravel, silt, and diamicts of indeterminate age and are divided locally based on grain size. Advance outwash and proglacial lake deposits of the Esperance and Lawton Clay Formations are mapped nearby in the steep slopes to the south.

Soils within the BNSF Property generally consist of approximately 2 to 5 feet of fill materials, including silty sands and gravels, overlying low-permeability silt units interbedded with silts and silty sands (Floyd Snyder 2020, SES 2014a). Soils on the adjacent Time Oil Properties are similar to those observed on the BNSF Property. Appendix B presents two geologic cross-sections showing the interpreted hydrostratigraphy within the BNSF Property and adjacent Time Oil Properties (SES 2014a).

3.2 Site Hydrogeology

Previous investigations indicate that at least three distinct WBZs underlie the BNSF Property. These units are referred to as the Perched, Shallow, and Intermediate WBZs. An additional saturated unit, referred to as the Deep WBZ, has been observed within the ASKO Hydraulic Parcel. The lithology of the WBZs generally consists of silty sands, separated by lower-permeability silty confining layers. The three WBZs and associated confining layers present within, or in the vicinity of, the BNSF Property are described in further detail below:

- **Perched WBZ –** A discontinuous zone of perched water typically encountered at depths of approximately 6 to 12 feet bgs. Groundwater in this unit historically was observed to flow to the north, with a horizontal gradient of 0.053 foot/foot (Floyd Snyder 2020).
- **Semi-confining Layer –** Perched groundwater appears to be separated from the Shallow WBZ at the BNSF Property by a discontinuous lens of low-permeability soils (silts and clays with sand) ranging in thickness from 10 to 15 feet (SES 2014a).
- **Shallow WBZ –** A saturated unit (silty sand) encountered at a depth of approximately 30 feet bgs. Thickness at the BNSF Property has been measured to be between 5 to 12 feet. Groundwater in this unit has been observed to flow to the northwest with a horizontal gradient of 0.061 foot/foot (Floyd Snyder 2020). Slug tests performed in the Shallow WBZ (SES 2014a) at the adjacent ASKO Hydraulic Parcel indicated hydraulic conductivities ranged from of 3.4 to 5.7 feet/day, and seepage velocities have been estimated at between 0.72 and 1.07 feet/day.
- **Confining Layer –** Separating the Shallow and Intermediate WBZs is an approximately 5-foot-thick, laterally continuous layer of lower-permeability silty sand.
- **Intermediate WBZ –** This saturated unit is comprised of predominantly silty sands, encountered at a depth of approximately 40 feet bgs. Groundwater in this unit flows to the west-northwest, with a horizontal gradient of 0.006 foot/foot (Floyd Snyder 2020). Estimated hydraulic conductivity for this zone is 2.8

feet/day based on slug tests performed on the adjacent ASKO Hydraulic Parcel in 2009. While no monitoring wells have been installed to the Intermediate WBZ within the BNSF Property, well 01MW78 was installed on the property line between the BNSF Property and the ASKO Hydraulic Parcel (Figure 3).

- **Confining Layer –** An approximately 10-foot-thick layer of silt has been observed at the base of the Intermediate WBZ on the ASKO Hydraulic Parcel.

According to Floyd Snyder (2019), downward vertical gradients have been measured consistently between the Perched and Shallow WBZs and between the Shallow and Intermediate WBZs. This observation is consistent with the conceptual understanding that the lower permeability confining layers impede infiltration of groundwater, limiting vertical hydraulic communication between the WBZs, and leading to perched or somewhat discontinuous zones of saturation.

As discussed in Section 2.4, an interceptor trench directed toward a PRB and the ISS monolith were recently constructed on the adjacent ASKO Hydraulic Parcel to the north (see Figures 8 through 11). The PRB was installed to intersect the bottom of the Perched WBZ, and the ISS monolith extends down to the top of the Shallow WBZ. The effects of these structures on the local groundwater flow conditions will be considered during the remedial investigation work within the BNSF Property.

3.3 Nature and Extent

The following sections summarize information from historical reports regarding the nature of site impacts and their lateral and vertical distribution in soil and groundwater.

3.3.1 Soil

Constituents of potential concern (COPCs) that were detected in soil within the BNSF Property include TPH (GRO, DRO, and HO), benzene, TCE, cis-1,2-DCE, trans-1,2-DCE, and PCP. Historical soil analytical data from locations on the BNSF Property and along the property boundary with adjacent Time Oil Properties are summarized in Table 2 and shown on Figures 4 through 7. Additional information regarding the nature and extent of soil impacts is provided below:

- **TPH in Soil –** TPH (GRO, DRO, and HO) has been detected at BNSF Property locations at concentrations ranging from 2.2 mg/kg (GRO at 01MW97/B265) to 5,200 mg/kg (total DRO+HO at 01MW98/B266). The deepest GRO detections were observed at 15 feet bgs in borings SB-07 and SB-09. On the ASKO Hydraulic Parcel, along the BNSF Property boundary, detected concentrations ranged from 3.0 mg/kg (GRO at 01MW64/B102) to 4,100 mg/kg (total DRO+HO at B116). The deepest detection was observed at 20 feet bgs at 01MW62/B85. The lateral and vertical extent of TPH impacts at the BNSF Property has largely been assessed, except for the area southeast of boring 01MW95/B261, northwest of boring 01MW98/B266, and southwest of boring B116.
- **BTEX in Soil –** BTEX concentrations have been detected at BNSF Property locations at concentrations ranging from 0.046 mg/kg (toluene at 01MW95/B261) to 18 mg/kg (total xylenes at SB-07). Detected concentrations on the ASKO Hydraulic Parcel along the BNSF Property boundary ranged from 0.030 mg/kg (toluene at 01MW60/B83) to 19 mg/kg (total xylenes at 01MW60/B83). All detections on the BNSF Property and on the ASKO Hydraulic Parcel were vertically delineated by samples with non-detect concentrations. The

lateral extent of BTEX impacts at the BNSF Property has largely been assessed, except for the area southeast of boring 01MW95/B261 and northwest of boring 01MW98/B266.

- **TCE in Soil –** TCE has been detected at BNSF Property locations at concentrations ranging from 0.05 mg/kg (01MW92/B258) to 7.9 mg/kg (01MW97/B265). Detected concentrations on the ASKO Hydraulic Parcel along and northeast of the BNSF Property boundary ranged from 0.033 mg/kg (01MW70/01SVE02/B134) to 120 mg/kg (01MW71/01SVE03/B133). All detections on the BNSF Property were vertically delineated by samples with non-detect concentrations; however, detections on the ASKO Hydraulic Parcel have not been vertically delineated. The lateral extent of TCE impacts at the BNSF Property has been assessed, except for the area south and southwest of borings B116, 01MW98 and 01MW93.
- **Cis-1,2-DCE in Soil –** Cis-1,2-DCE was detected at one BNSF Property location at a concentration of 0.071 mg/kg (01MW97/B265). Detected concentrations on the ASKO Hydraulic Parcel along the BNSF Property boundary ranged from 0.068 mg/kg at 01MW71/01SVE03/B133 to 0.34 mg/kg at 01MW71/01SVE03/B133. All detections on the BNSF Property were vertically delineated by samples with non-detect concentrations, as were all detections on the ASKO Hydraulic Parcel, except for 01MW71/01SVE03/B133. The lateral extent of cis-1,2-DCE impacts at the BNSF Property has largely been assessed, except for the area southeast of 01MW97.
- **Trans-1,2-DCE in Soil –** Trans-1,2-DCE was not detected at any locations on the BNSF Property and was detected at only one location at a concentration of 0.15 mg/kg on the ASKO Hydraulic Parcel along the BNSF Property boundary (01MW70/01SVE02/B134). The detection on the ASKO Hydraulic Parcel was not vertically delineated with non-detect concentrations. The lateral and vertical extent of trans-1,2-DCE impacts at the BNSF Property has been fully delineated.
- **PCP in Soil –** PCP was detected at BNSF Property locations at concentrations ranging from 0.056 mg/kg (SB-08) to 0.057 mg/kg (SB-07). Detected concentrations on the ASKO Hydraulic Parcel along the BNSF Property boundary were 0.055 mg/kg (SB-06). Vertical and lateral delineation will need to be fully delineated during the remedial investigation for PCP at the BNSF Property.

3.3.2 Groundwater

COPCs that have been detected in groundwater within the BNSF Property include TPH (GRO, DRO and HO), TCE, 1,1-DCE, cis-1,2-DCE, and VC. The most recent (May 2019) groundwater sampling analytical data indicate impacts at the BNSF Property are limited to the Perched WBZ. Historical groundwater analytical data are presented in Table 4 and shown on Figures 8 through 11. Additional information regarding the nature and extent of groundwater impacts is provided below.

- **TPH in Groundwater –** TPH (GRO, DRO and HO) has been detected in multiple Perched WBZ wells on the BNSF Property and ranges from 65 µg/L (DRO at 01MW97, May 2019) to 7,500 µg/L (total DRO+HO at 01MW92, April 2014). In the Perched WBZ wells along the BNSF Property boundary on the ASKO Hydraulic Parcel, detected TPH concentrations ranged from 120 µg/L (GRO at 01MW70, April 2012) to 4,000 µg/L (total DRO+HO at 01MW71, May 2016). Detected concentrations in the Shallow WBZ on the BNSF Property ranged from 54 µg/L (DRO at 01MW93, May 2019) to 120 µg/L (DRO at 01MW94, September 2012). In the Shallow WBZ wells along the property boundary on the ASKO Hydraulic Parcel, TPH concentrations ranged from 50 µg/L (DRO at 01MW64, April 2012) to 270 µg/L (DRO at 01MW60, January 2009). No concentrations of TPH were detected in the Intermediate WBZ well along the BNSF Property boundary on the ASKO

Hydraulic Parcel. The lateral extent of TPH impacts at the BNSF Property have been delineated in the Shallow WBZ but requires further delineation in the Perched WBZ, southeast of 01MW96 and northwest of 01MW98.

- **BTEX in Groundwater –** Benzene and toluene have been detected in Perched WBZ wells on the BNSF Property and range from 1.3 µg/L (benzene at 01MW96, May 2019) to 1.7 µg/L (toluene at 01MW92, April 2014). In the Perched WBZ wells along the BNSF Property boundary on the ASKO Hydraulic Parcel, toluene and ethylbenzene were detected at concentrations ranging from 1.1 µg/L (ethylbenzene at 01MW71) to 1.5 µg/L (toluene at 01MW70, October 2012). No concentrations of BTEX were detected in the Shallow WBZ on the BNSF Property. In the Shallow WBZ wells along the BNSF Property boundary on the ASKO Hydraulic Parcel, benzene, toluene, and ethylbenzene were detected at concentrations ranging from 0.35 µg/L (benzene at 01MW62, May 2019) to 3.2 µg/L (benzene at 01MW62, July 2010). No concentrations of BTEX were detected in the Intermediate WBZ well along the BNSF Property boundary on the ASKO Hydraulic Parcel. The lateral extent of BTEX impacts at the BNSF Property have been delineated in the Shallow WBZ but requires further delineation in the Perched WBZ, southeast of 01MW96.
- **CVOCs in Groundwater –** CVOC detections, specifically TCE, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, and VC, have been detected in Perched WBZ groundwater as recently as May 2019. Detected concentrations of CVOCs in the Perched WBZ at the BNSF Property ranged from 1.5 µg/L (TCE at 01MW96, May 2019) to 7,800 µg/L (TCE at 01MW92, April 2014). Detected concentrations of CVOCs in the Perched WBZ at the BNSF Property boundary on the ASKO Hydraulic Parcel ranged from 0.41 µg/L (VC at 01MW70, April 2014) to 4,300 µg/L (TCE at 01MW71, April 2014). CVOCs have not been detected in the Shallow WBZ on the BNSF Property, except for TCE in well 01MW93 at 1.5 µg/L in September 2012, 5.5 µg/L in May 2013, and 3.4 µg/L in April 2014. TCE was not detected in the Shallow WBZ at the BNSF Property during subsequent (2019) sampling. TCE and VC have historically been detected at the Shallow WBZ wells on the ASKO Hydraulic Parcel, but VC has not been detected since 2011. The detected concentrations of TCE ranged from 1.1 µg/L at 01MW64 (January 2011) to 2,500 µg/L at 01MW62 (August 2011), with the most recent concentrations detected in May 2019 at 15 µg/L at 01MW60 and 850 µg/L at 01MW62. PCE was also detected in one sample from 01MW62 in April 2011 at a concentration of 24 µg/L, and cis-1,2-DCE has been detected in 01MW62 at concentrations ranging from 1.5 µg/L in November 2013 to 15 µg/L in May 2019. TCE and cis-1,2-DCE have also been detected in the Intermediate WBZ well along the BNSF Property boundary on the ASKO Hydraulic Parcel with TCE ranging from 1.1 µg/L in December 2011 to 16 µg/L in March 2011 and cis-1,2-DCE ranging from 1.0 µg/L in April and November 2013 to 5.5 µg/L in May 2019. The lateral extent of CVOCs impacts at the BNSF Property have been delineated in the Shallow WBZ but requires further delineation in the Perched WBZ, southeast of 01MW96 and northwest of 01MW98. The lateral extent of CVOC impacts in the Intermediate WBZ on the BNSF Property is unknown, however Intermediate WBZ monitoring wells are adjacent and down gradient from the BNSF Property and will be addressed through remedial actions of the Perched and Shallow WBZs on the Time Oil Properties (Ecology 2020c).

3.4 Transport Pathways

As discussed in Sections 3.2 and 3.3, CVOCs and, to a lesser extent, TPH and PCP, historically had elevated concentrations in shallow soil and/or groundwater on the BNSF Property. Impacts are present within the vadose zone and Perched WBZ. The characteristics affecting transport within the vadose and saturated zones include soil porosity, permeability, sorption/retardation characteristics of the soil (e.g., organic carbon), chemical characteristics, the initial volume of the release, the timing of the release, biodegradation, recharge, and groundwater heads.

CVOCs detected in vadose zone soils and the Perched WBZ indicate there is the potential for volatilization into the vadose zone soil vapor. For soil vapor, the primary transport mechanisms are diffusion and advection, assuming subsurface pressure differences exist. There is also a potential for some leaching downward into groundwater to the Perched WBZ.

Downward migration of CVOCs and TPH from the Perched WBZ to the underlying Shallow WBZ is limited by the presence of low-permeability soils, which form a semi-confining layer separating the Perched and Shallow WBZs. This conceptual understanding is consistent with the reported presence of consistent downward vertical gradients between the Perched and Shallow WBZs.

Lateral migration of the constituents of potential concern in the Perched and Shallow WBZ is in the direction of the ASKO Hydraulic Parcel based on historical groundwater flow directions. Further impacts to the ASKO Hydraulic Parcel are limited due to the implementation of remedial technologies (PRB and ISS) (Floyd Snider 2022).

In general, TPH and BTEX readily attenuate in the natural environment. Attenuation mechanisms for these COPCs include volatilization, biodegradation, sorption, and dilution. Attenuation of CVOCs and PCP biodegrade less readily and are primarily controlled by volatilization, sorption, and dilution.

3.5 Current and Future Land Use

The Time Oil Bulk Terminal Site is located within the Ballard Interbay North Manufacturing Industrial Center, with a portion located along the waterfront area of Salmon Bay (City of Seattle 2022a, 2022b). Based on the City of Seattle’s Zoning Map, the Time Oil Bulk Terminal Site is zoned as Industrial General 2 Unlimited/65 and Industrial Buffer Unlimited/45 (City of Seattle 2022c). These land uses allow for industrial and commercial uses and a buffer between industrial and residential and/or commercial zones, respectively. The BNSF AOC is within an active railroad right of way, and there are no plans for development. Active double mainline tracks are immediately to the south of the BNSF AOC and a steep embankment leading up to Government Way is south of the mainline tracks. Continued operation as an active rail corridor is the current and continued future land use for BNSF property for the foreseeable future.

3.6 Potential Receptors

Potential ecological and human receptors, with consideration of the information presented in Sections 3.3, 3.4, and 3.5, are discussed below:

3.6.1 Ecological Receptors

The BNSF Property is largely unpaved, and impacts have been detected in shallow/surficial soils. As such, terrestrial plants, soil biota, and wildlife are considered potential receptors to impacts in soil within the BNSF Property. An Upland Ecological Risk Assessment prepared for the Time Oil Bulk Terminal Site concluded that a site-specific terrestrial ecological evaluation (TEE) should be performed due to proximity to priority species (Great Blue Heron) and management recommendations designated for the area (Ecology 2020d). Proposed site-specific protective values for DRO and HO have been considered as part of the screening level evaluation included in Section 4. A TEE will be performed for the BNSF Property in accordance with Washington Administrative Code 173-340-7492 to provide an additional assessment of potential terrestrial ecological receptors and exposure pathways.

3.6.2 Human Receptors and Potential Exposure Pathways

The BNSF Property is an industrial rail corridor that consists of unpaved land that is part of an active mainline. Site workers are present within the BNSF Property only for short periods of time, and there are no residential or commercial land uses. Potential human exposure pathways are discussed below for the three media.

- **Soil –** Impacts within the BNSF Property are present in shallow soils in unpaved areas. Impacted soils have the potential to affect human health through possible ingestion and direct contact, as well as migration (leaching) to groundwater. If impacted soils are exposed, inhalation of particulates may also present a potential for exposure. Accordingly, this pathway should be considered potentially complete and retained for further evaluation.
- **Groundwater –** Groundwater at the Time Oil Bulk Terminal Site is considered potable (Ecology 2020c). However, the BNSF Property and surrounding areas are served by municipal water. Additionally, according to Washington Department of Natural Resources and Ecology well-log databases, drinking-water supply wells are not located within the BNSF Property, the adjacent site, or in downgradient locations. The recent remedial efforts on the adjacent ASKO Hydraulic Parcel (i.e., PRB and ISS monolith) have reduced the potential for downgradient transport of potentially impacted groundwater within the Perched WBZ.
- **Vapor Intrusion –** CVOC volatilization and migration from soil and groundwater is a potential exposure pathway for vapor intrusion into future nearby structures. According to Ecology guidance, buildings within 100 lateral feet of CVOC-contaminated soil and/or shallow groundwater are at potential risk for vapor intrusion (Ecology 2021c). This pathway will be considered as the planned future use for the Time Oil Properties proposes a building to be constructed within 30 feet of the BNSF Property.
- **Surface Water –** Due to the proximity of the Salmon Bay, surface water exposure pathways (human consumption of water and organisms) have been retained for further evaluation. Receptors associated with the adjacent surface water body include benthic and aquatic species. The groundwater to surface water pathway may or may not be complete, but, will be considered for further evaluation.

4 Initial Screening Levels

Laboratory analytical results for samples collected during the planned remedial investigation activities will be compared to proposed screening levels in Tables 5 and 6 of this RIWP and in Tables 1a and 1b of the associated SAP/QAPP (Appendix A). Initial screening levels were developed based on an evaluation of screening levels applicable to the Time Oil Bulk Terminal Site. The following initial screening levels were included in the evaluation:

- **Soil**
    - MTCA Method A Soil Cleanup Levels for Unrestricted Land Uses – table values derived for protection of varying soil exposure pathways, depending on the compound.
    - Protection of Direct Contact – MTCA Method B (non-cancer and cancer) levels.
    - Protection of Terrestrial Ecological Receptors – Terrestrial ecological indicator soil concentrations and site-specific recommended TEE values.
    - Protection of Groundwater, Leaching from Saturated Zone – Protection of groundwater (saturated) and protection of the groundwater to surface water (fresh water) pathway based on the MTCA fixed-parameter three-phase partitioning model.
- **Groundwater**
    - Protection of Drinking Water – MTCA Method A, MTCA Method B (non-cancer and cancer), and state and federal maximum contaminant levels.
    - Protection of Surface Water – MTCA Method B (non-cancer and cancer) for surface water, and state and federal water quality standards for freshwater aquatic life [chronic] and for human consumption of water and organisms.
    - Protection of Sediment – Washington sediment management standards and sediment cleanup objectives for bioaccumulation and benthic species, and human health direct contact criteria derived from the modified MTCA fixed-parameter three-phase partitioning model.
    - Protection of Indoor Air – MTCA Method B (non-cancer and cancer) vapor intrusion for groundwater.

Laboratory practical quantitation limits and method detection limits from Pace National Center for Testing and Innovation (Pace) of Mt. Juliet, Tennessee were also included in the evaluation. Cleanup standards will be developed as part of the remedial investigation process and presented in the Remedial Investigation Report.

5 Remedial Investigation Scope of Work

This section describes the proposed remedial investigation activities to be completed at the BNSF Property to achieve the objectives of this RIWP.

5.1 Data Gaps Analysis

Historical data and prior investigation findings indicate that the extent of contamination within the BNSF Property is not fully delineated. Additional groundwater monitoring data would also be useful in assessing concentration trends over time. These identified data gaps are discussed in detail in the following sections.

5.1.1 Soil

Although the vertical extent of CVOCs, BTEX, and TPH in soil are defined on the BNSF Property, the vertical extent of TCE, cis-1,2-DCE, and trans-1,2-DCE has not been delineated at locations along the BNSF Property boundary on the ASKO Hydraulic Parcel. The lateral extent of CVOCs, BTEX, and TPH has also not been fully delineated. Specifically, additional sampling is necessary to laterally delineate TCE to the northwest and BTEX and TPH (GRO and DRO+HO) to the northwest and southeast of the BNSF AOC. Vertical delineation of TPH is also necessary in the northwest. Lateral and vertical characterization of PCP in soil, to the extent feasible given the laboratory quantitation limit, is also necessary in the northwest and southeastern portion of the BNSF AOC.

5.1.2 Groundwater

The lateral extent of CVOC and TPH impacts in the Perched WBZ has not been fully delineated, specifically to the northwest and southeast of the BNSF AOC. It is necessary to investigate the lateral and vertical extent of PCP in the Perched WBZ due to soil concentrations exceeding the leaching to groundwater screening levels. In addition, it is necessary to delineate BTEX in the Shallow WBZ to the south of 01MW62. Furthermore, the nature of any seasonal groundwater elevation fluctuations and the effect of those fluctuations on CVOC, BTEX, and TPH concentrations have not been assessed.

The Intermediate WBZ is separated from the Perched WBZ by two confining layers (aquitards) that restrict the downward movement of both groundwater and COPCs. Analytical results from monitoring well 01MW78, which is immediately adjacent to the BNSF AOC on the ASKO Hydraulic Parcel, indicate COPC concentrations in the Intermediate WBZ are at least an order of magnitude lower than the Perched and Shallow WBZ COPC concentrations and show decreasing trends. To reduce the potential for drag down of COPCs from the Perched and/or Shallow WBZs to the Intermediate WBZ, advancing borings that penetrate the confining layer between the Shallow and Intermediate WBZs are not proposed. This approach was established in consultation with Ecology. Residual COPC impacts in the Intermediate WBZ on the adjacent ASKO Hydraulic Parcel are being addressed through remedial actions in the Perched and Shallow WBZs and compliance with final cleanup levels are monitored at well 01MW112, along the conditional point of compliance (Ecology 2020c).

Total and dissolved iron, total and dissolved manganese, nitrate, sulfate, and total organic carbon will be evaluated to support an overall understanding of the potential for ongoing biodegradation and support future assessment of natural degradation or enhanced biodegradation as remedial technologies. In the event that biodegradation or natural attenuation are components of future remedial actions, this geochemical sampling will also be useful to evaluate a baseline set of conditions and support ongoing performance monitoring. Specific geochemical parameters will be interpreted as follows:

- Total and dissolved iron and total and dissolved manganese in impacted areas will be used as indications of oxidizing versus reducing conditions. When the overall presence of these metals is dominated by dissolved/soluble forms, the geochemical environment is reducing and potentially suitable for both anaerobic degradation of petroleum hydrocarbons and reductive dechlorination of CVOCs.
- Nitrate and sulfate concentrations in impacted areas will be compared to concentrations at upgradient or unimpacted areas. Depleted concentrations in impacted areas are evidence that these naturally occurring ions are being used as electron acceptors in biological processes.
- Total organic carbon results will be used to establish a range of naturally occurring values for comparison in the event that the addition of organic carbon or promotion of biomass growth is a component of future remedial actions.

5.2 Pre-field Activities

5.2.1 Health and Safety

All personnel working on BNSF Property will be subject to BNSF training and health and safety requirements. Arcadis and its subcontractors will adhere to the site-specific Health and Safety Plan (HASP; Appendix C) that covers the specific risks encountered through their work in accordance with all local, state, and federal requirements, including but not limited to Occupational Safety and Health Administration 1910.120 requirements for Hazardous Waste Operations and Emergency Response. Before the initiation of work, Arcadis will verify the training records of all contractor staff and will complete a daily tailgate review of the HASP (Appendix C). The HASP (Appendix C) will be updated as needed to include the most current information.

5.3 Field Activities

Remedial investigation field activities will be conducted to investigate the vertical and horizontal extent of impacts within the BNSF Property. The following field activities are proposed to provide additional characterization of soil and groundwater conditions within the BNSF Property and are summarized in Appendix A, Tables 5 and 6:

- Advance 11 soil borings (SB-BN-01 through SB-BN-11, Figure 12) to a total depth of between 20 and 40 feet bgs using sonic drilling technology. The proposed soil boring locations are intended to horizontally and vertically delineate CVOC, BTEX, TPH, and PCP impacts to the extent practical as detailed in Table 7, Proposed Boring and Well Rationale.
    - Complete five of the 11 soil borings (SB-BN-03, SB-BN-05, SB-BN-06, SB-BN-08, and SB-BN-10) as temporary wells (Figure 12) in the Shallow WBZ with a screen-point sampler to allow for the collection of an equilibrated groundwater sample. Then complete three of these five temporary wells as permanent Perched WBZ monitoring wells (SB-BN-03, SB-BN-08, and SB-BN-10) to allow for continued monitoring and delineation of CVOC, TPH, and PCP impacts in groundwater.

  - Complete two of the 11 soil borings (SB-BN-09 and SB-BN-11) as temporary wells in the Perched WBZ with a screen-point sampler to allow for the collection of an equilibrated groundwater sample. These temporary wells will be sampled to delineate PCP impacts in groundwater. Analytical samples will be placed on hold and analyzed for CVOCs and TPH pending analysis from MW-BN-04 and MW-BN-05.
  - Complete two of the 11 soil borings (SB-BN-04 and SB-BN-07) as permanent Perched WBZ and Shallow WBZ monitoring wells, respectively, to allow for continued monitoring and delineation of CVOC, TPH, and PCP impacts in groundwater.
- Perform lithological logging and field screening (i.e., sheen testing and VOC screening using a photoionization detector) for petroleum hydrocarbon impacts on each of the cores generated during drilling activities.
- Collect soil samples for laboratory analysis in accordance with Table 7 and the SAP/QAPP (Appendix A) to evaluate the vertical and horizontal distribution of impacts in soil.
- Collect low-flow groundwater samples and gauge water levels on a quarterly basis from the BNSF Property monitoring wells for one year to assess: 1) COPC concentrations and geochemistry in groundwater, 2) potentiometry, and 3) potential seasonality.
- Collect hydraulic conductivity data to support the conceptual site model and inform remedial technology evaluations.

5.3.1 Utility Clearance

Arcadis will notify the appropriate BNSF departments before performing intrusive work to allow for the identification and marking of any privately owned infrastructure within the work areas (i.e., signals and telecommunications). Arcadis will retain a subcontractor to perform a private utility locate to identify potential underground infrastructure using a ground-penetrating radar survey prior to intrusive activities. Arcadis will be responsible for notifying One-Call (811) at least 48 hours prior to conducting intrusive activities in accordance with the Washington State Dig Law, RCW 19.122. Before drilling, each location will be cleared to a minimum of 5 feet bgs using an air knife/vacuum truck combination or hand auger.

5.3.2 Drilling Methodology and Soil Boring Locations

The proposed soil boring locations are shown on Figure 12. Boring locations were selected with consideration of the historical soil and groundwater analytical results (Figures 4 through 11). Actual boring locations may be adjusted based on field observations, including utility locations or anomalies identified during the private utility locate. Following soft dig clearance, the borings will be advanced using sonic drilling technology to the proposed depths included in Table 7 (Boring and Well Rationale); however, actual depths will be dependent on field conditions. Continuous soil cores will be retrieved, screened, sampled and logged during drilling as described in Section 5.3.5. Following completion, the entire borehole will either be sealed using hydrated bentonite to prevent vertical transport between units or the boring will be converted to a temporary and/or permanent monitoring well as described in Sections 5.3.3 and 5.3.4 below.

5.3.3 Temporary Well Sampling

Five of the 11 soil borings (SB-BN-03, SB-BN-05, SB-BN-06, SB-BN-08, and SB-BN-10) will initially be converted to temporary Shallow WBZ wells using a screened-point sampler or temporary screen at approximately 25 to 35 feet bgs (Appendix A, Table 6). In addition, two of the 11 soil borings (SB-BN-09 and SB-BN-11) will be converted to temporary Perched WBZ wells using a screened-point sampler or temporary screen at approximately 5 to 15 feet bgs (Appendix A, Table 6). A groundwater sample will be collected from each of the seven temporary wells for laboratory analysis via low-flow purge methodology in accordance with the Arcadis Technical Guidance Instruction (TGI) – Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells (Appendix D). Proposed groundwater sample collection intervals are provided in Appendix A, Table 6, however final groundwater sample collection intervals will be determined in the field based on groundwater observations and lithologic data collected during drilling and will target the upper saturated portions of the Perched or Shallow WBZs.

5.3.4 Monitoring Well Installation

Once the grab groundwater samples are collected from the Shallow WBZ temporary wells, if needed, the borings will be backfilled to approximately 15 feet bgs and completed as permanent Perched WBZ groundwater monitoring wells to facilitate continued collection of groundwater data from the Perched WBZ. SB-BN-07 will be backfilled to approximately 35 feet bgs and completed as a Shallow WBZ groundwater monitoring well. Monitoring wells will be constructed of 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) pipe with 10 feet of 0.010-inch slotted PVC screen, in accordance with the Arcadis TGI – Monitoring Well Installation (Appendix D). Wells will be installed to an approximate depth of 15 feet bgs (Perched WBZ) or 35 feet bgs (Shallow WBZ); however, the screen interval and total well depth will be determined in the field based on the depth to the water table and soil lithology. Soil borings will be completed as monitoring wells if there is a minimum of 5 feet of saturated thickness to ensure the wells are viable for monitoring/sampling and do not run dry during well purging. The completed monitoring wells will be developed in accordance with Arcadis TGI – Monitoring Well Development (Appendix D).

5.3.5 Soil and Groundwater Sample Collection and Analytical Methods

Soil and groundwater samples will be collected in accordance with the SAP/QAPP (Appendix A) and the Arcadis TGI documents provided in Appendix D. Soil will be logged continuously during the advancement of each boring in accordance with the Arcadis TGI – Soil Description (Appendix D) and screened (i.e., sheen testing and VOC readings) every 5 feet or as lithology or visible changes in the core dictate. Soil cores will also be screened for visible petroleum hydrocarbon impacts (e.g., sheen or staining), and any observations will be noted in the boring log. Soil samples will be collected for laboratory analysis from the sonic core of each boring as specified in Appendix A, Table 6. Additional soil samples may be collected based on field screening or for geotechnical properties. Permeability samples from two borings (SB-BN-01 and SB-BN-10) will be collected using split-barrel sampler or equivalent to collect an undisturbed soil sample. Intervals for collection of laboratory analytical samples will be selected to provide delineation of any known or inferred areas of impacted soil nearby, based on the judgment of field personnel in communication with the Arcadis project team (Appendix A, Table 6).

Groundwater gauging and sampling will be conducted on a quarterly basis for all monitoring wells on the BNSF Property (Appendix A, Table 5) for one year after the installation of the five new monitoring wells (MW-BN-01 through MW-BN-05). Water levels will be measured via oil-water interface probe in accordance with the Arcadis TGI – Manual Water-Level and NAPL Monitoring. Groundwater samples will be collected via low-flow purge methodology in accordance with the Arcadis TGI – Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells (Appendix D). Groundwater quality parameters also will be measured and recorded using a water quality meter during groundwater sampling, and, once the parameters have equilibrated, a groundwater sample will be collected in accordance with the Arcadis TGI – Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells (Appendix D).

Soil and groundwater samples will be collected in laboratory-provided sample containers and submitted under standard chain-of-custody procedures for laboratory analysis as described in SAP/QAPP (Appendix A) and Arcadis Standard Operating Procedure – Sample Chain of Custody (Appendix D). Soil and groundwater samples will be submitted to Pace and will be analyzed in accordance with the SAP/QAPP (Appendix A). In addition to the COPC analyses, soil samples will be collected from discrete lithologies and analyzed for vertical permeability and fraction of organic carbon as described in the SAP/QAPP (Appendix A). It is understood that Ecology may elect to collect split or duplicate samples of any samples collected during completion of remedial investigation field activities, provided that doing so does not interfere with the sampling efforts.

5.3.6 Hydraulic Conductivity Testing

Hydraulic conductivity of both the Perched and Shallow WBZs will be estimated by using either the slug testing methodology and/or by the low flow drawdown testing methodology. The hydraulic testing will be completed at three Perched WBZ wells (01MW92, 01MW96, and MW-BN-01) and two Shallow WBZ wells (01MW94 and 01MW95) in accordance with either the Arcadis TGI – Slug Testing – Solid Slug Testing or the TGI – Low Flow Steady State Drawdown Testing (Appendix D). Slug tests will include both slug-in and slug-out tests at each well. Additional hydraulic conductivity testing may be completed at other monitoring wells contingent on field conditions, such as access, data quality, or schedule. In addition, select soil samples will be analyzed for vertical permeability and fraction of organic carbon as described in Section 5.3.5 and the SAP/QAPP (Appendix A). The results of the hydraulic conductivity testing will help inform remedial technology evaluations and assessment of COPC transport.

5.3.7 Equipment Decontamination

Down-hole equipment, including sonic casing, split-barrel samplers, and non-dedicated sampling equipment, will be decontaminated prior to initial boring and between each boring thereafter using a three-stage decontamination process. Equipment will be decontaminated by first rinsing with clean potable water, scrubbing using hand brushes and an Alconox detergent solution, followed by rinsing with water after each use in accordance with the Arcadis TGI – Groundwater and Soil Sampling Equipment Decontamination (Appendix D). Sonic drilling casing will be decontaminated using a pressure washer. Decontamination water will be containerized in United States Department of Transportation approved 55-gallon drums and handled as described in Section 5.3.9.

5.3.8 Analytical Data Quality Assurance and Quality Control

QA and QC procedures will be followed during monitoring and sampling to verify the provision of reliable, accurate, and defensible data. These procedures include laboratory QC analyses and data validation of laboratory analytical results.

Laboratory data will be validated in accordance with the SAP/QAPP (Appendix A) and a validation report will be compiled for each sample delivery group (laboratory report). Data validation will include a review of data quality indicators (DQIs). DQIs are generally defined in terms of six parameters: representativeness, comparability, completeness, precision, accuracy, and sensitivity. The process includes the review of holding times, laboratory and field blanks, duplicates, laboratory instrument calibration, matrix spikes, laboratory control samples, and surrogate recoveries. The results of the data validation will be assessed, and data qualifiers will be applied to the dataset as appropriate. Subsequent to data validation, a QC summary will be provided that discusses the quality and usability of the data.

Validated data will be uploaded to the Ecology Environmental Information Management System (EIMS) in accordance with WAC 173-340-840(5) and Ecology's Toxics Cleanup Program Policy 840: Data Submittal Requirements. Data will be entered into the EIMS database within 45 days of data validation completion (Ecology 2021a).

5.3.9 Survey

All monitoring wells on the BNSF Property will be surveyed by a surveyor licensed in the State of Washington after construction. The survey will reference the North American Datum of 1983 (NAD 83) State Plan Coordinates and the North American Vertical Datum of 1988 (NAVD 88). Horizontal and vertical accuracy should be within 0.1 foot. The survey will include top of casing elevations for all wells.

5.3.10 Investigation-Derived Waste Management

Investigation-derived waste (IDW) that may be generated during field activities includes soil cuttings, purge water from groundwater sampling, and decontamination water. IDW will be handled according to the Arcadis TGI – Investigation-Derived Waste Handling and Storage (Appendix D). The management of IDW will be protective of human health and the environment, and be consistent with local, state, and federal regulatory requirements. IDW composite samples will be collected from the containerized solid and liquid wastes and submitted separately for laboratory analysis to support characterization and determine the appropriate disposal method for each waste stream. The samples will be analyzed for all COPCs, as well as Resource Conservation and Recovery Act 8 metals. Additionally, analyses may be performed at the request of the waste receiving facility. All waste will be disposed of at a BNSF-approved disposal facility according to characterization requirements of that facility. If waste is determined to be hazardous, the IDW will be removed from the property within 90 days of generation.

5.4 Data Evaluation

Data collected during the remedial investigation will be screened against the initial screening levels discussed in Section 4 and presented in Tables 5 and 6. The analytical results of the remedial investigation will be used to assess the vertical and horizontal extent of impacts on the BNSF Property and to update the preliminary CSM presented in Section 3. The updated CSM will present an assessment of exposure pathways and potential receptors based on the results of the data collected. Additionally, the data collected as part of this investigation will inform the screening of remedial action alternatives, which will be evaluated as part of the Feasibility Study.

5.5 Reporting

The data collected as part of this investigation will be presented to Ecology during a Remedial Investigation Pre-Report Check-In (Ecology 2021a). During this meeting, Ecology and BNSF will discuss the available data and the updated CSM. The organization and content of the draft Remedial Investigation Report, such as a TEE performed in accordance with the WAC 173-340-7490, will also be determined during this meeting.

Within 90 days of receiving the final round of validated laboratory data collected during the remedial investigation, a Draft Remedial Investigation Report will be prepared for agency review summarizing the data collected during the remedial investigation. This report will also identify any interim actions for the BNSF Property, if necessary. Once reviewed by Ecology, the Remedial Investigation Report may be submitted for public review then finalized or may be incorporated into the Feasibility Study as a combined document. The reporting process will be discussed with Ecology during the Remedial Investigation Pre-Report Check-in meeting.

6 Project Schedule and Progress Reporting

The following is the proposed schedule for the remedial investigation field activities:

Task	Completion Date
Task 1: Contractor Procurement	Within 30 days of Ecology approval of Final RIWP
Task 2: Utility Locate, Boring and Well Installation and Development, Initial Sampling, and Well Survey	Within 30 days of Contractor Procurement
Task 3: Quarterly Monitoring	Within 1 year of Well Installation

In accordance with the AO, Arcadis will prepare quarterly Progress Reports on behalf of BNSF to summarize actions taken during the previous quarter (Ecology 2021a). The Progress Reports will be submitted to Ecology by the 15th day of the month after the prior quarter. Once the remedial investigation activities are complete, the Remedial Investigation Report will be submitted to Ecology in accordance with the schedule detailed in Exhibit B of the AO. The following submittal schedule will be met in accordance with the AO (Ecology 2021a):

Task	Completion Date
Task 1: Environmental Information Management System Data Submittal	Within 45 days of completion of data validation for last data collection.
Task 2: Remedial Investigation Report	Agency Review Draft – Within 90 days of receiving data validation from last data collection. Public Review Draft – Within 45 days of receiving Ecology comments. Final Remedial Investigation Report – Within 45 days of receiving Ecology comments.
Task 3: Quarterly Progress Reports	Within 15 days of the prior quarter.

7 References

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Tables

Table 1
Well Construction Details - BNSF Property
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Well ID	Installation Date	Top of Casing Elevation (feet NAVD88)	2019 Water Bearing Zone	Screened Interval (feet below top of casing)
01MW92	8/16/2012	58.47	Perched	6-16
01MW93	8/16/2012	58.92	Shallow	23.5-38.5
01MW94	8/17/2012	58.50	Shallow	28-40
01MW95	8/17/2012	59.29	Shallow	27-37
01MW96	5/7/2013	59.51	Perched	5-15
01MW97	5/7/2013	58.73	Perched	5-15
01MW98	5/7/2013	57.73	Perched	5-15

Note:

1. Well construction details are from the Supplemental Upland Remedial Investigation and Feasibility Study (Floyd Snider 2020).

Acronyms and Abbreviations:

BNSF = BNSF Railway Company
ID = identification
NAVD88 = North American Vertical Datum of 1988

Reference:

Floyd Snider. 2020. Supplemental Upland Remedial Investigation and Feasibility Study, Prepare
Cantera Development Group, LLC. September.

Table 2
Historical Soil Analytical Data
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Well/Boring ID	Sample ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO + HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	PCE	TCE	EDC	Cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	Vinyl Chloride	Pentachlorophenol
Preliminary Cleanup Levels[1]				30[2]	570	1,600	2,000[3]	0.0010	0.023	0.0059	0.030	0.0025	0.0010	0.0025	0.0052	0.032	0.0025	0.0025	0.00896
All units in milligrams per kilogram (mg/kg)																			
BNSF Property																			
01MW92/B258	B258-02.5	8/16/12	2.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**0.18**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B258-05		5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**0.39**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B258-10		10	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**0.050**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B258-12.5		12.5	--	--	--	--	--	--	--	--	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050	--
01MW93/B259	B259-02.5	8/16/12	2.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B259-05		5.0	--	--	--	--	--	--	--	--	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050	--
	B259-07.5		7.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**0.18**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B259-17.5		17.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B259-22.5		22.5	--	--	--	--	--	--	--	--	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050	--
01MW94/B260	B260-02.5	8/17/12	2.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B260-12.5		12.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B260-17.5		17.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
01MW95/B261	B261-0.5	8/17/12	0.5	<2.0	**140**	<250	**390**	<0.020	<0.020	<0.020	<0.060	--	--	<0.050	--	--	--	--	--
	B261-02.5		2.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050	--
	B261-05		5	**240**	**3,000**	<250	**3,250**	<0.020	**0.046**	**1.6**	**4.3**	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B260-07.5		7.5	**8.7**	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
01MW96/B264	B264-02.5	5/7/13	2.5	**30**	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B264-07.5		7.5	**16**	**68**	<250	**318**	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B264-10		10	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
01MW97/B265	B265-03	5/7/13	3	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**0.098**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B265-06		6	**2.2**	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**0.12**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B265-11		11	**3.2**	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**7.9**	<0.050	**0.071**	<0.050	<0.050	<0.050	--
	B265-16		16	--	--	--	--	--	--	--	--	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050	--
01MW98/B266	B266-03.5	5/7/13	3.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B266-06		6	**130**	**4,100**	**1,100**	**5,200**	<0.020	<0.020	**0.33**	**0.56**	<0.025	**0.55**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B266-08		8	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**0.12**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B266-16		16	--	--	--	--	--	--	--	--	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050	--
SB-07	SB-07-5	2001	5	**1,240**	**1,190**	**783**	**1,973**	**2.2**	<1.0	**7.6**	**18**	--	--	--	--	--	--	--	<0.250
	SB-07-10		10	<5.0	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	<0.250
	SB-07-15		15	**7.6**	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	**0.057**
SB-08	SB-08-5	2001	5	**26**	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	**0.056**
	SB-08-10		10	**15**	**447**	<25	**472**	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	--
	SB-08-15		15	<5.0	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	--
SB-09	SB-09-5	2001	5	**17**	**30**	<25	**55**	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	--
	SB-09-10		10	<5.0	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	--
	SB-09-15		15	**9.0**	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	--
Time Oil Properties																			
B116	B116-03	3/18/09	3.0	<2.0	**1,900**	**2,200**	**4,100**	<0.020	<0.020	<0.030	<0.060	<0.020	**0.21**	<0.030	<0.020	<0.020	<0.050	<0.020	--
	B116-07		7	--	<50	<250	<300	--	--	--	--	--	--	--	--	--	--	--	--
	B116-16		16	--	--	--		<0.020	<0.020	<0.030	<0.030	<0.020	<0.030	<0.030	**0.20**	<0.020	<0.050	<0.020	--
01MW60/B83	B083-05	12/29/08	5	**240**	**1,200**	**1,700**	**2,900**	<0.030	<0.050	**1.2**	**1.7**	<0.025	<0.030	<0.05	<0.050	<0.050	<0.050	<0.050	--
	B083-07.5		7.5	**1,600**	**1,500**	**1,700**	**3,200**	**0.61**	**0.88**	**14**	**19**	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B083-15		15	<2.0	--	--	--	<0.020	**0.030**	<0.020	<0.060	--	--	--	--	--	--	--	--
	B083-37.5		37.5	--	--	--	--	<0.030	<0.050	<0.050	<0.15	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
01MW61/B84	B084-05	12/29/08	5	**30**	**220**	<250	**470**	<0.030	<0.050	<0.050	<0.15	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B084-07.5		7.5	<2.0	<50	<250	<300	<0.030	<0.050	<0.050	<0.15	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B084-27.5		27.5	--	--	--	--	--	--	--	--	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
01MW62/B85	B085-05	12/30/08	5	<2.0	<50	<250	<300	<0.030	<0.050	<0.050	<0.15	<0.025	**0.22**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B085-17.5		17.5	**27**	<50	<250	<300	<0.030	<0.050	<0.050	<0.15	<0.025	**66**	<0.050	**0.12**	<0.050	<0.050	<0.050	--
	B085-20		20	**11**	<50	<250	<300	<0.030	<0.050	<0.050	<0.15	<0.025	**52**	<0.050	**0.14**	<0.050	<0.050	<0.050	--
	B085-30		30	--	--	--	--	--	--	--	--	<0.025	**4.2**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B085-37.5		37.5	--	--	--	--	--	--	--	--	<0.035	**0.10**	<0.050	<0.050	<0.050	<0.050	<0.050	--

Table 2
Historical Soil Analytical Data
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Well/Boring ID	Sample ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO + HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	PCE	TCE	EDC	Cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	Vinyl Chloride	Pentachlorophenol
		Preliminary Cleanup Levels[1]		30[2]	570	1,600	2,000[3]	0.0010	0.023	0.0059	0.030	0.0025	0.0010	0.0025	0.0052	0.032	0.0025	0.0025	0.00896
All units in milligrams per kilogram (mg/kg)																			
Time Oil Properties (continued)																			
01MW64/B102	B102-02.5	3/17/09	2.5	**68**	**320**	**350**	**670**	<0.020	<0.020	<0.020	<0.060	--	--	<0.050	--	--	--	--	--
	B102-05		5	<2.0	--	--		<0.020	<0.020	<0.020	<0.060	--	--	--	--	--	--	--	--
	B102-07.5		7.5	**3.0**	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	--	--	<0.050	--	--	--	--	--
	B102-17.5		17.5	--	--	--	--	<0.020	<0.020	<0.020	<0.030	--	--	<0.030	--	--	--	--	--
	B102-20		20	--	--	--	--	<0.020	<0.020	<0.020	<0.030	--	--	<0.030	--	--	--	--	--
01MW70/01SVE02/ B134	B134-02.5	2/11/10	2.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**0.033**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B134-10.5		10.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**1.7**	<0.050	<0.050	**0.15**	<0.050	<0.050	--
01MW71/01SVE03/ B133	B133-05.5	2/11/10	5.5	<2.0	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**0.80**	<0.050	**0.068**	<0.050	<0.050	<0.050	--
	B133-20		20	--	--	--	--	--	--	--	--	<0.025	**120**	<0.050	**0.34**	<0.050	<0.050	<0.050	--
01MW78/B173	B173-07.5	3/2/11	7.5	**4.4x**	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**7.7**	<0.050	**0.065**	<0.050	<0.050	<0.050	--
	B173-10		10	--	--	--	--	--	--	--	--	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B173-15		15	--	--	--	--	--	--	--	--	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B173-25		25	--	--	--	--	--	--	--	--	<0.025	**47**	<0.050	<0.050	<0.050	<0.050	<0.050	--
	B173-27.5		27.5	**3.8x**	<50	<250	<300	<0.020	<0.020	<0.020	<0.060	<0.025	**5.3**	<0.050	<0.050	<0.050	<0.050	<0.050	--
SB-06	SB-06-5	2001	5	**10.6**	**553**	**369**	**922**	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	<0.250
	SB-06-10		10	<5.0	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	**0.055**
	SB-06-15		15	<5.0	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	**0.055**
SB-10	SB-10-5	2001	5	<5.0	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	--
	SB-10-10		10	<5.0	<10	<25	<35	<0.050	<0.050	<0.050	**0.12**	--	--	--	--	--	--	--	--
	SB-10-15		15	<5.0	<10	<25	<35	<0.050	<0.050	<0.050	<0.10	--	--	--	--	--	--	--	--

Table 2
Historical Soil Analytical Data
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Notes:

1. Preliminary cleanup levels as presented in Tables 6.
2. Screening level of 30 mg/kg is appropriate as benzene has been detected in groundwater within the BNSF Property.
3. Screening level of 2,000 mg/kg is used to screen the combined concentration of DRO and HO.

Qualifiers:

x = The pattern of peaks present is not indicative of diesel or the sample chromatographic pattern does not resemble the fuel standard used for quantitation.

Acronyms and Abbreviations:

-- = not analyzed
< = less than reporting detection limit
Bold = Analyte detected at a concentration greater than the reporting detection limit
Highlight and Bold = Detected concentration exceeds preliminary cleanup levels for soil.
AOC = area of concern
bgs = below ground surface
DCE = dichloroethene
BNSF = BNSF Railway Company
DRO = diesel range organics
EDC = 1,2-dichloroethene
GRO = gasoline range organics
HO = heavy oil
ID = identification
mg/kg = milligrams per kilogram
PCE = tetrachloroethene
TCE = trichloroethene

Reference:

Washington State Department of Ecology. 2013. *Model Toxics Control Act Regulation and Statute* . Publication No. 94-06.

Table 3
Historical Groundwater Elevations
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Well ID	Top-of-Casing Elevation (feet NAVD88)	Water-Bearing Zone	Date	Depth to LNAPL (feet btoc)	Depth to Water (feet btoc)	LNAPL Thickness (feet)	Groundwater Elevation (feet NAVD88)
01MW92	58.47	Perched	8/23/2012	--	9.53	--	48.94
	58.47		9/4/2012	--	10.99	--	47.48
	58.47		9/5/2012	--	10.00	--	48.47
	58.47		5/10/2013	--	7.57	--	50.90
	58.47		6/4/2013	--	8.18	--	50.29
	58.47		07/2019	--	8.30	--	50.17
01MW93	58.92	Shallow	8/23/2012	--	30.82	--	28.10
	58.92		9/4/2012	--	30.89	--	28.03
	58.92		9/5/2012	--	30.71	--	28.21
	58.92		5/10/2013	--	30.56	--	28.36
	58.92		5/14/2019	--	29.94	--	28.98
01MW94	58.5	Shallow	8/23/2012	--	31.32	--	27.18
	58.5		9/4/2012	--	31.41	--	27.09
	58.5		9/5/2012	--	31.19	--	27.31
	58.5		5/10/2013	--	31.21	--	27.29
	58.5		5/14/2019	--	30.55	--	27.95
01MW95	59.29	Shallow	8/23/2012	--	30.44	--	28.85
	59.29		9/4/2012	--	30.48	--	28.81
	59.29		9/5/2012	--	30.32	--	28.97
	59.29		5/10/2013	--	30.14	--	29.15
	59.29		07/2019	--	29.48	--	29.81
01MW96	59.51	Perched	5/10/2013	--	11.30	--	48.21
	59.51		6/4/2013	--	10.29	--	49.22
	59.51		07/2019	--	10.80	--	48.71
01MW97	58.73	Perched	5/10/2013	--	7.95	--	50.78
	58.73		6/4/2013	--	8.43	--	50.30
	58.73		5/14/2019	--	8.25	--	50.48
01MW98	57.73	Perched	5/10/2013	--	6.53	--	51.20
	57.73		6/4/2013	--	7.03	--	50.70
	57.73		5/14/2019	--	6.93	--	50.80

Notes:

1. Top-of-casing elevations from the Supplemental Upland Remedial Investigation and Feasibility Study (Floyd Snider 2020).

Acronyms and Abbreviations:

BNSF = BNSF Railway Company
-- = not collected
btoc = below top of casing
ID = identification
NAVD88 = North American Vertical Datum of 1988

Reference:

Floyd Snider. 2020. Supplemental Upland Remedial Investigation and Feasibility Study, Prepared for Cantera Development Group, LLC. September.

Table 4
Historical Groundwater Analytical Data
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Well/Boring ID	Sample ID	Date Sampled	GRO	DRO	HO	DRO + HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	PCE	TCE	EDC	cis-1,2-DCE	trans-1,2-DCE	1,1-DCE	Vinyl Chloride	Pentachlorophenol
Preliminary Cleanup Levels[1]			800[2]	500	500	500[3]	0.44	53	12	57	2.4	0.30	0.48	16	77	7.0	1 / 0.10	0.313
All units in micrograms per liter (μg/L)																		
Perched Water Bearing Zone - BNSF Property																		
01MW92	01MW92-20120823	8/23/2012	<100	**2,300**	**640x**	**2,940**	<1.0	<1.0	<1.0	<3.0	<1.0	**110**	<1.0	**100**	**2.2**	**3.0**	**9.3**	--
	01MW92-20120905	9/5/2012	**220x**	**3,100x**	**1,100x**	**4,200**	<1.0	<1.0	<1.0	<3.0	<1.0	**300**	<1.0	**120**	**3.8**	**3.3**	**9.4**	--
	01MW92-20130510	5/10/2013	**770x**	**3,400x**	**770x**	**4,170**	<1.0	<1.0	<1.0	<3.0	<1.0	**6,700**	<1.0	**420**	**43**	**6.2**	**5.8**	--
	01MW92-20140404	4/4/2014	**1,500**	**6,400**	**1,100**	**7,500**	<1.0	**1.7**	<1.0	<3.0	<1.0	**7,800**	<1.0	**640**	**35**	<1.0	**5.8**	--
	01MW92-051419	5/14/2019	**1,500**	**4,600**	**1,300x**	**5,900**	<70	<200	<200	<400	<200	**5,200**	<200	**570**	<200	<200	<40	--
01MW96	01MW96-20130510	5/10/2013	<100	**2,000x**	**380x**	**2,380**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	FD01-20130510 (DUP)	5/10/2013	<100	**1,800x**	**340x**	**2,140**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW96-20140404	4/4/2014	<100	**1,900**	**290**	**2,190**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW96-051419	5/14/2019	--	**2,100**	**450x**	**2,550**	**1.3**	<1.0	<1.0	<2.0	<1.0	**1.5**	<1.0	**3.1**	<1.0	<1.0	**6.0**	--
01MW97	01MW97-20130510	5/10/2013	**620x**	**3,200x**	**740x**	**3,940**	<1.0	<1.0	<1.0	<3.0	<1.0	**6,300**	<1.0	**300**	**14**	**6.5**	**2.0**	--
	01MW97-20140404	4/4/2014	<100	**82**	<250	**332**	<1.0	<1.0	<1.0	<3.0	<1.0	**29**	<1.0	**4.9**	<1.0	<1.0	<0.20	--
	01MW97-051419	5/14/2019	--	**65 J**	<250 J	**285**	--	--	--	--	<1.0	**56**	<1.0	**20**	<1.0	<1.0	<0.20	--
01MW98	01MW98-20130510	5/10/2013	**170x**	**4,000x**	**820x**	**4,820**	<1.0	<1.0	<1.0	<3.0	<1.0	**190**	<1.0	**19**	<1.0	<1.0	<0.20	--
	01MW98-20140404	4/4/2014	**140**	**4,200**	**1,200**	**5,400**	<1.0	<1.0	<1.0	<3.0	<1.0	**190**	<1.0	**16**	<1.0	<1.0	<0.20	--
	01MW98-051419	5/14/2019	**370**	**3,600**	**1,300x**	**4,900**	--	--	--	--	<10	**810**	<10	**57**	<10	<10	<2.0	--
Shallow Water Bearing Zone - BNSF Property																		
01MW93	01MW93-20120823	8/23/2012	<100	**62**	<250	**312**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW93-20120905	9/5/2012	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1.5**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW93-20130513	5/13/2013	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**5.5**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW93-20140409	4/9/2014	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**3.4**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW93-051419	5/14/2019	<100	**54**	<250	**304**	--	--	--	--	<1.0	<0.50	<1.0	<1.0	<1.0	<1.0	<0.20	--
01MW94	01MW94-20120823	8/23/2012	<100	**89**	<250	**339**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW94-20120905	9/5/2012	<100	**120x**	<250	**370**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW94-20130510	5/10/2013	<100	**56x**	<250	**306**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW94-20140409	4/9/2014	<100	**71**	<250	**321**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW94-051419	5/14/2019	--	<50	<250	<300	--	--	--	--	<1.0	<0.50	<1.0	<1.0	<1.0	<1.0	<0.20	--
01MW95	01MW95-20120823	8/23/2012	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW95-20120905	9/5/2012	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW95-20130510	5/10/2013	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW95-20140409	4/9/2014	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW95-051419	5/14/2019	--	--	--	--	--	--	--	--	<1.0	<0.50	<1.0	<1.0	<1.0	<1.0	<0.20	--
Perched Water Bearing Zone - Time Oil Properties																		
01MW70	01MW70-20100408	4/8/2010	**200**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**400**	<1.0	**37**	**16**	<1.0	**0.46**	--
	01MW70-20100709	7/9/2010	**320**	<50	<250	<300	<1.0	**1.3**	<1.0	<3.0	<1.0	**560**	<1.0	**51**	**20**	<1.0	**0.99**	--
	01MW70-20110111	1/11/2011	**170x**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**410**	<1.0	**41**	**29**	<1.0	**0.93**	--
	01MW70-20110413	4/13/2011	**190x**	**980x**	**760x**	**1,740**	<1.0	<1.0	<1.0	<3.0	<1.0	**330**	<1.0	**38**	**19**	<1.0	**1.1**	--
	01MW70-20110825	8/25/2011	**170x**	**830x**	**530x**	**1,360**	<1.0	<1.0	<1.0	<3.0	<1.0	**400**	<1.0	**94**	**180**	<1.0	**1.3**	--
	01MW70-20111209	12/9/2011	**220x**	**830x**	**680x**	**1,510**	<1.0	<1.0	<1.0	<3.0	<1.0	**560**	<1.0	**51**	**20**	<1.0	**1.4**	--
	01MW70-20120403	4/3/2012	**120x**	**1,500x**	**900x**	**2,400**	<1.0	<1.0	<1.0	<3.0	<1.0	**300**	<1.0	**32**	**18**	<1.0	**0.81**	--
	01MW70-20121012	10/12/2012	**200x**	**710x**	**480x**	**1,190**	<1.0	**1.5**	<1.0	<3.0		**370**	<1.0	**78**	**140**	<1.0	**0.76**	--
	01MW70-20130402	4/2/2013	**160x**	**1,200x**	**1,000x**	**2,200**	<1.0	<1.0	<1.0	<3.0	<5.0	**360**	<5.0	**36**	**19**	<5.0	**0.80 J**	--
	01MW70-20131104	11/4/2013	**150**	**990**	**920**	**1,910**	<1.0	<1.0	<1.0	<3.0	<1.0	**480**	--	**55**	**36**	<1.0	**1.1**	--
	01MW70-20140403	4/3/2014	**140**	**1,200**	**910**	**2,110**	<1.0	<1.0	<1.0	<3.0	<1.0	**300**	--	**28**	**19**	<1.0	**0.41**	--
	01MW70-20150528	5/28/2015	**250**	**1,000**	**1,200**	**2,200**	<1.0	<1.0	<1.0	<3.0	<1.0	**450**	--	**49**	**40**	<1.0	<0.20	--
	01MW70-20160518	5/18/2016	**210**	**1,200**	**1,500**	**2,700**	<1.0	<1.0	<1.0	<3.0	<1.0	**430**	--	**37**	**7.3**	<1.0	**0.87**	--
	01MW70-050219	5/2/2019	**160**	**1,100**	**850**	**1,950**	--	--	--	--	<1.0	**310**	<1.0	**52**	**71**	<1.0	**0.69**	--
01MW71	01MW71-20100408	4/8/2010	**450**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1,100**	<1.0	**99**	**3.3**	**2.8**	**6.7**	--
	01MW71-20100709	7/9/2010	**170x**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**290**	<1.0	**23**	**2.1**	<1.0	**3.8**	--
	01MW71-20110111	1/11/2011	**460x**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1,100**	<1.0	**79**	**5.5**	**2.5**	**5.1**	--
	01MW71-20110413	4/13/2011	**900x**	**1,100x**	**860x**	**1,960**	<1.0	**1.4**	<1.0	<3.0	<1.0	**1,700**	<1.0	**95**	**5.5**	**2.0**	**4.9**	--
	01MW71-20110825	8/25/2011	**270x**	**1,400x**	**730x**	**2,130**	<1.0	<1.0	<1.0	<3.0	<1.0	**820**	<1.0	**62**	**11**	**1.9**	**6.7**	--
	01MW71-20111209	12/9/2011	**540x**	**1,100x**	**820x**	**1,920**	<1.0	<1.0	<1.0	<3.0	<1.0	**1,400**	<1.0	**92**	**7.7**	**3.2**	**7.0**	--
	01MW71-20120404	4/4/2012	**740x**	**1,400x**	**980x**	**2,380**	<1.0	<1.0	**1.1**	<3.0	<1.0	**3,600**	<1.0	**94**	**8.2**	**3.9**	**6.3**	--
	01MW71-20121011	10/11/2012	**380x**	**1,100x**	**780x**	**1,880**	<1.0	<1.0	<1.0	<3.0	<1.0	**790**	<1.0	**51**	**7.00**	**1.5**	**1.4**	--
	01MW71-20130402	4/2/2013	**330x**	**1,500x**	**1,400x**	**2,900**	<1.0	<1.0	<1.0	<3.0	<1.0	**3,600**	<10	**110**	**11**	<10	**8.8**	--
	01MW71-20131104	11/4/2013	**740**	**1,300**	**1,000**	**2,300**	<1.0	<1.0	<1.0	<3.0	<1.0	**3,100**	--	**110**	**22**	**6.5**	**9.7**	--
	01MW71-20140403	4/3/2014	**830**	**2,000**	**1,300**	**3,300**	<1.0	<1.0	<1.0	<3.0	<1.0	**4,300**	--	**120**	**11**	**7.3**	**7.1**	--
	01MW71-20150528	5/28/2015	**1,500**	**1,600**	**2,100**	**3,700**	<1.0	**1.3**	**1.4**	<3.0	<1.0	**2,600**	--	**120**	**21**	**11**	**12**	--
	01MW71-20160518	5/18/2016	**930**	**1,700**	**2,300**	**4,000**	<1.0	**1.4**	<1.0	<3.0	<1.0	**2,200**	--	**110**	**20**	**11**	**12**	--
	01MW71-050219	5/2/2019	--	--	--	--	<0.35	<1.0	<1.0	<2.0	<1.0	**2,800**	<1.0	**120**	**17**	**13**	**7.9**	--

Table 4
Historical Groundwater Analytical Data
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Well/Boring ID	Sample ID	Date Sampled	GRO	DRO	HO	DRO + HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	PCE	TCE	EDC	cis-1,2-DCE	trans-1,2-DCE	1,1-DCE	Vinyl Chloride	Pentachlorophenol
		Preliminary Cleanup Levels[1]	800[2]	500	500	500[3]	0.44	53	12	57	2.4	0.30	0.48	16	77	7.0	1 / 0.10	0.313
All units in micrograms per liter (µg/L)																		
Shallow Water Bearing Zone - Time Oil Properties																		
01MW60	01MW60-20090108	1/8/2009	**390**	**270**	<250	**520**	**1.2**	<1.0	**1.2**	<3.0	<1.0	**41**	<1.0	**1.6**	<1.0	<1.0	<0.20	--
	01MW60-20090129	1/29/2009	**190**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**6.3**	<1.0	<1.0	<1.0	<1.0	**0.32**	--
	01MW60-20090407	4/7/2009	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**17**	<1.0	<1.0	<1.0	<1.0	**0.23**	--
	01MW60-20090709	7/9/2009	<100	**130**	<250	**380**	<1.0	<1.0	<1.0	<3.0	<1.0	**7.6**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20100128	1/28/2010	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**8.9**	<1.0	<1.0	<1.0	<1.0	**0.30**	--
	01MW60-20100408	4/8/2010	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**42**	<1.0	<5.0	<1.0	<1.0	**0.31**	--
	01MW60-20100713	7/13/2010	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**18**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20110113	1/13/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**26**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20100415	4/15/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**4.9**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20110824	8/24/2011	<100	**60x**	<250	**310**	<1.0	<1.0	<1.0	<3.0	<1.0	**4.0**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20111207	12/7/2011	<100	**78x**	<250	**328**	<1.0	<1.0	<1.0	<3.0	<1.0	**29**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20120404	4/4/2012	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**6.5**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20121010	10/10/2012	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**2.6**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20130402	4/2/2013	<100	**120x**	<250	**370**	<1.0	<1.0	<1.0	<3.0	<1.0	**4.5**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20131104	11/4/2013	<100	<60	<300	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**2.7**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20140403	4/3/2014	<100	**68**	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**4.1**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20150528	5/28/2015	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1.8**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-20160512	5/12/2016	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1.5**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW60-050219	5/2/2019	--	<50	<250	<300	--	--	--	--	<1.0	**15**	<1.0	<1.0	<1.0	<1.0	<0.20	--
01MW61	01MW61-20090108	1/8/2009	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**0.37**	--
	01MW61-20090129	1/29/2009	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20090407	4/7/2009	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20090709	7/9/2009	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20100128	1/28/2010	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20100408	4/8/2010	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20100708	7/8/2010	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20110111	1/11/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20110414	4/14/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20110823	8/23/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20111208	12/8/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20120403	4/3/2012	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20121009	10/9/2012	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20130402	4/2/2013	<100	**230x**	<250	**480**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20131105	11/5/2013	<100	<55	<280	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20140409	4/9/2014	<100	**75**	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20150528	5/28/2015	<100	**58**	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW61-20160513	5/13/2016	<100	**56**	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
01MW62	01MW62-20090108	1/8/2009	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**59**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW62-20090129	1/29/2009	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**75**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW62-20090407	4/7/2009	**280**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1,300**	<1.0	**1.7**	<1.0	<1.0	<0.20	--
	01MW62-20090709	7/9/2009	**130**	**58**	<250	**308**	<1.0	<1.0	<1.0	<3.0	<1.0	**220**	<1.0	**1.8**	<1.0	<1.0	<0.20	--
	01MW62-20100128	1/28/2010	**270**	<50	<250	<300	<1.0	**2.0**	<1.0	<3.0	<1.0	**570**	<1.0	**4.5**	<1.0	<1.0	**0.36**	--
	01MW62-20100407	4/7/2010	**540**	<50	<250	<300	<1.0	**2.0**	<1.0	<3.0	<1.0	**1,200**	<1.0	**10**	<1.0	<1.0	**0.50**	--
	01MW62-20100708	7/8/2010	**240**	<50	<250	<300	**3.2**	<1.0	<1.0	<3.0	<1.0	**450**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW62-20110113	1/13/2011	**520x**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1,400**	<1.0	**6.1**	<1.0	<1.0	**0.53**	--
	01MW62-20110415	4/15/2011	**510x**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	**24**	**1,600**	<10	<10	<10	<10	<2.0	--
	01MW62-20110824	8/24/2011	**430x**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**2,500**	<1.0	**5.2**	<1.0	<1.0	**0.28**	--
	01MW62-20111208	12/8/2011	**150x**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**330**	<1.0	**1.8**	<1.0	<1.0	<0.20	--
	01MW62-20120404	4/4/2012	**130x**	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**390**	<1.0	**2.9**	<1.0	<1.0	<0.20	--
	01MW62-20121011	10/11/2012	**260x**	**57x**	<250	**307**	<1.0	<1.0	<1.0	<3.0	<1.0	**390**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW62-20130402	4/2/2013	**290x**	**110x**	<250	**360**	<1.0	**1.9**	<1.0	<3.0	<4.3	**890**	<50	<4.5	<50	<50	<3.5 J	--
	01MW62-20130510	5/10/2013	--	--	--	--	--	--	--	--	<1.0	**360**	--	**2.1**	<1.0	<1.0	<0.20	--
	01MW62-20131105	11/5/2013	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**250**	--	**1.5**	<1.0	<1.0	<0.20	--
	01MW62-20140403	4/3/2014	**460**	**180**	<250	**430**	<1.0	<1.0	<1.0	<3.0	<1.0	**950**	--	**9.0**	<1.0	<1.0	<0.20	--
	01MW62-20150528	5/28/2015	**790**	**88**	<250	**338**	<1.0	<1.0	<1.0	<3.0	<1.0	**1,700**	--	<1.0	<1.0	<1.0	<0.20	--
	01MW62-20160513	5/13/2016	**270**	**53**	<250	**303**	<1.0	<1.0	<1.0	<3.0	<1.0	**630**	--	**7.0**	<1.0	<1.0	<0.20	--
	01MW62-050219	5/2/2019	**460**	**100**	<250	**350**	**0.35**	<1.0	<1.0	<2.0	<1.0	**850**	<1.0	**15**	<1.0	<1.0	<0.20	--

Table 4
Historical Groundwater Analytical Data
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Well/Boring ID	Sample ID	Date Sampled	GRO	DRO	HO	DRO + HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	PCE	TCE	EDC	cis-1,2-DCE	trans-1,2-DCE	1,1-DCE	Vinyl Chloride	Pentachlorophenol
		Preliminary Cleanup Levels[1]	800[2]	500	500	500[3]	0.44	53	12	57	2.4	0.30	0.48	16	77	7.0	1 / 0.10	0.313
All units in micrograms per liter (µg/L)																		
Shallow Water Bearing Zone - Time Oil Properties (continued)																		
01MW64	01MW64-20090409	4/7/2009	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**9.0**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20090709	7/9/2009	<100	**170**	<250	**420**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20100127	1/27/2010	<100	**180x**	<250	**430**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20100406	4/6/2010	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20100708	7/8/2010	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20110112	1/12/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1.1**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20110414	4/14/2011	<100	**110x**	<250	**360**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20110823	8/23/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20111208	12/8/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**12**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20120404	4/4/2012	<100	**50**	<250	**300**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20121010	10/10/2012	<100	**88x**	<250	**338**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20130402	4/2/2013	<100	**120x**	<250	**370**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20131101	11/1/2013	<100	**91**	<250	**341**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	--	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20140410	4/10/2014	<100	**130**	<250	**380**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	--	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20150529	5/29/2015	<100	**82**	<250	**332**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	--	<1.0	<1.0	<1.0	<0.20	--
	01MW64-20160512	5/12/2016	<100	**100**	<250	**350**	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	--	<1.0	<1.0	<1.0	<0.20	--
	01MW64-050219	5/2/2019	--	**100**	<250	**350**	--	--	--	--	--	--	--	--	--	--	--	--
Intermediate Water Bearing Zone - Adjacent Properties																		
01MW78	01MW78-20110307	3/7/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**16**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW78-20110414	4/14/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**11**	<1.0	<1.0	<1.0	<1.0	<0.20	--
	01MW78-20110824	8/24/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**3.1**	<1.0	**3.6**	<1.0	<1.0	<0.20	--
	01MW78-20111208	12/8/2011	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1.1**	<1.0	**2.2**	<1.0	<1.0	<0.20	--
	01MW78-20120404	4/4/2012	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	<1.0	<1.0	**1.5**	<1.0	<1.0	<0.20	--
	01MW78-20121010	10/10/2012	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**1.2**	<1.0	**1.6**	<1.0	<1.0	<0.20	--
	01MW78-20130401	4/1/2013	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**2.3**	<1.0	**1.0**	<1.0	<1.0	<0.20	--
	01MW78-20131101	11/1/2013	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**3.5**	--	**1.0**	<1.0	<1.0	<0.20	--
	01MW78-20140403	4/3/2014	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**4.4**	--	**1.3**	<1.0	<1.0	<0.20	--
	01MW78-20150529	5/29/2015	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**5.2**	--	<1.0	<1.0	<1.0	<0.20	--
	01MW78-20160513	5/13/2016	<100	<50	<250	<300	<1.0	<1.0	<1.0	<3.0	<1.0	**4.0**	--	<1.0	<1.0	<1.0	<0.20	--
	01MW78-050219	5/2/2019	--	--	--	--	--	--	--	--	<1.0	**1.2**	<1.0	**5.5**	<1.0	<1.0	<0.20	--

Notes:

1. Preliminary cleanup levels as presented in Tables 5.
2. Screening level of 800 µg/L is appropriate as benzene has been detected in groundwater within the BNSF Property.
3. Screening level of 500 µg/L is used to screen the combined concentration of DRO and HO.

Qualifiers:

J = Result is less than the reporting limit but greater than or equal to the method detection limit, and the concentration is an approximate value.
x = The pattern of peaks present is not indicative of diesel, or the sample chromatographic pattern does not resemble the fuel standard used for quantitation.

Acronyms and Abbreviations:

-- = not analyzed
< = less than reporting detection limit
Bold = Analyte detected at a concentration greater than the reporting detection limit.
Highlight and Bold = Detected concentration exceeds preliminary cleanup levels for groundwater.
BNSF = BNSF Railway Company
DCE = dichloroethene
DRO = diesel range organics
EDC = 1,2-dichloroethene
GRO = gasoline range organics
HO = heavy oil
ID = identification
PCE = tetrachloroethene
TCE = trichloroethene

Reference:

Washington State Department of Ecology. 2013. *Model Toxics Control Act Regulation and Statute* . Publication No. 94-06.

Table 5
Initial Screening Levels - Groundwater
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Chemicals of Interest	CAS No.	Protection of Drinking Water				Protection of Surface Water			
						MTCA Method B		Protection of Aquatic Life[1]	
		MTCA Method A Cleanup Levels	MTCA Method B Cleanup Levels - Noncancer	MTCA Method B Cleanup Levels - Cancer	Washington State/Federal Maximum Contaminant Level	Noncancer	Cancer	WA WQS—Freshwater Chronic WAC 173-201A	NRWQC—Freshwater Chronic CWA Section 304
		All units in micrograms per liter (µg/L)							
Total Petroleum Hydrocarbons									
Gasoline range organics	GRO	800[6]	--	--	--	--	--	1,000	1,000
Diesel range organics	DRO	500	--	--	--	--	--	150/3,000	150/3,000
Heavy Oils	HO	500	--	--	--	--	--	--	--
Diesel range organics + Heavy Oils	DRO + HO	500	--	--	--	--	--	--	--
Volatile Organic Compounds									
Benzene	71-43-2	5.0	32	0.80	5.0	2,000	23	10	10
1,2-Dichloroethane [EDC]	107-06-2	5.0	48	0.48	5.0	13,000	59	--	--
1,1-Dichloroethene	75-35-4	--	400	--	7.0	23,000	--	--	--
cis-1,2-Dichloroethene	156-59-2	--	16	--	70	--	--	--	--
trans-1,2-Dichloroethene	156-60-5	--	160	--	100	33,000	--	--	--
Ethylbenzene	100-41-4	700	800	--	700	6,900	--	12	12
Tetrachloroethene	127-18-4	5.0	48	21	5.0	500	100	--	--
Toluene	108-88-3	1,000	640	--	1,000	19,000	--	53	53
Trichloroethene	79-01-6	5.0	4.0	0.54	5.0	120	4.9	--	--
Vinyl chloride	75-01-4	0.20	24	0.029	2.0	6,600	3.7	--	--
Total Xylenes	1330-20-7	1,000	1,600	--	10,000	--	--	57	57
Semivolatile Organic Compounds									
Pentachlorophenol	87-86-5	--	80	0.22	1.0	1,200	1.5	13	15

Table 5
Initial Screening Levels - Groundwater
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Chemicals of Interest	CAS No.	Protection of Surface Water			Protection of Sediment	Protection of Indoor Air		Adjustment Factors	Most Stringent Risk-Based Criteria	Proposed PCUL[5]
		Protection of Human Health								
		WA WQS Consumption of Water + Organisms WAC 173-201A	WA Toxics Rule Consumption of Water + Organisms 40 CFR 131.45	NRWQC - Consumption of Water + Organisms CWA Section 304	Criteria Protective of the Lesser of SMS SCO and Human Health Criteria[2]	MTCA Method B Groundwater Criteria Protective of Volatilization to Soil Vapor then Indoor Air - Noncancer	MTCA Method B Groundwater Criteria Protective of Volatilization to Soil Vapor then Indoor Air - Cancer	Practical Quantitation Limit[3,4]		
		All units in micrograms per liter (µg/L)								
Total Petroleum Hydrocarbons										
Gasoline range organics	GRO	--	--	--	--	--	--	100	800	800
Diesel range organics	DRO	--	--	--	--	--	--	100	500	500
Heavy Oils	HO	--	--	--	--	--	--	250	500	500
Diesel range organics + Heavy Oils	DRO + HO	--	--	--	--	--	--	350	500	500
Volatile Organic Compounds										
Benzene	71-43-2	0.44	--	0.58	--	100	2.4	1 / 0.04	0.44	0.44
1,2-Dichloroethane [EDC]	107-06-2	9.3	8.9	9.9	--	120	3.5	1 / 0.1	0.48	0.48
1,1-Dichloroethene	75-35-4	1,200	700	300	--	130	--	1 / 0.1	7.0	7.0
cis-1,2-Dichloroethene	156-59-2	--	--	--	--	180	--	1 / 0.1	16	16
trans-1,2-Dichloroethene	156-60-5	600	200	100	--	77	--	1 / 0.2	77	77
Ethylbenzene	100-41-4	200	29	68	--	2,800	--	1 / 0.1	12	12
Tetrachloroethene	127-18-4	4.9	2.4	10	--	48	25	1 / 0.1	2.4	2.4
Toluene	108-88-3	180	72	57		15,000	--	1 / 0.2	53	53
Trichloroethene	79-01-6	0.38	0.30	0.60	--	3.9	1.4	1 / 0.04	0.30	0.30
Vinyl chloride	75-01-4	0.020	--	0.022	--	54	0.33	1 / 0.1	0.020	1 / 0.1
Total Xylenes	1330-20-7	--	--	--		320	--	3 / 0.26	57	57
Semivolatile Organic Compounds										
Pentachlorophenol	87-86-5	0.046	0.0020	0.030	0.87	--	--	0.313	0.0020	0.313

Table 5
Initial Screening Levels - Groundwater
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Notes:

1. Implementation Memo #23 provides Aquatic Life Protective Values (Ecology 2021). DRO values are either for unweathered/weathered substances.
2. Criteria for protection of sediment via groundwater discharge are based on a modified MTCA fixed parameter three-phase partitioning model (WAC 173-340-747, equation 747-1). The lower of the sediment criteria for protection of human health direct contact (including beach play, clamming, and net fishing pathways), bioaccumulation, and benthic species was selected as the target concentration.
3. Practical quantitation limit values from Pace National Center for Testing and Innovation (Pace) of Mt. Juliet, Tennessee. For pentachlorophenol, the method detection limit has been provided in lieu of the practical quantitation limit.
4. Practical quantitation limits for ultra-low level VOC analysis are provided. Note that this analysis is performed on a pristine instrument so any impacted samples will need to be analyzed by the standard VOC method.
5. Preliminary cleanup level is based on the lowest of the protection of direct contact, terrestrial receptors, and protection of groundwater leaching, as appropriate.
6. Benzene has been detected at the site (see Table 4), so the lower cleanup level is applicable.

Acronyms and Abbreviations:

🟧 = PCUL based on the practical quantitation limit (reporting limit) provided by the laboratory
🟨 = PCUL based on the method detection limit provided by the laboratory (see Appendix A, Table 1a)
-- = not applicable
BNSF = BNSF Railway Company
CAS = Chemical Abstracts Service
CFR = Code of Federal Regulations
CWA = Clean Water Act
Ecology = Washington Department of Ecology
MTCA = Model Toxics Control Act
NRWQC = National Recommended Water Quality Criteria
PCUL = preliminary cleanup level
SCO = Sediment Cleanup Objective
SMS = Sediment Management Standards
WAC = Washington Administrative Code
WA WQS = Washington Water Quality Standards

References:

Washington State Department of Ecology. 2013. *Model Toxics Control Act Regulation and Statute* . Publication No. 94-06.

Washington State Department of Ecology. 2021. Implementation Memorandum No. 23: Concentrations of Gasoline and Diesel Range Organics Predicted to be Protective of Aquatic Receptors in Surface Waters. August.

Table 6
Initial Screening Levels - Soil
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Chemicals of Interest	CAS No.	MTCA Method A Cleanup Levels	Protection of Direct Contact		Protection of Terrestial Ecological Receptors		Protection of Groundwater Leaching		Adjustment Factors	Most Stringent Risk-Based Criteria	Preliminary Cleanup Level[5]
			MTCA Method B Cleanup Levels - Noncancer	MTCA Method B Cleanup Levels - Cancer	Terrestrial Ecological Indicator Soil Concentrations[1]	Site-Specific Recommended Terrestrial Ecological Evaluation[2]	Protective of Groundwater Saturated[3]	Protective of Groundwater to Surface Water Saturated (Fresh Water)[3]	Practical Quantitation Limit[4]		
All units in milligrams per kilogram (mg/kg)											
Total Petroleum Hydrocarbons											
Gasoline range organics	GRO	30[6]	--	--	100	--	--	--	0.10	30	30
Diesel range organics	DRO	2,000	--	--	200	570	--	--	4.0	200	570[7]
Heavy oils	HO	2,000	--	--	--	1,600	--	--	10	1,600	1,600[7]
Diesel range organics + Heavy oils	DRO + HO	2,000	--	--	--	--	--	--	14	2,000	2,000
Volatile Organic Compounds											
Benzene	71-43-2	0.030	320	18	--	--	0.0017	0.00015	0.0010	0.00015	0.0010
1,2-Dichloroethane [EDC]	107-06-2	--	480	11	--	--	0.0016	0.0029	0.0025	0.0016	0.0025
1,1-Dichloroethene	75-35-4	--	4,000	--	--	--	0.0025	0.11	0.0025	0.0025	0.0025
cis-1,2-Dichloroethene	156-59-2	--	160	--	--	--	0.0052	--	0.0025	0.0052	0.0052
trans-1,2-Dichloroethene	156-60-5	--	1,600	--	--	--	0.032	0.032	0.0050	0.032	0.032
Ethylbenzene	100-41-4	6.0	8,000	--	--	--	0.34	0.0059	0.0025	0.0059	0.0059
Tetrachloroethene	127-18-4	0.050	480	480	--	--	0.0028	0.0013	0.0025	0.0013	0.0025
Toluene	108-88-3	7.0	6,400	--	--	--	0.27	0.023	0.0050	0.023	0.023
Trichloroethene	79-01-6	0.030	40	12	--	--	0.0015	1.1E-04	0.0010	0.00011	0.0010
Vinyl chloride	75-01-4	--	240	0.67	--	--	9.0E-05	6.2E-06	0.0025	6.2E-06	0.0025
Total xylenes	1330-20-7	9.0	16,000	--	--	--	0.83	0.030	0.0065	0.030	0.030
Semivolatile Organic Compounds											
Pentachlorophenol	87-86-5	--	400	2.5	3.0	--	8.8E-04	1.8E-06	0.00896	1.8E-06	0.00896

Notes:
1. The Terrestrial Ecological Evaluations are based on MTCA Table 749-3, with the lowest of the plant, soil biota, and wildlife screening levels selected.
2. The cleanup levels are based on the site-specific Terrestrial Ecological Evaluation summarized in the Upland Ecological Risk Assessment (Ecology 2020).
3. Criteria for protection of groundwater and surface water are based on the MTCA fixed-parameter three-phase partitioning model (WAC 173-340-747, equation 747-1). Default values used.
4. Practical quantitation limit values from Pace National Center for Testing and Innovation (Pace) of Mt. Juliet, Tennessee. For pentachlorophenol, the method detection limit has been provided in lieu of the practical quantitation limit.
5. Preliminary cleanup level is based on the lowest of the screening levels for protection of direct contact, terrestrial receptors, and protection of groundwater leaching, as appropriate.
6. Benzene has been detected at the site (see Table 2), so the lower cleanup level is applicable.
7. PCUL based on site-specific Terrestrial Ecological Evaluation.

Acronyms and Abbreviations:
🟧 = PCUL based on the practical quantitation limit (reporting limit) provided by the laboratory
🟨 = PCUL based on the method detection limit provided by the laboratory (See Appendix A, Table 1b)
-- = not applicable
BNSF = BNSF Railway Company
CAS = Chemical Abstracts Service
MTCA = Model Toxics Control Act
PCUL = preliminary cleanup level

References:

Washington State Department of Ecology. 2013. *Model Toxics Control Act Regulation and Statute* . Publication No. 94-06.
Washington State Department of Ecology. 2020. Time Oil Site: Upland Ecological Risk Assessment, Memo to Mark Adams, LHG, Toxic Cleanup Program. June 26.

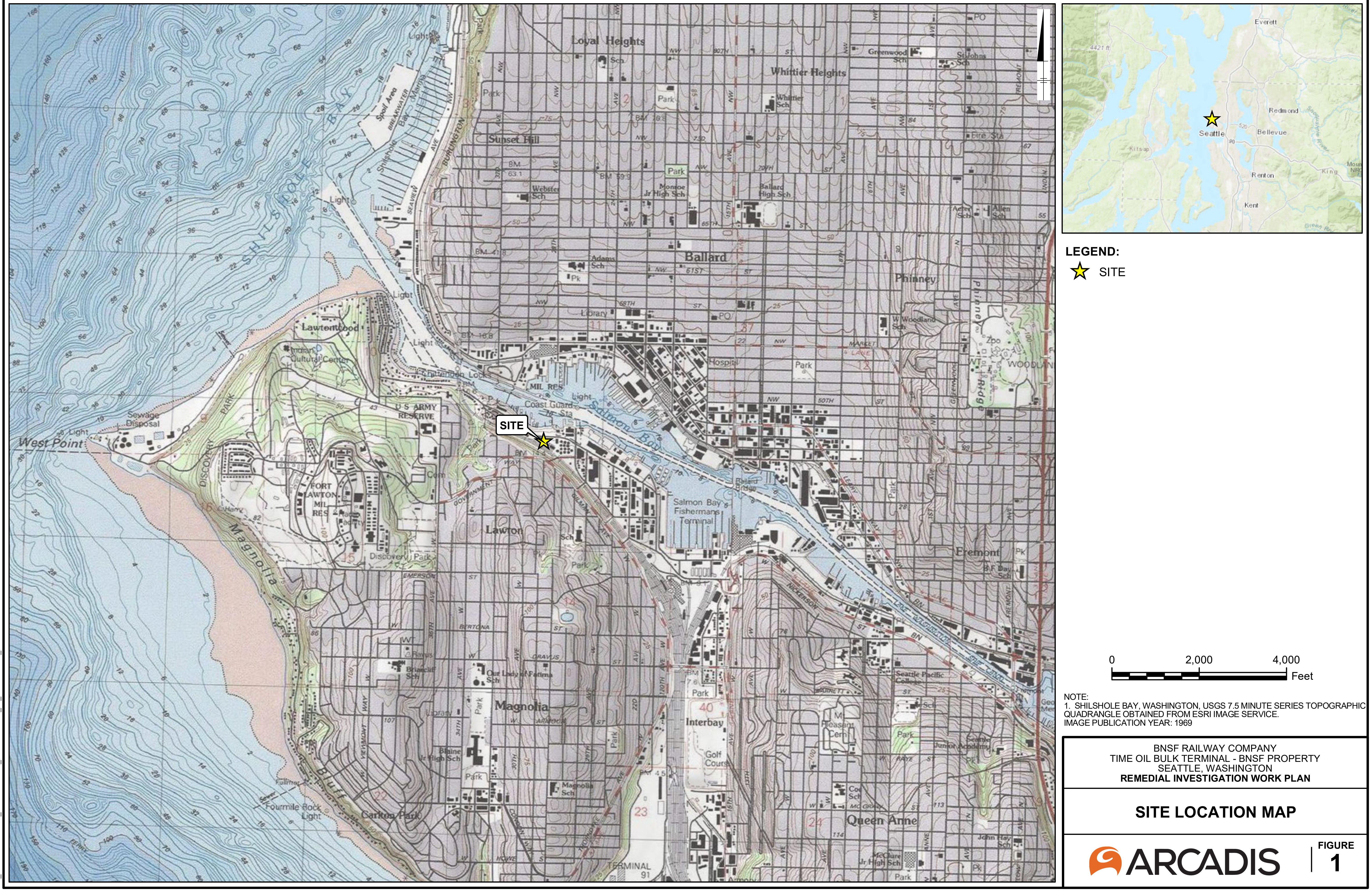
Table 7
Proposed Boring and Well Rationale
Remedial Investigation Work Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Sampling Location	Sample Quantity and Depth	Approximate Drilling Order	Location/Description	Rationale	Laboratory Analysis[1,2]
SB-BN-01	Up to four soil samples between 2.5 and 20 ft bgs	1	NW corner of BNSF AOC, near B-116 location	Lateral and vertical CVOC and TPH delineation in soil (west)	CVOCs, TPH, FOC*, Permeability* (standard TAT)
SB-BN-02	Up to four soil samples between 5 and 20 ft bgs	2	SW corner of BNSF AOC, west of 01MW98	Lateral CVOC, BTEX, and TPH delineation in soil (southwest)	CVOCs, BTEX, TPH (standard TAT)
SB-BN-03/ MW-BN-01	Up to eight soil samples between 2.5 and 40 ft bgs; Groundwater sample collected from Shallow WBZ (temporary well-screen); Groundwater sample collected from Perched WBZ (permanent well)	3	NW corner of BNSF AOC, near 01MW64 location	Lateral CVOC and TPH delineation in soil (northwest) and groundwater (Perched WBZ)	CVOCs, TPH, geochemical parameters (standard TAT)
SB-BN-04/ MW-BN-02	Up to four soil samples between 2.5 and 20 ft bgs; Groundwater sample collected from Perched WBZ (permanent well)	4	SW corner of BNSF AOC, near 01MW94 location	Lateral CVOC and TPH delineation in soil (southwest) and groundwater (Perched WBZ)	CVOCs, BTEX, TPH, geochemical parameters (standard TAT)
SB-BN-05	Up to eight soil samples between 2.5 and 40 ft bgs; Groundwater sample collected from Shallow WBZ (temporary well-screen)	5	Northern middle area of BNSF AOC, near 01MW71 location	Vertical CVOC delineation in soil and groundwater (Shallow WBZ)	CVOCs (standard TAT)
SB-BN-06	Up to eight soil samples between 2.5 and 40 ft bgs; Groundwater sample collected from Shallow WBZ (temporary well-screen)	6	Northern middle area of BNSF AOC, near 01MW78 location	Vertical CVOC delineation in soil and groundwater (Shallow WBZ)	CVOCs (standard TAT)
SB-BN-07/ MW-BN-03	Up to eight soil samples between 2.5 and 40 ft bgs; Groundwater sample collected from Shallow WBZ (permanent well)	7	Middle of BNSF AOC, near 01MW92 location	Lateral CVOC and BTEX delineation in groundwater (Shallow WBZ)	CVOCs, BTEX, PCP[3], geochemical parameters (standard TAT)
SB-BN-08/ MW-BN-04	Up to eight soil samples between 2.5 and 40 ft bgs; Groundwater sample collected from Shallow WBZ (temporary well-screen); Groundwater sample collected from Perched WBZ (permanent well)	8	NE corner of BNSF AOC, near SB-06 and 01MW96 locations	Lateral TPH, BTEX, and PCP delineation in soil (east); Vertical PCP delineation in soil; Lateral CVOC, TPH, and PCP delineation in groundwater (Perched WBZ)	CVOCs, BTEX, TPH, PCP, geochemical parameters (standard TAT)
SB-BN-09	Up to four soil samples between 2.5 and 20 ft bgs; Groundwater sample collected from Perched WBZ (temporary well-screen)	9	SE corner of the BNSF AOC, near 01MW95	Lateral CVOC, BTEX, TPH, and PCP delineation in soil (southeast); Vertical PCP delineation in soil	CVOCs, BTEX, TPH, PCP[4] (standard TAT)
SB-BN-10/ MW-BN-05	Up to eight soil samples between 2.5 and 40 ft bgs; Groundwater sample collected from Shallow WBZ (temporary well-screen); Groundwater sample collected from Perched WBZ (permanent well)	10	NE corner of BNSF AOC, near 01MW61 location	Lateral TPH and PCP delineation in soil (east); Vertical PCP delineation in soil; Lateral TPH and PCP delineation in groundwater (Perched WBZ)	CVOCs, BTEX, TPH, PCP, FOC*, Permeability*, geochemical parameters (standard TAT)
SB-BN-11	Up to four soil samples between 2.5 and 20 feet bgs; Groundwater sample collected from Perched WBZ (temporary well-screen)	11	SE corner of the BNSF AOC, between SB-08 and SB-09	Lateral BTEX and PCP delineation in soil (southeast); Vertical PCP delineation in soil	CVOCs, BTEX, TPH, PCP[4] (standard TAT)

Notes:
1. See Sampling and Analysis Plan/Quality Assurance Project Plan (attached as Appendix A) for additional details.
2. FOC and permeability samples will only be analyzed for soil samples. Geochemical parameters will only be analyzed for groundwater samples.
3. PCP will be analyzed in soil at SB-BN-07, if PCP is detected in soil at SB-BN-08.
4. CVOCs and PCP will be analyzed in perched groundwater from SB-BN-09 and SB-BN-11 temporary wells, if CVOCs or PCP are detected at MW-BN-04 or MW-BN-05.

Acronyms and Abbreviations:
* = samples collected at intervals representative of unique soil types
AOC = Area of Concern
bgs = below ground surface
BNSF = BNSF Railway Company
BTEX = benzene, toluene, ethylbenzene, and total xylenes
CVOC = chlorinated volatile organic compound
ft = feet
FOC = fraction of organic carbon
NE = northeast
NW = northwest
PCP = pentachlorophenol
SE = southeast
SW = southwest
TAT = turnaround time
TPH = total petroleum hydrocarbons
WBZ = water-bearing zone

Figures



NOTE:
1. SHILSHOLE BAY, WASHINGTON, USGS 7.5 MINUTE SERIES TOPOGRAPHIC QUADRANGLE OBTAINED FROM ESRI IMAGE SERVICE.
IMAGE PUBLICATION YEAR: 1969

BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

SITE LOCATION MAP

ARCADIS

FIGURE
1

Div/Group: GEC Created By: Akshaya.D Last Saved By: dholmes
T:_ENV\BNSF\BNSF_FormerTimeOil_WA\MXD\2023_RI_WorkPlan\F1_SiteLoc.mxd 1/29/2023 9:33:54 AM

LEGEND

- TIME OIL PROPERTIES
- BNSF PROPERTY
- PARCEL BOUNDARY
- BNSF AREA OF CONCERN

0 180 360

SCALE IN FEET

NOTE:
1. PARCEL DATA OBTAINED FROM KING COUNTY GIS OPEN DATA, ACCESSED ON 6/21/2021.
2. PIN = PROPERTY IDENTIFICATION NUMBER
3. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.

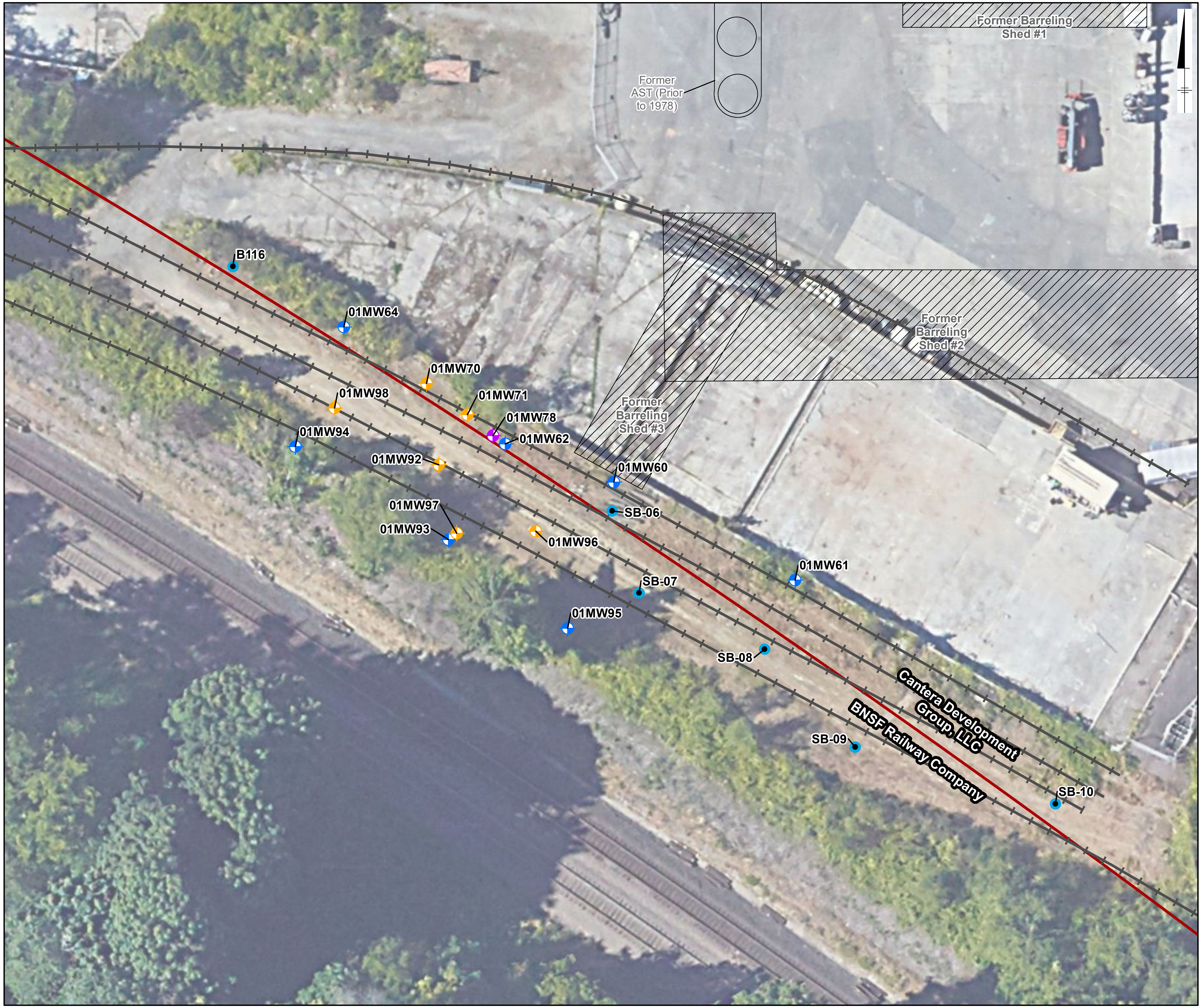
BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

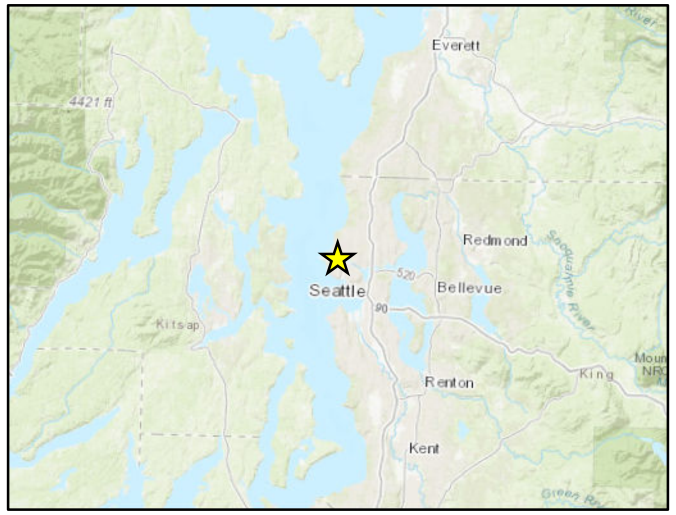
PROPERTY DIAGRAM

ARCADIS

FIGURE
2

CITY:(DEN-TECH) DIV/GROUP:(ENV/GIS) DB: DHOLMES LD: PIC: PM: TM:
PROJECT: PATH: T:_ENV\BNSF\BNSF_FormerTimeOil_WA\MXD\2023_RI_WorkPlan\F2_PropertyDiagram.mxd





LEGEND:

- ☆ SITE
- ⊕ PERCHED MONITORING WELL
- ⊕ SHALLOW MONITORING WELL
- ⊕ INTERMEDIATE MONITORING WELL
- ● SOIL BORING
- — PROPERTY BOUNDARY
- ┼ HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
- ▨ HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

0 30 60
Feet

NOTE:
1. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 08/14/2020.
2. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.

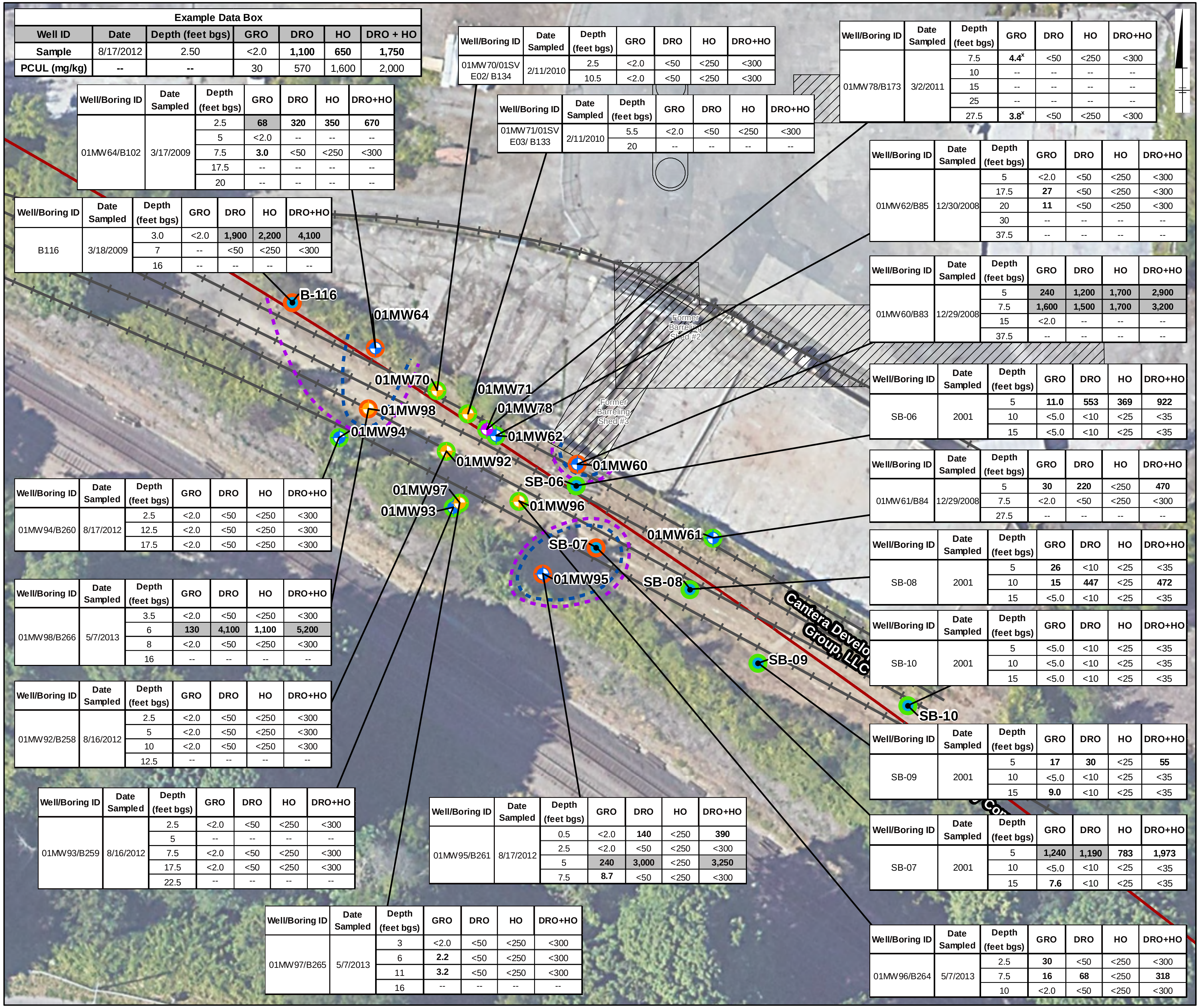
BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

SITE MAP

ARCADIS

FIGURE
3

Last Saved By: dholmes
T:_ENV\BNSF\BNSF_FormerTimeOil_WA\MXD\2023_RI_WorkPlan\F3_SiteMap.mxd 1/29/2023 9:35:35 AM



Example Data Box						
Well ID	**Date**	**Depth (feet bgs)**	**GRO**	**DRO**	**HO**	**DRO + HO**
Sample	8/17/2012	2.50	<2.0	**1,100**	**650**	**1,750**
PCUL (mg/kg)	**--**	**--**	30	570	1,600	2,000

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW70/01SV E02/ B134	2/11/2010	2.5	<2.0	<50	<250	<300
		10.5	<2.0	<50	<250	<300

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW78/B173	3/2/2011	7.5	**4.4**^{x}	<50	<250	<300
		10	--	--	--	--
		15	--	--	--	--
		25	--	--	--	--
		27.5	**3.8**^{x}	<50	<250	<300

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW64/B102	3/17/2009	2.5	**68**	**320**	**350**	**670**
		5	<2.0	--	--	--
		7.5	**3.0**	<50	<250	<300
		17.5	--	--	--	--
		20	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW71/01SV E03/ B133	2/11/2010	5.5	<2.0	<50	<250	<300
		20	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW62/B85	12/30/2008	5	<2.0	<50	<250	<300
		17.5	**27**	<50	<250	<300
		20	**11**	<50	<250	<300
		30	--	--	--	--
		37.5	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
B116	3/18/2009	3.0	<2.0	**1,900**	**2,200**	**4,100**
		7	--	<50	<250	<300
		16	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW60/B83	12/29/2008	5	**240**	**1,200**	**1,700**	**2,900**
		7.5	**1,600**	**1,500**	**1,700**	**3,200**
		15	<2.0	--	--	--
		37.5	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
SB-06	2001	5	**11.0**	**553**	**369**	**922**
		10	<5.0	<10	<25	<35
		15	<5.0	<10	<25	<35

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW61/B84	12/29/2008	5	**30**	**220**	<250	**470**
		7.5	<2.0	<50	<250	<300
		27.5	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW94/B260	8/17/2012	2.5	<2.0	<50	<250	<300
		12.5	<2.0	<50	<250	<300
		17.5	<2.0	<50	<250	<300

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
SB-08	2001	5	**26**	<10	<25	<35
		10	**15**	**447**	<25	**472**
		15	<5.0	<10	<25	<35

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW98/B266	5/7/2013	3.5	<2.0	<50	<250	<300
		6	**130**	**4,100**	**1,100**	**5,200**
		8	<2.0	<50	<250	<300
		16	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
SB-10	2001	5	<5.0	<10	<25	<35
		10	<5.0	<10	<25	<35
		15	<5.0	<10	<25	<35

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW92/B258	8/16/2012	2.5	<2.0	<50	<250	<300
		5	<2.0	<50	<250	<300
		10	<2.0	<50	<250	<300
		12.5	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
SB-09	2001	5	**17**	**30**	<25	**55**
		10	<5.0	<10	<25	<35
		15	**9.0**	<10	<25	<35

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW93/B259	8/16/2012	2.5	<2.0	<50	<250	<300
		5	--	--	--	--
		7.5	<2.0	<50	<250	<300
		17.5	<2.0	<50	<250	<300
		22.5	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW95/B261	8/17/2012	0.5	<2.0	**140**	<250	**390**
		2.5	<2.0	<50	<250	<300
		5	**240**	**3,000**	<250	**3,250**
		7.5	**8.7**	<50	<250	<300

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
SB-07	2001	5	**1,240**	**1,190**	**783**	**1,973**
		10	<5.0	<10	<25	<35
		15	**7.6**	<10	<25	<35

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW97/B265	5/7/2013	3	<2.0	<50	<250	<300
		6	**2.2**	<50	<250	<300
		11	**3.2**	<50	<250	<300
		16	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	GRO	DRO	HO	DRO+HO
01MW96/B264	5/7/2013	2.5	**30**	<50	<250	<300
		7.5	**16**	**68**	<250	**318**
		10	<2.0	<50	<250	<300

LEGEND:

⊕	PERCHED MONITORING WELL
⊕	SHALLOW MONITORING WELL
⊕	INTERMEDIATE MONITORING WELL
●	SOIL BORING
●	SOIL BORING EXCEEDING THE PETROLEUM HYDROCARBON PCULS
●	SOIL BORING NOT EXCEEDING THE PETROLEUM HYDROCARBON PCULS
- -	APPROXIMATE EXTENT OF DRO+HO IN SOIL EXCEEDING THE PCUL
- -	APPROXIMATE EXTENT OF GRO IN SOIL EXCEEDING THE PCUL
—	PROPERTY BOUNDARY
-+-	HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
▨	HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

0 40 80
Feet

NOTE:
1. WELL LOCATIONS APPROXIMATE.
2. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.
3. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.
-- = NOT ANALYZED
BGS = BELOW GROUND SURFACE
GRO = GASOLINE RANGE ORGANICS
DRO = DIESEL RANGE ORGANICS
HO = HEAVY OIL
mg/kg = MILLIGRAM PER KILOGRAM
< = LESS THAN REPORTING DETECTION LIMIT
X = THE PATTERN OF PEAKS PRESENT IS NOT INDICATIVE OF DIESEL OR THE SAMPLE CHROMATOGRAPHIC PATTERN DOES NOT RESEMBLE THE FUEL STANDARD USED FOR QUANTITATION.
PCUL = PRELIMINARY CLEANUP LEVEL
BOLD = ANALYTE DETECTED AT A CONCENTRATION GREATER THAN THE METHOD DETECTION LIMIT.
HIGHLIGHT AND BOLD = DETECTED CONCENTRATION EXCEEDS PRELIMINARY CLEANUP LEVELS FOR SOIL.

BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

SOIL ANALYTICAL RESULTS - PETROLEUM HYDROCARBONS

ARCADIS

FIGURE
4

Last Saved By: dholmes
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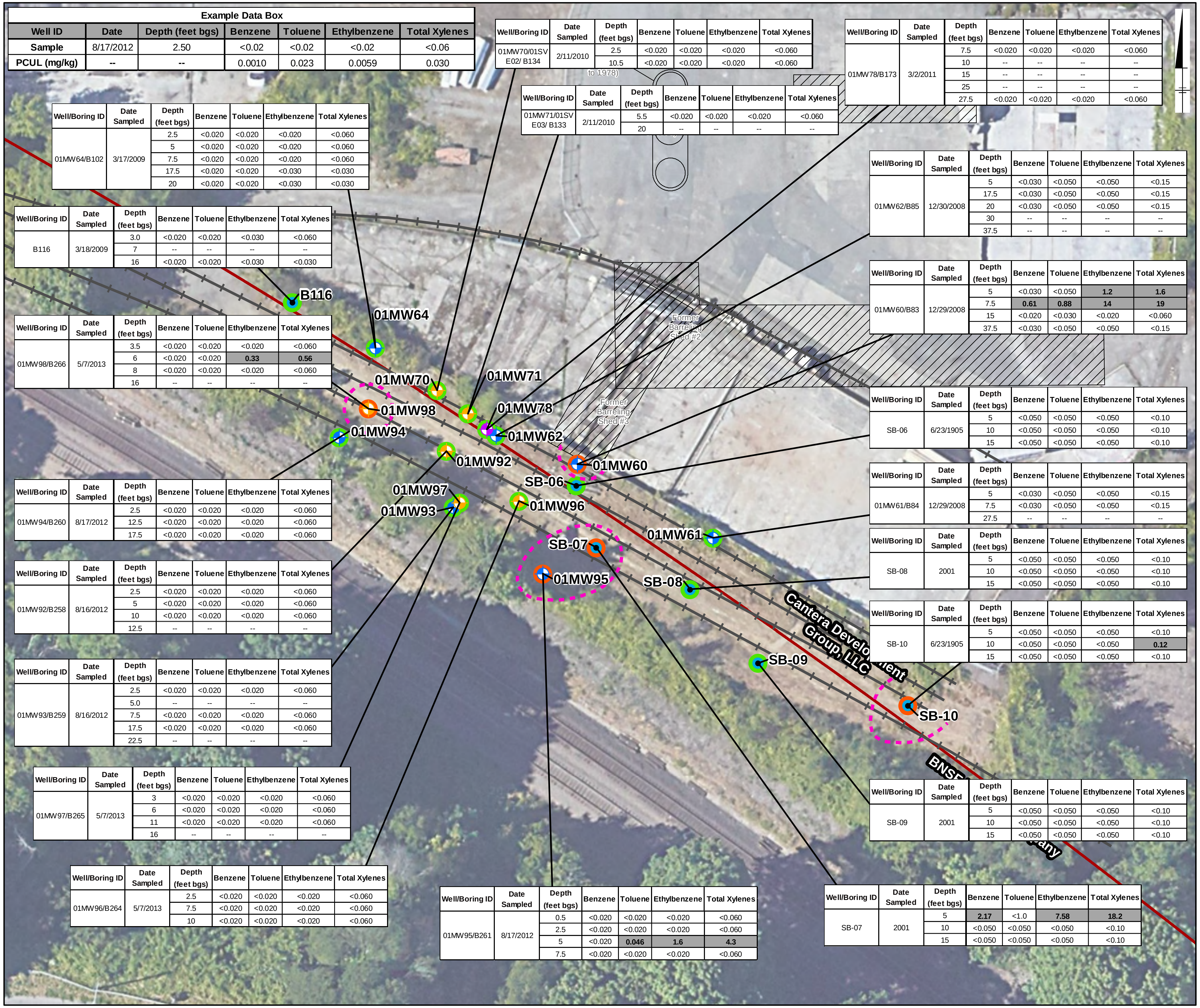

Example Data Box						
Well ID	**Date**	**Depth (feet bgs)**	**Benzene**	**Toluene**	**Ethylbenzene**	**Total Xylenes**
Sample	8/17/2012	2.50	<0.02	<0.02	<0.02	<0.06
PCUL (mg/kg)	--	--	0.0010	0.023	0.0059	0.030

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW70/01SV E02/ B134	2/11/2010	2.5	<0.020	<0.020	<0.020	<0.060
		10.5	<0.020	<0.020	<0.020	<0.060

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW78/B173	3/2/2011	7.5	<0.020	<0.020	<0.020	<0.060
		10	--	--	--	--
		15	--	--	--	--
		25	--	--	--	--
		27.5	<0.020	<0.020	<0.020	<0.060

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW64/B102	3/17/2009	2.5	<0.020	<0.020	<0.020	<0.060
		5	<0.020	<0.020	<0.020	<0.060
		7.5	<0.020	<0.020	<0.020	<0.060
		17.5	<0.020	<0.020	<0.030	<0.030
		20	<0.020	<0.020	<0.030	<0.030

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW71/01SV E03/ B133	2/11/2010	5.5	<0.020	<0.020	<0.020	<0.060
		20	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
B116	3/18/2009	3.0	<0.020	<0.020	<0.030	<0.060
		7	--	--	--	--
		16	<0.020	<0.020	<0.030	<0.030

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW62/B85	12/30/2008	5	<0.030	<0.050	<0.050	<0.15
		17.5	<0.030	<0.050	<0.050	<0.15
		20	<0.030	<0.050	<0.050	<0.15
		30	--	--	--	--
		37.5	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW60/B83	12/29/2008	5	<0.030	<0.050	**1.2**	**1.6**
		7.5	**0.61**	**0.88**	**14**	**19**
		15	<0.020	<0.030	<0.020	<0.060
		37.5	<0.030	<0.050	<0.050	<0.15

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW98/B266	5/7/2013	3.5	<0.020	<0.020	<0.020	<0.060
		6	<0.020	<0.020	**0.33**	**0.56**
		8	<0.020	<0.020	<0.020	<0.060
		16	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
SB-06	6/23/1905	5	<0.050	<0.050	<0.050	<0.10
		10	<0.050	<0.050	<0.050	<0.10
		15	<0.050	<0.050	<0.050	<0.10

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW94/B260	8/17/2012	2.5	<0.020	<0.020	<0.020	<0.060
		12.5	<0.020	<0.020	<0.020	<0.060
		17.5	<0.020	<0.020	<0.020	<0.060

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW61/B84	12/29/2008	5	<0.030	<0.050	<0.050	<0.15
		7.5	<0.030	<0.050	<0.050	<0.15
		27.5	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
SB-08	2001	5	<0.050	<0.050	<0.050	<0.10
		10	<0.050	<0.050	<0.050	<0.10
		15	<0.050	<0.050	<0.050	<0.10

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW92/B258	8/16/2012	2.5	<0.020	<0.020	<0.020	<0.060
		5	<0.020	<0.020	<0.020	<0.060
		10	<0.020	<0.020	<0.020	<0.060
		12.5	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
SB-10	6/23/1905	5	<0.050	<0.050	<0.050	<0.10
		10	<0.050	<0.050	<0.050	**0.12**
		15	<0.050	<0.050	<0.050	<0.10

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW93/B259	8/16/2012	2.5	<0.020	<0.020	<0.020	<0.060
		5.0	--	--	--	--
		7.5	<0.020	<0.020	<0.020	<0.060
		17.5	<0.020	<0.020	<0.020	<0.060
		22.5	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW97/B265	5/7/2013	3	<0.020	<0.020	<0.020	<0.060
		6	<0.020	<0.020	<0.020	<0.060
		11	<0.020	<0.020	<0.020	<0.060
		16	--	--	--	--

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
SB-09	2001	5	<0.050	<0.050	<0.050	<0.10
		10	<0.050	<0.050	<0.050	<0.10
		15	<0.050	<0.050	<0.050	<0.10

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW96/B264	5/7/2013	2.5	<0.020	<0.020	<0.020	<0.060
		7.5	<0.020	<0.020	<0.020	<0.060
		10	<0.020	<0.020	<0.020	<0.060

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
01MW95/B261	8/17/2012	0.5	<0.020	<0.020	<0.020	<0.060
		2.5	<0.020	<0.020	<0.020	<0.060
		5	<0.020	**0.046**	**1.6**	**4.3**
		7.5	<0.020	<0.020	<0.020	<0.060

Well/Boring ID	Date Sampled	Depth (feet bgs)	Benzene	Toluene	Ethylbenzene	Total Xylenes
SB-07	2001	5	**2.17**	<1.0	**7.58**	**18.2**
		10	<0.050	<0.050	<0.050	<0.10
		15	<0.050	<0.050	<0.050	<0.10

LEGEND:

- PERCHED MONITORING WELL
- SHALLOW MONITORING WELL
- INTERMEDIATE MONITORING WELL
- ● SOIL BORING
- 🟠 SOIL BORING EXCEEDING THE BTEX PCULS
- 🟢 SOIL BORING NOT EXCEEDING THE BTEX PCULS
- APPROXIMATE EXTENT OF BTEX IN SOIL EXCEEDING THE PCULS
- PROPERTY BOUNDARY
- HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
- ▨ HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

NOTE:
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3. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.
-- = NOT ANALYZED
BGS = BELOW GROUND SURFACE
PCUL = PRELIMINARY CLEANUP LEVEL
BTEX = BENZENE, TOLUENE, ETHYLBENZENE, AND TOTAL XYLENES
mg/kg = MILLIGRAM PER KILOGRAM
< = LESS THAN REPORTING DETECTION LIMIT
BOLD = ANALYTE DETECTED AT A CONCENTRATION GREATER THAN THE METHOD DETECTION LIMIT.
HIGHLIGHT AND BOLD = DETECTED CONCENTRATION EXCEEDS PRELIMINARY CLEANUP LEVELS FOR SOIL.

BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

SOIL ANALYTICAL RESULTS - BTEX

ARCADIS

FIGURE
5

Last Saved By: dholmes
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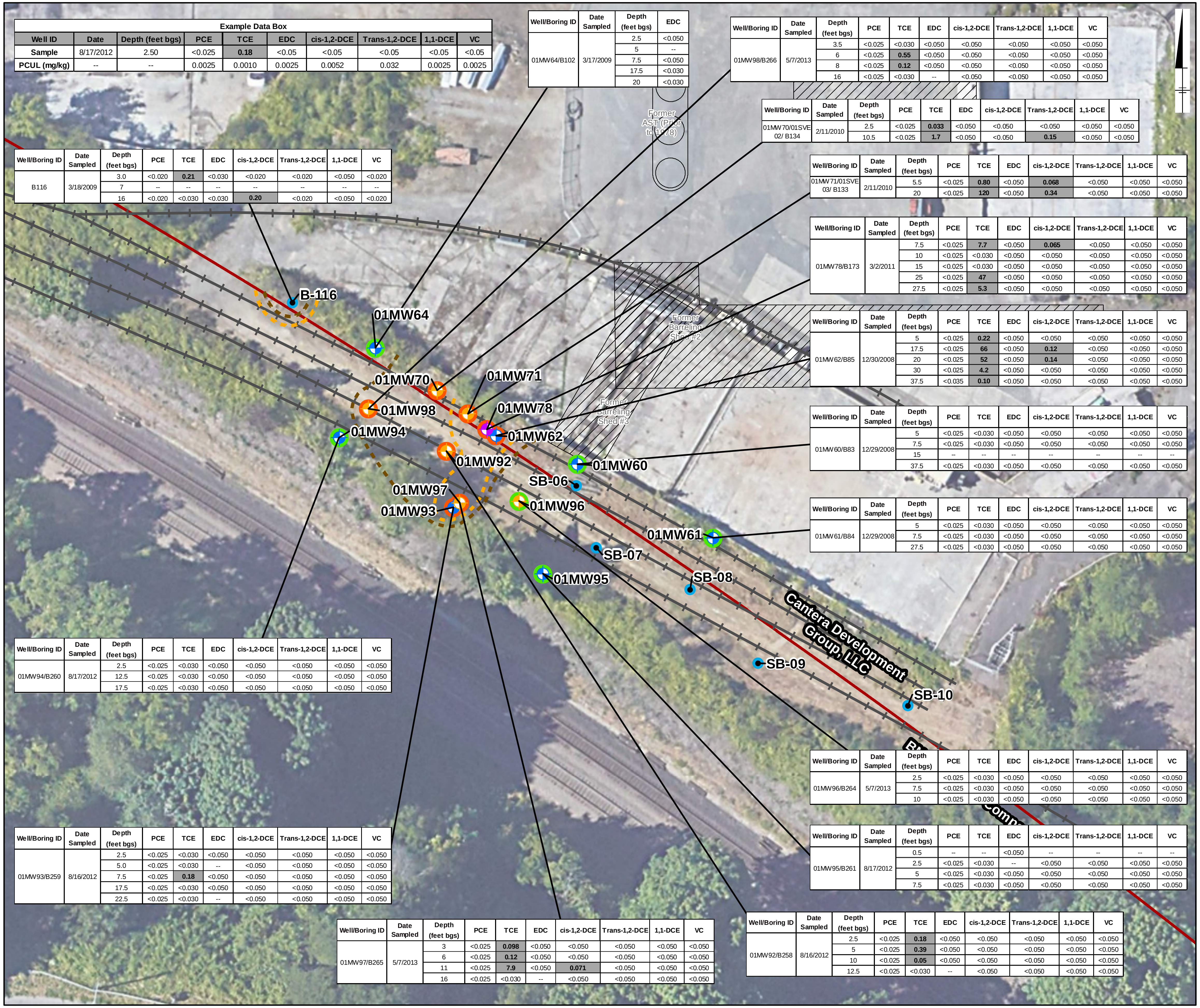


Example Data Box									
Well ID	**Date**	**Depth (feet bgs)**	**PCE**	**TCE**	**EDC**	**cis-1,2-DCE**	**Trans-1,2-DCE**	**1,1-DCE**	**VC**
Sample	8/17/2012	2.50	<0.025	**0.18**	<0.05	<0.05	<0.05	<0.05	<0.05
PCUL (mg/kg)	--	--	0.0025	0.0010	0.0025	0.0052	0.032	0.0025	0.0025

Well/Boring ID	Date Sampled	Depth (feet bgs)	EDC
01MW64/B102	3/17/2009	2.5	<0.050
		5	--
		7.5	<0.050
		17.5	<0.030
		20	<0.030

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW98/B266	5/7/2013	3.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		6	<0.025	**0.55**	<0.050	<0.050	<0.050	<0.050	<0.050
		8	<0.025	**0.12**	<0.050	<0.050	<0.050	<0.050	<0.050
		16	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW70/01SVE 02/ B134	2/11/2010	2.5	<0.025	**0.033**	<0.050	<0.050	<0.050	<0.050	<0.050
		10.5	<0.025	**1.7**	<0.050	<0.050	**0.15**	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
B116	3/18/2009	3.0	<0.020	**0.21**	<0.030	<0.020	<0.020	<0.050	<0.020
		7	--	--	--	--	--	--	--
		16	<0.020	<0.030	<0.030	**0.20**	<0.020	<0.050	<0.020

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW71/01SVE 03/ B133	2/11/2010	5.5	<0.025	**0.80**	<0.050	**0.068**	<0.050	<0.050	<0.050
		20	<0.025	**120**	<0.050	**0.34**	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW78/B173	3/2/2011	7.5	<0.025	**7.7**	<0.050	**0.065**	<0.050	<0.050	<0.050
		10	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		15	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		25	<0.025	**47**	<0.050	<0.050	<0.050	<0.050	<0.050
		27.5	<0.025	**5.3**	<0.050	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW62/B85	12/30/2008	5	<0.025	**0.22**	<0.050	<0.050	<0.050	<0.050	<0.050
		17.5	<0.025	**66**	<0.050	**0.12**	<0.050	<0.050	<0.050
		20	<0.025	**52**	<0.050	**0.14**	<0.050	<0.050	<0.050
		30	<0.025	**4.2**	<0.050	<0.050	<0.050	<0.050	<0.050
		37.5	<0.035	**0.10**	<0.050	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW60/B83	12/29/2008	5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		7.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		15	--	--	--	--	--	--	--
		37.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW61/B84	12/29/2008	5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		7.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		27.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW94/B260	8/17/2012	2.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		12.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		17.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW96/B264	5/7/2013	2.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		7.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		10	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW93/B259	8/16/2012	2.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		5.0	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050
		7.5	<0.025	**0.18**	<0.050	<0.050	<0.050	<0.050	<0.050
		17.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		22.5	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW95/B261	8/17/2012	0.5	--	--	<0.050	--	--	--	--
		2.5	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050
		5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050
		7.5	<0.025	<0.030	<0.050	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW97/B265	5/7/2013	3	<0.025	**0.098**	<0.050	<0.050	<0.050	<0.050	<0.050
		6	<0.025	**0.12**	<0.050	<0.050	<0.050	<0.050	<0.050
		11	<0.025	**7.9**	<0.050	**0.071**	<0.050	<0.050	<0.050
		16	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCE	TCE	EDC	cis-1,2-DCE	Trans-1,2-DCE	1,1-DCE	VC
01MW92/B258	8/16/2012	2.5	<0.025	**0.18**	<0.050	<0.050	<0.050	<0.050	<0.050
		5	<0.025	**0.39**	<0.050	<0.050	<0.050	<0.050	<0.050
		10	<0.025	**0.05**	<0.050	<0.050	<0.050	<0.050	<0.050
		12.5	<0.025	<0.030	--	<0.050	<0.050	<0.050	<0.050

LEGEND:

- ⊕ PERCHED MONITORING WELL
- ⊕ SHALLOW MONITORING WELL
- ⊕ INTERMEDIATE MONITORING WELL
- ● SOIL BORING
- ● SOIL BORING EXCEEDING THE CVOC PCULS
- ● SOIL BORING NOT EXCEEDING THE CVOC PCULS
- ‐ ‐ APPROXIMATE EXTENT OF CIS-1,2-DCE IN SOIL EXCEEDING THE PCUL
- ‐ ‐ APPROXIMATE EXTENT OF TCE IN SOIL EXCEEDING THE PCUL
- — PROPERTY BOUNDARY
- ┼ HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
- ▨ HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

NOTE:
1. WELL LOCATIONS APPROXIMATE.
2. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.
3. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.
-- = NOT ANALYZED
mg/kg = MILLIGRAM PER KILOGRAM
CVOC = CHLORINATED VOLATILE ORGANIC COMPOUND
PCE = TETRACHLOROETHENE
TCE = TRICHLOROETHENE
DCE = DICHLOROETHENE
EDC = 1,2-DICHLOROETHENE
VC = VINYL CHLORIDE
PCUL = PRELIMINARY CLEANUP LEVEL
BGS = BELOW GROUND SURFACE
< = LESS THAN REPORTING DETECTION LIMIT
BOLD = ANALYTE DETECTED AT A CONCENTRATION GREATER THAN THE METHOD DETECTION LIMIT.
HIGHLIGHT AND BOLD = DETECTED CONCENTRATION EXCEEDS PRELIMINARY CLEANUP LEVELS FOR SOIL.

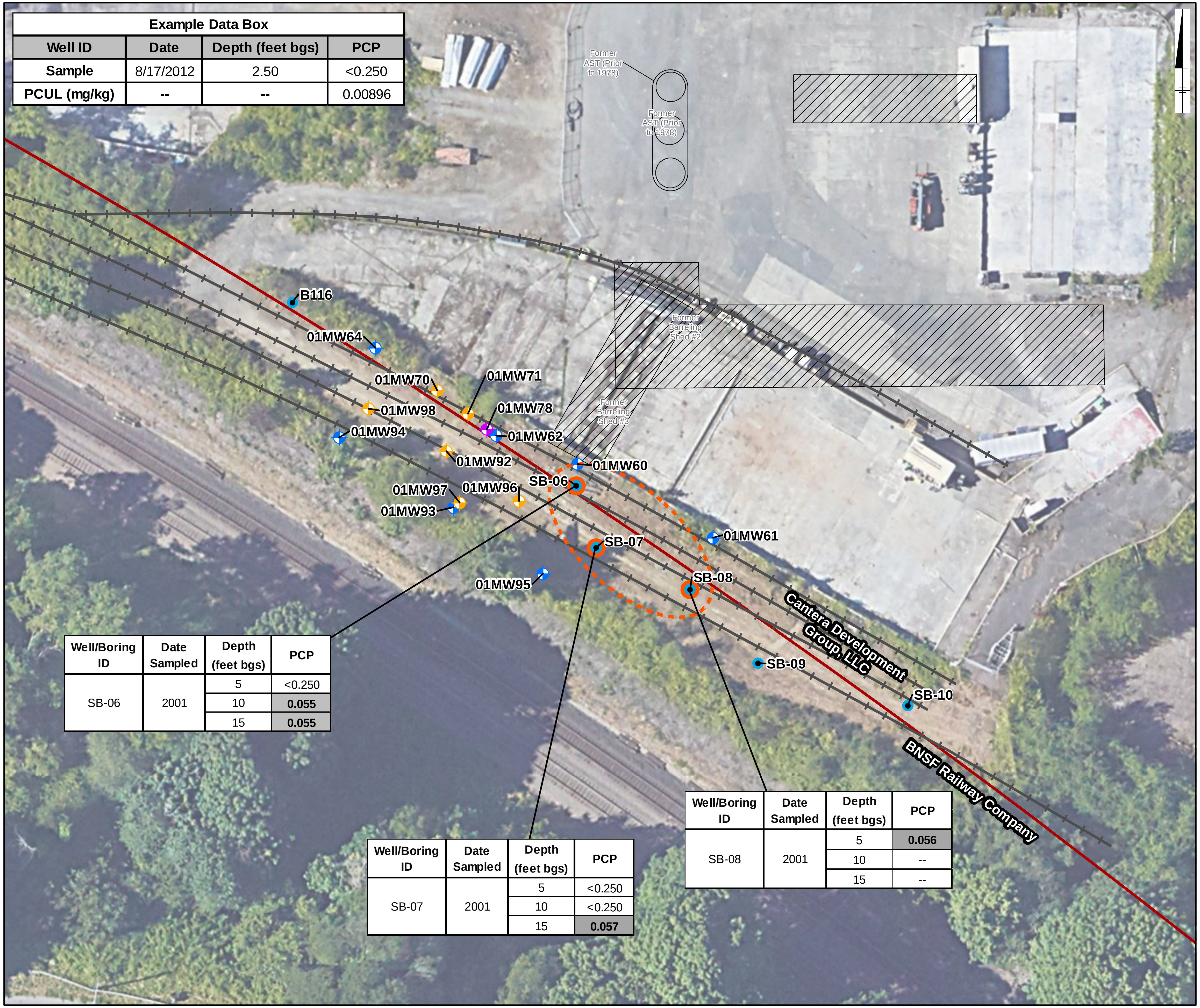
BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

SOIL ANALYTICAL RESULTS - CVOCS

ARCADIS

FIGURE
6

Last Saved By: dholmes
T:_ENV\BNSF\BNSF_FormerTimeOil_WA\MXD\2023_RI_WorkPlan\F6_SoilResult_CVOC.mxd 6/7/2023 1:12:22 PM



Example Data Box			
Well ID	**Date**	**Depth (feet bgs)**	**PCP**
Sample	8/17/2012	2.50	<0.250
PCUL (mg/kg)	--	--	0.00896

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCP
SB-06	2001	5	<0.250
		10	**0.055**
		15	**0.055**

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCP
SB-07	2001	5	<0.250
		10	<0.250
		15	**0.057**

Well/Boring ID	Date Sampled	Depth (feet bgs)	PCP
SB-08	2001	5	**0.056**
		10	--
		15	--

LEGEND:

⊕	PERCHED MONITORING WELL
⊕	SHALLOW MONITORING WELL
⊕	INTERMEDIATE MONITORING WELL
●	SOIL BORING
●	SOIL BORING EXCEEDING THE PCP PCUL
- - -	APPROXIMATE EXTENT OF PCP IN SOIL EXCEEDING THE PCUL
—	PROPERTY BOUNDARY
┼┼	HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
▨	HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

NOTE:
1. WELL LOCATIONS APPROXIMATE.
2. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.
3. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.
-- = NOT ANALYZED
mg/kg = MILLIGRAM PER KILOGRAM
PCP = PENTACHLOROPHENOL
PCUL = PRELIMINARY CLEANUP LEVEL
BGS = BELOW GROUND SURFACE
< = LESS THAN REPORTING DETECTION LIMIT
BOLD = ANALYTE DETECTED AT A CONCENTRATION GREATER THAN THE METHOD DETECTION LIMIT.
HIGHLIGHT AND BOLD = DETECTED CONCENTRATION EXCEEDS PRELIMINARY CLEANUP LEVELS FOR SOIL.

BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

SOIL ANALYTICAL RESULTS - PENTACHLOROPHENOL

ARCADIS

FIGURE
7

Last Saved By: dholmes
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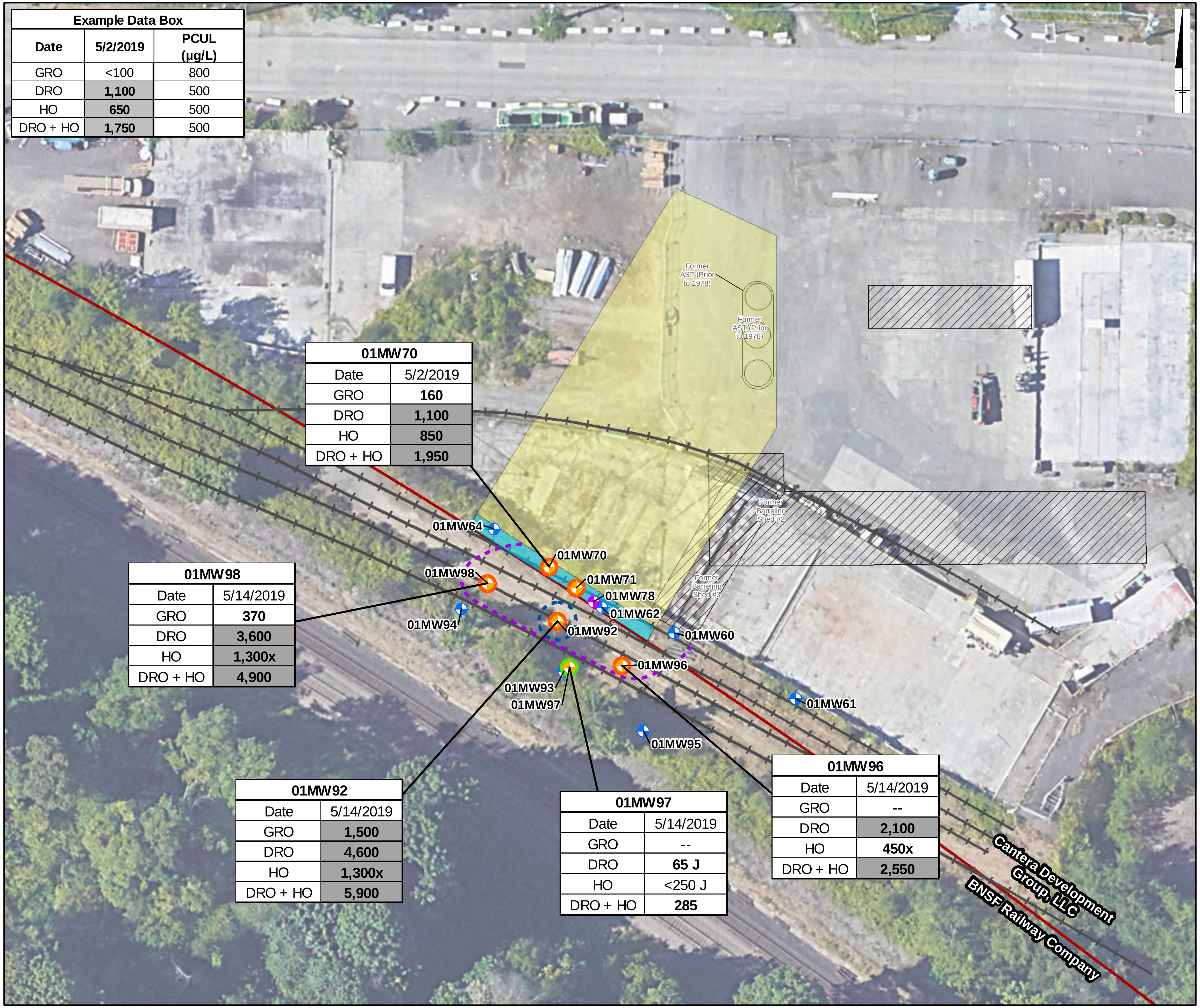

Example Data Box

Date	5/2/2019	PCUL (µg/L)
GRO	<100	800
DRO	**1,100**	500
HO	**650**	500
DRO + HO	**1,750**	500

01MW70

Date	5/2/2019
GRO	**160**
DRO	**1,100**
HO	**850**
DRO + HO	**1,950**

01MW98

Date	5/14/2019
GRO	**370**
DRO	**3,600**
HO	**1,300x**
DRO + HO	**4,900**

01MW92

Date	5/14/2019
GRO	**1,500**
DRO	**4,600**
HO	**1,300x**
DRO + HO	**5,900**

01MW97

Date	5/14/2019
GRO	--
DRO	**65 J**
HO	<250 J
DRO + HO	**285**

01MW96

Date	5/14/2019
GRO	--
DRO	**2,100**
HO	**450x**
DRO + HO	**2,550**

LEGEND:

- PERCHED MONITORING WELL
- SHALLOW MONITORING WELL
- INTERMEDIATE MONITORING WELL
- ● GROUNDWATER EXCEEDING THE PETROLEUM HYDROCARBON PCULS
- ● GROUNDWATER NOT EXCEEDING THE PETROLEUM HYDROCARBON PCULS
- APPROXIMATE EXTENT OF DRO+HO IN PERCHED WBZ EXCEEDING THE PCUL
- APPROXIMATE EXTENT OF GRO IN PERCHED WBZ EXCEEDING THE PCUL
- PROPERTY BOUNDARY
- HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
- PERCHED ZONE INTERCEPTOR TRENCH
- EXTENT OF IN-SITU STABILIZATION
- ▨ HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

NOTE:
1. ALTHOUGH NOT SAMPLED DURING MAY 2019, HISTORICAL ANALYTICAL DATA AT 01MW71 SUGGESTS EXCEEDANCES OF PCULS FOR PETROLEUM HYDROCARBONS.
2. WELL LOCATIONS APPROXIMATE.
3. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.
4. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.
-- = NOT ANALYZED
µg/L = MICROGRAM PER LITER
GRO = GASOLINE RANGE ORGANICS
DRO = DIESEL RANGE ORGANICS
HO = HEAVY OIL
WBZ = WATER BEARING ZONE
PCUL = PRELIMINARY CLEANUP LEVEL
J = THE ANALYTE WAS POSITIVELY IDENTIFIED; HOWEVER, THE ASSOCIATED NUMERICAL VALUE IS AN ESTIMATED CONCENTRATION ONLY.
X = THE PATTERN OF PEAKS PRESENT IS NOT INDICATIVE OF DIESEL OR THE SAMPLE CHROMATOGRAPHIC PATTERN DOES NOT RESEMBLE THE FUEL STANDARD USED FOR QUANTITATION.
< = LESS THAN REPORTING DETECTION LIMIT
BOLD = ANALYTE DETECTED AT A CONCENTRATION GREATER THAN THE METHOD DETECTION LIMIT.
HIGHLIGHT AND BOLD = DETECTED CONCENTRATION EXCEEDS PRELIMINARY CLEANUP LEVELS FOR GROUNDWATER.

BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

GROUNDWATER ANALYTICAL RESULTS - PERCHED WBZ PETROLEUM HYDROCARBONS - MAY 2019

ARCADIS

FIGURE
8

Last Saved By: dholmes
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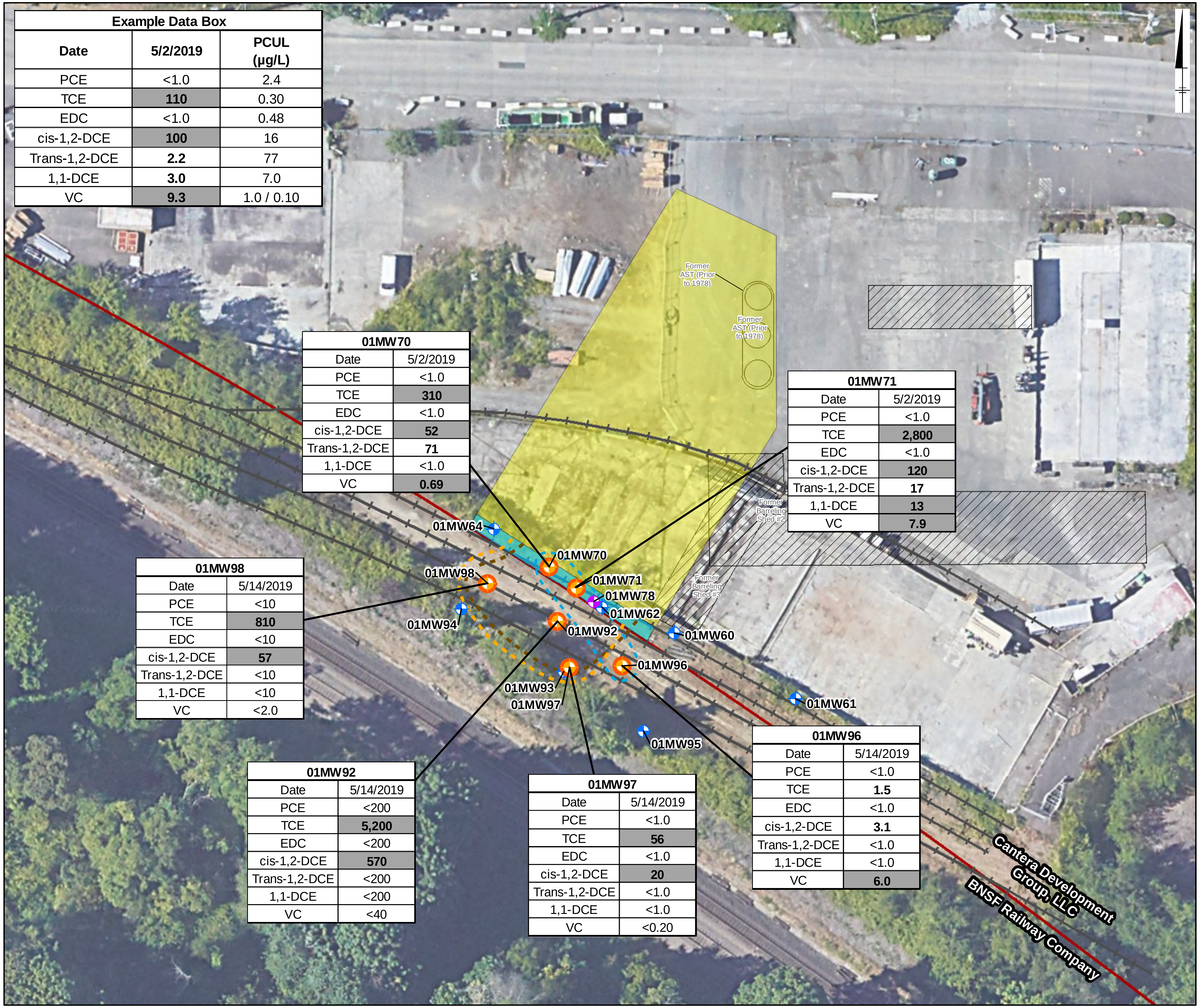

Example Data Box		
Date	5/2/2019	PCUL (µg/L)
PCE	<1.0	2.4
TCE	**110**	0.30
EDC	<1.0	0.48
cis-1,2-DCE	**100**	16
Trans-1,2-DCE	**2.2**	77
1,1-DCE	**3.0**	7.0
VC	**9.3**	1.0 / 0.10

01MW70	
Date	5/2/2019
PCE	<1.0
TCE	**310**
EDC	<1.0
cis-1,2-DCE	**52**
Trans-1,2-DCE	**71**
1,1-DCE	<1.0
VC	**0.69**

01MW71	
Date	5/2/2019
PCE	<1.0
TCE	**2,800**
EDC	<1.0
cis-1,2-DCE	**120**
Trans-1,2-DCE	**17**
1,1-DCE	**13**
VC	**7.9**

01MW98	
Date	5/14/2019
PCE	<10
TCE	**810**
EDC	<10
cis-1,2-DCE	**57**
Trans-1,2-DCE	<10
1,1-DCE	<10
VC	<2.0

01MW92	
Date	5/14/2019
PCE	<200
TCE	**5,200**
EDC	<200
cis-1,2-DCE	**570**
Trans-1,2-DCE	<200
1,1-DCE	<200
VC	<40

01MW97	
Date	5/14/2019
PCE	<1.0
TCE	**56**
EDC	<1.0
cis-1,2-DCE	**20**
Trans-1,2-DCE	<1.0
1,1-DCE	<1.0
VC	<0.20

01MW96	
Date	5/14/2019
PCE	<1.0
TCE	**1.5**
EDC	<1.0
cis-1,2-DCE	**3.1**
Trans-1,2-DCE	<1.0
1,1-DCE	<1.0
VC	**6.0**

LEGEND:

⊕ PERCHED MONITORING WELL
⊕ SHALLOW MONITORING WELL
⊕ INTERMEDIATE MONITORING WELL
● GROUNDWATER EXCEEDING THE CVOC PCULS
- - - APPROXIMATE EXTENT OF CIS-1,2-DCE IN PERCHED WBZ EXCEEDING THE PCUL
- - - APPROXIMATE EXTENT OF TCE IN PERCHED WBZ EXCEEDING THE PCUL
- - - APPROXIMATE EXTENT OF VC IN PERCHED WBZ EXCEEDING THE PCUL
— PROPERTY BOUNDARY
┼┼ HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
🟦 PERCHED ZONE INTERCEPTOR TRENCH
🟨 EXTENT OF IN-SITU STABILIZATION
▨ HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

NOTE:
1. WELL LOCATIONS APPROXIMATE.
2. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.
3. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.
-- = NOT ANALYZED
µg/L = MICROGRAM PER LITER
CVOC = CHLORINATED VOLATILE ORGANIC COMPOUND
PCE = TETRACHLOROETHENE
TCE = TRICHLOROETHENE
DCE = DICHLOROETHENE
EDC = 1,2-DICHLOROETHENE
VC = VINYL CHLORIDE
PCUL = PRELIMINARY CLEANUP LEVEL
WBZ = WATER BEARING ZONE
< = LESS THAN REPORTING DETECTION LIMIT
BOLD = ANALYTE DETECTED AT A CONCENTRATION GREATER THAN THE METHOD DETECTION LIMIT.
HIGHLIGHT AND BOLD = DETECTED CONCENTRATION EXCEEDS PRELIMINARY CLEANUP LEVELS FOR GROUNDWATER.

BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

GROUNDWATER ANALYTICAL RESULTS - PERCHED WBZ CVOCS - MAY 2019

ARCADIS

FIGURE
9

Last Saved By: dholmes
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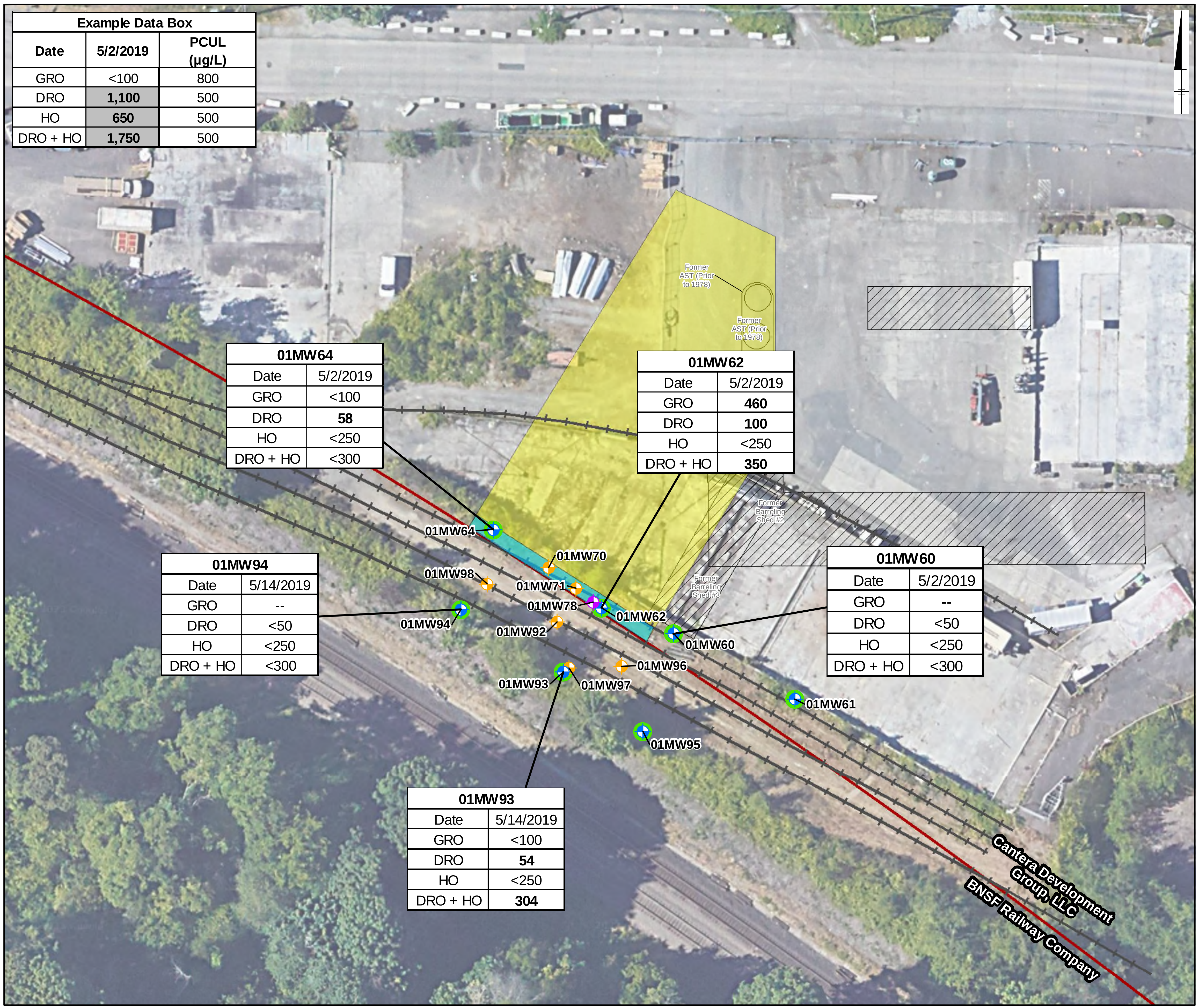

Example Data Box

Date	5/2/2019	PCUL (µg/L)
GRO	<100	800
DRO	**1,100**	500
HO	**650**	500
DRO + HO	**1,750**	500

01MW64

Date	5/2/2019
GRO	<100
DRO	**58**
HO	<250
DRO + HO	<300

01MW62

Date	5/2/2019
GRO	**460**
DRO	**100**
HO	<250
DRO + HO	**350**

01MW94

Date	5/14/2019
GRO	--
DRO	<50
HO	<250
DRO + HO	<300

01MW60

Date	5/2/2019
GRO	--
DRO	<50
HO	<250
DRO + HO	<300

01MW93

Date	5/14/2019
GRO	<100
DRO	**54**
HO	<250
DRO + HO	**304**

LEGEND:

- PERCHED MONITORING WELL
- SHALLOW MONITORING WELL
- INTERMEDIATE MONITORING WELL
- ● GROUNDWATER NOT EXCEEDING THE PETROLEUM HYDROCARBON PCULS
- PROPERTY BOUNDARY
- HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
- PERCHED ZONE INTERCEPTOR TRENCH
- EXTENT OF IN-SITU STABILIZATION
- ▨ HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

NOTE:
1. ALTHOUGH NOT SAMPLED DURING MAY 2019, HISTORICAL ANALYTICAL DATA AT 01MW61 AND 01MW95 SUGGEST NO EXCEEDANCES OF PCULS FOR PETROLEUM HYDROCARBONS.
2. WELL LOCATIONS APPROXIMATE.
3. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.
4. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.
-- = NOT ANALYZED
µg/L = MICROGRAM PER LITER
GRO = GASOLINE RANGE ORGANICS
DRO = DIESEL RANGE ORGANICS
HO = HEAVY OIL
PCUL = PRELIMINARY CLEANUP LEVEL
WBZ = WATER BEARING ZONE
< = LESS THAN REPORTING DETECTION LIMIT
BOLD = ANALYTE DETECTED AT A CONCENTRATION GREATER THAN THE METHOD DETECTION LIMIT.
HIGHLIGHT AND BOLD = DETECTED CONCENTRATION EXCEEDS PRELIMINARY CLEANUP LEVELS OR GROUNDWATER.

BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

GROUNDWATER ANALYTICAL RESULTS - SHALLOW WBZ PETROLEUM HYDROCARBONS - MAY 2019

ARCADIS

FIGURE
10

Last Saved By: dholmes
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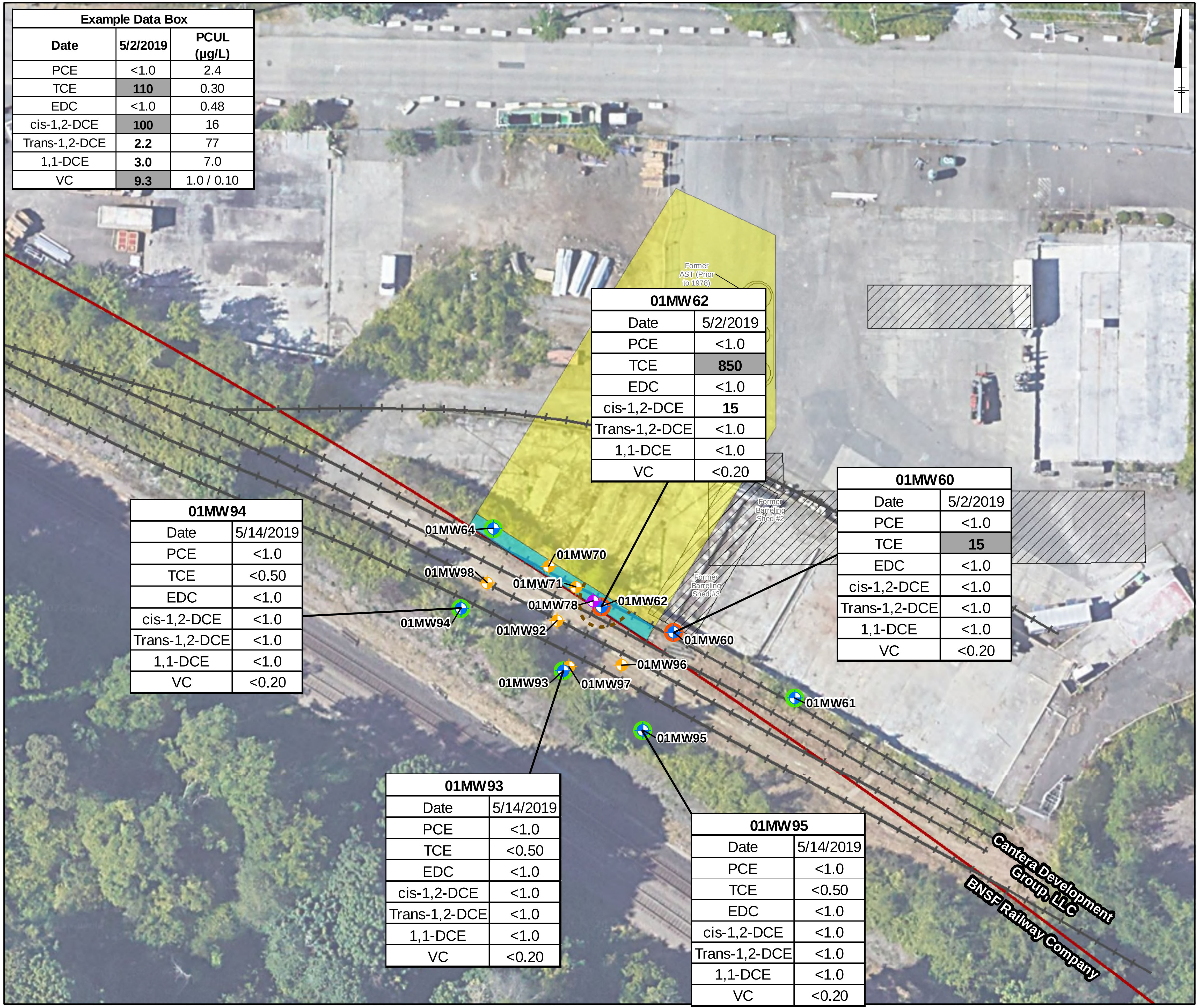

Example Data Box

Date	5/2/2019	PCUL (µg/L)
PCE	<1.0	2.4
TCE	**110**	0.30
EDC	<1.0	0.48
cis-1,2-DCE	**100**	16
Trans-1,2-DCE	**2.2**	77
1,1-DCE	**3.0**	7.0
VC	**9.3**	1.0 / 0.10

01MW62

Date	5/2/2019
PCE	<1.0
TCE	**850**
EDC	<1.0
cis-1,2-DCE	**15**
Trans-1,2-DCE	<1.0
1,1-DCE	<1.0
VC	<0.20

01MW60

Date	5/2/2019
PCE	<1.0
TCE	**15**
EDC	<1.0
cis-1,2-DCE	<1.0
Trans-1,2-DCE	<1.0
1,1-DCE	<1.0
VC	<0.20

01MW94

Date	5/14/2019
PCE	<1.0
TCE	<0.50
EDC	<1.0
cis-1,2-DCE	<1.0
Trans-1,2-DCE	<1.0
1,1-DCE	<1.0
VC	<0.20

01MW93

Date	5/14/2019
PCE	<1.0
TCE	<0.50
EDC	<1.0
cis-1,2-DCE	<1.0
Trans-1,2-DCE	<1.0
1,1-DCE	<1.0
VC	<0.20

01MW95

Date	5/14/2019
PCE	<1.0
TCE	<0.50
EDC	<1.0
cis-1,2-DCE	<1.0
Trans-1,2-DCE	<1.0
1,1-DCE	<1.0
VC	<0.20

LEGEND:

⊕	PERCHED MONITORING WELL
⊕	SHALLOW MONITORING WELL
⊕	INTERMEDIATE MONITORING WELL
●	GROUNDWATER EXCEEDING THE CVOC PCULS
●	GROUNDWATER NOT EXCEEDING THE CVOC PCULS
- - -	APPROXIMATE EXTENT OF TCE IN SHALLOW WBZ EXCEEDING THE PCUL
—	PROPERTY BOUNDARY
┼─┼	HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
■	PERCHED ZONE INTERCEPTOR TRENCH
■	EXTENT OF IN-SITU STABILIZATION
▨	HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

0 40 80
Feet

NOTE:
1. ALTHOUGH NOT SAMPLED DURING MAY 2019, HISTORICAL ANALYTICAL DATA AT 01MW61 AND 01MW64 SUGGEST NO EXCEEDANCES OF PCULS FOR CVOCS SINCE 2012.
2. WELL LOCATIONS APPROXIMATE.
3. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.
4. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.
-- = NOT ANALYZED
µg/L = MICROGRAM PER LITER
CVOC = CHLORINATED VOLATILE ORGANIC COMPOUND
PCE = TETRACHLOROETHENE
TCE = TRICHLOROETHENE
DCE = DICHLOROETHENE
EDC = 1,2-DICHLOROETHENE
VC = VINYL CHLORIDE
PCUL = PRELIMINARY CLEANUP LEVEL
WBZ = WATER BEARING ZONE
< = LESS THAN REPORTING DETECTION LIMIT
BOLD = ANALYTE DETECTED AT A CONCENTRATION GREATER THAN THE METHOD DETECTION LIMIT.
HIGHLIGHT AND BOLD = DETECTED CONCENTRATION EXCEEDS PRELIMINARY CLEANUP LEVELS FOR GROUNDWATER.

BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

GROUNDWATER ANALYTICAL RESULTS - SHALLOW WBZ CVOCS - MAY 2019

ARCADIS

FIGURE
11

Last Saved By: dholmes
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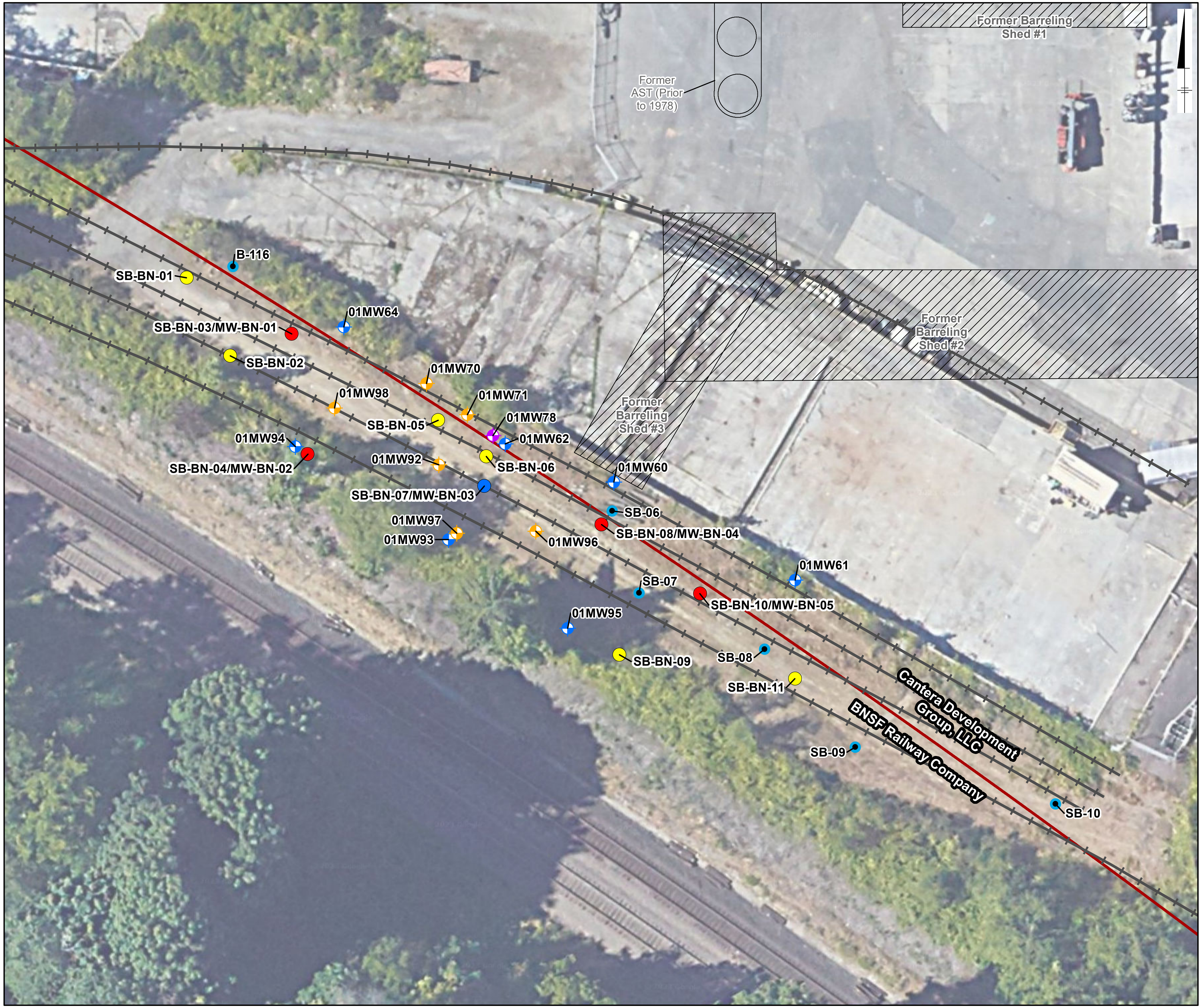

LEGEND:

- 🔴 PROPOSED PERCHED MONITORING WELL LOCATION
- 🔵 PROPOSED SHALLOW MONITORING WELL LOCATION
- 🟡 PROPOSED SOIL BORING
- ⊕ PERCHED MONITORING WELL
- ⊕ SHALLOW MONITORING WELL
- ⊕ INTERMEDIATE MONITORING WELL
- ● SOIL BORING
- — PROPERTY BOUNDARY
- ┼ HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
- ▨ HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

NOTE:
1. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 06/20/2021.
2. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.

BNSF RAILWAY COMPANY
FORMER TIME OIL BULK TERMINAL
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

PROPOSED SOIL BORING AND WELL INSTALLATION LOCATIONS MAP

ARCADIS

FIGURE
12

Div/Group: GEC Created By: Akshaya.D Last Saved By: dholmes
T:_ENV\BNSF\BNSF_FormerTimeOil_WA\MXD\2023_RI_WorkPlan\F12_ProposedBoring_MW.mxd 2/21/2023 1:15:41 PM

Appendix A

Sampling and Analysis Plan/Quality Assurance Project Plan

BNSF Railway Company

Sampling and Analysis Plan/Quality Assurance Project Plan

Time Oil Bulk Terminal – BNSF Property

Agreed Order No. DE 18042

Facility Site Identification No. 75486194

Cleanup Site Identification No. 14604

June 26, 2023

Sampling and Analysis Plan/Quality Assurance Project Plan

Time Oil Bulk Terminal – BNSF Property

Agreed Order No. DE 18042

Facility Site Identification No. 75486194

Cleanup Site Identification No. 14604

June 26, 2023

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Contents

Tables

Attachment

Acronyms and Abbreviations

%R	percent recovery
AO	Agreed Order No. DE 18042
AOC	area of concern
Arcadis	Arcadis, U.S., Inc.
BNSF	BNSF Railway Company
BTEX	benzene, toluene, ethylbenzene, and total xylenes
COC	chain of custody
CVOC	chlorinated volatile organic compounds
DCE	dichloroethane
DQI	data quality indicator
DQO	data quality objective
DRO	diesel range organics
Ecology	State of Washington Department of Ecology
EDC	dichloroethane
EDD	electronic data deliverable
EIM	Environmental Information Management System
GC/MS	gas chromatography/mass spectrometry
GRO	gasoline range organics
HazMat	hazardous material
HO	heavy oil
IDW	investigation-derived waste
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate
NAPL	non-aqueous phase liquid
OSHA	Occupational Safety and Health Administration
Pace	Pace National Center for Testing and Innovation
PCE	tetrachloroethene

PCP	pentachlorophenol
PM	Project Manager
QA	quality assurance
QC	quality control
RIWP	Remedial Investigation Work Plan
RL	reporting limit
RPD	relative percent difference
SAP/QAPP	Sampling and Analysis Plan/Quality Assurance Project Plan
SOP	Standard Operating Procedure
TCE	trichloroethene
TGI	Technical Guidance Instruction
TM	Task Manager
TOC	total organic carbon
TPH	total petroleum hydrocarbons
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VOC	volatile organic compound
WBZ	water bearing zone

1 Introduction

On behalf of BNSF Railway Company (BNSF), Arcadis, U.S., Inc. (Arcadis) has prepared this Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) for the BNSF Property within the Time Oil Bulk Terminal Site located in Seattle, Washington. This SAP/QAPP is provided as Appendix A to the Remedial Investigation Work Plan (RIWP); as such, the work plan will be referenced in this SAP/QAPP to avoid redundancies where possible.

The RIWP describes the activities to be undertaken to determine the nature and extent of releases on the BNSF Property, to inform potential interim actions, and to inform final remedial actions, as described in the Agreed Order No. DE 18042 (AO; State of Washington Department of Ecology [Ecology], 2021). This SAP/QAPP presents the quality control (QC), quality assurance (QA), sampling protocol, and chain-of-custody (COC) procedures that will be used in carrying out tasks described in the RIWP.

This SAP/QAPP was prepared in a manner consistent with the following reference and guidance documents:

- Ecology Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies, Publication No. 04-03-030 (Ecology 2016);
- United States Environmental Protection Agency (USEPA). Requirements for Quality Assurance Project Plans, EPA-QA/R-5 (USEPA 2001) (https://www.epa.gov/quality/agency-wide-quality-system-documents);
- USEPA Guidance for Quality Assurance Project Plans, EPA-QA/G-5 (USEPA 2002) (https://www.epa.gov/quality/agency-wide-quality-system-documents); and
- USEPA Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA-QA/G-4 (USEPA 2006) (https://www.epa.gov/quality/agency-wide-quality-system-documents).

Information contained in this SAP/QAPP has been organized into the following sections:

Section	Content
1. Introduction	
2. Project Management	
2.1	Distribution List
2.2	Project/Task Organization
2.3	Project Definition/Background
2.4	Project/Task Description
2.5	Quality Objectives and Criteria for Measurement Data
2.6	Special Training Needs/Certification
2.7	Documents and Records
3. Data Generation and Acquisition	
3.1	Sampling Process Design
3.2	Sampling Methods

Section	Content
3.3	Sample Handling and Custody
3.4	Analytical Methods
3.5	Quality Control
3.6	Instrument/Equipment Testing, Inspection, and Maintenance
3.7	Instrument/Equipment Calibration and Frequency
3.8	Inspection/Acceptance of Supplies and Consumables
3.9	Non-Direct Measurements
3.10	Data Management
4. Assessment and Oversight	
4.1	Assessments and Response Actions
4.2	Reports to Management
5. Data Validation and Usability	
5.1	Data Review, Verification, and Validation
5.2	Verification and Validation Methods
5.3	Reconciliation with User Requirements

Details on each of the subjects listed above are provided in the subsequent sections.

2 Project Management

2.1 Distribution List

Copies of the SAP/QAPP and any subsequent revisions and/or addenda will be distributed to the individuals listed in the following table.

SAP/QAPP Recipient	Title	Name	Telephone Number	E-mail Address
BNSF	Project Coordinator	Shane DeGross	253-591-2567	shane.degross@BNSF.com
Ecology	Project Coordinator	Tena Seeds	425-457-3143	tena.seeds@ecy.wa.gov
Arcadis	Project Manager	Kyle Haslam	206-726-4753	kyle.haslam@arcadis.com
Arcadis	Task Manager	Emily Zikmund	206-413-6534	emily.zikmund@arcadis.com
Arcadis	Quality Assurance Coordinator	Jeff Davin	315-671-9468	jeffrey.davin@arcadis.com
Pace National Center for Testing and Innovation (Pace)	Project Manager	Mark Beasley	615-773-9672	mark.beasley@pacelabs.com

2.2 Project/Task Organization

The activities to be completed under the AO will require integration of personnel from the organizations identified below, collectively referred to as the project team.

The responsibilities of the various team members are summarized below. Regulatory oversight to ensure work is completed according to the AO will be provided by Ecology. On behalf of BNSF, Arcadis has overall technical responsibility for site activities. Project direction will be provided by BNSF. Arcadis personnel will perform related sampling activities, evaluate data, and prepare the deliverables.

2.2.1 Ecology Project Coordinator

- Providing regulatory oversight of activities associated with the remedial investigation to ensure it is completed according to the AO;
- Reviewing documents prepared for this project and providing comments and direction to BNSF and Arcadis;
- Coordinating with other Ecology staff as required to review and comment on materials associated with the remedial investigation;
- Providing approval of the RIWP and this SAP/QAPP; and
- Approving data use and potential further data collection.

2.2.2 BNSF

- Overseeing Arcadis work products;
- Providing approval of Arcadis major project deliverables prior to delivery to Ecology for regulatory approval; and
- Reviewing Arcadis work products.

2.2.3 Arcadis

Project Manager (PM)

- Managing and coordinating all aspects of the project with an emphasis on adhering to the objectives of site activities;
- Reviewing documents prepared by Arcadis;
- Managing relevant day-to-day activities;
- Managing project schedule and budget;
- Verifying that corrective actions are taken for deficiencies cited during audits of relevant site activities; and
- Coordinating client requests and meetings with project team.

Task Manager (TM)

- Managing task specific activities;
- Developing, establishing, and maintaining files on relevant site activities;
- Reviewing data reductions from relevant site activities;
- Performing overall QA/QC of relevant portions of the site activities;
- Reviewing relevant field records and logs;
- Instructing personnel working on relevant site activities;
- Coordinating field and laboratory schedules pertaining to relevant site activities;
- Requesting sample bottles from the laboratory;
- Reviewing field instrumentation maintenance and calibration to meet quality objectives;
- Preparing reports pertaining to relevant site activities; and
- Maintaining field project files of notebooks/logs, data reductions, and calculations.

Field Personnel

- Performing field procedures associated with the investigations;
- Performing field analyses and collecting QA/QC samples;
- Calibrating, operating, and maintaining field equipment;
- Reducing field data;
- Maintaining sample custody; and
- Preparing field records and logs.

Quality Assurance Coordinator

- Reviewing laboratory data packages;
- Overseeing and interfacing with the analytical laboratory;
- Reviewing audit reports; and
- Preparing data validation reports.

2.2.4 Analytical Laboratory

Pace National Center for Testing and Innovation (Pace) of Mt. Juliet, Tennessee will serve as the analytical laboratory for the project. General responsibilities and duties include:

- Performing sample analyses and associated laboratory QA/QC procedures;
- Supplying sample bottles and coolers;
- Maintaining laboratory custody of samples; and
- Strictly adhering to all protocols in the SAP/QAPP.

Laboratory Project Manager

- Serving as primary communication link between Arcadis and laboratory technical staff;
- Monitoring workloads and maintaining availability of resources;
- Overseeing preparation of analytical reports; and
- Supervising in-house chain of custody.

Quality Assurance Manager

- Supervising laboratory technical staff and inspecting all project-related laboratory activities; and
- Conducting audits of all laboratory activities.

Sample Custodian

- Receiving and inspecting the incoming sample containers;
- Recording the condition of the incoming sample containers;
- Verifying chain of custody;
- Notifying laboratory project manager of sample receipt and inspection discrepancies;
- Assigning a unique identification number to each sample;
- Initiating transfer of samples to laboratory sections; and
- Controlling and monitoring access/storage of samples and extracts.

Laboratory Technical Personnel

- Analyzing samples and executing the laboratory procedures developed to determine the data quality; and
- Properly preparing and analyzing project samples in accordance with the laboratory quality assurance manual and Standard Operating Procedures (SOPs).

2.3 Project Definition/Background

The BNSF Property is part of the Time Oil Bulk Terminal Site, located in the Magnolia neighborhood of Seattle, Washington. The Time Oil Bulk Terminal Site is located within the Ballard Interbay North Manufacturing Industrial Center, with a portion located along the waterfront area of Salmon Bay (City of Seattle 2022a and 2022b). The Time Oil Bulk Terminal Site consists of multiple properties, collectively referred to as the “Time Oil Properties,” in addition to the BNSF Property, a portion of the West Commodore Way right-of-way, and portions of Salmon Bay. The Time Oil Properties include two upland properties adjacent to the BNSF Property, known as the Bulk Terminal Parcel (4.08 acres) and the ASKO Hydraulic Parcel (1.59 acres), and two waterfront properties known as the East Waterfront Property (3.05 acres) and West Waterfront Property (1.69 acres) (Floyd Snider 2019). A map showing the four Time Oil Properties and the BNSF Property is included as Figure 2 of the RIWP.

The Time Oil Properties were previously owned by the TOC Holdings Co. until 2017, when the company filed for bankruptcy (Ecology 2021). The Time Oil Properties are currently owned (as of November 2020) by TOC Seattle Terminal 1, LLC (TOCST) (City of Seattle 2022b). In conjunction with the 2020 property transaction, TOCST entered into a Prospective Purchaser Consent Decree (PPCD) with Ecology to clean up the Time Oil Properties (PPCD No. 20-2-15215-3 SEA).

The BNSF Property was previously owned by the Great Northern Railway Company and is currently owned by BNSF. The BNSF Property contained five rail spurs that delivered rail cars to the Time Oil Properties to load and unload petroleum products. While BNSF parcel number 423790-0240 is approximately 5.6 acres (Ecology 2021), the BNSF area where known contamination is present on the BNSF Property, or area of concern (AOC), is approximately 0.4 acre (Ecology 2020). The BNSF AOC is located south of the ASKO Hydraulic Parcel and the area of four former rail spurs (RIWP Figure 3). The activities proposed in the RIWP are intended to address characterization data gaps associated with the BNSF AOC.

As a result of historical activities, the primary constituent of potential concern (COPC) impacts on the BNSF Property consist of TPH (gasoline range organics [GRO], diesel range organics [DRO] and heavy oil [HO]), chlorinated volatile organic compounds (CVOCs, including cis-1,2-dichloroethene [cis-1,2-DCE], trichloroethene [TCE], and vinyl chloride [VC]), and pentachlorophenol (PCP). The presumed transport pathway of these constituents is downward migration from surficial soils to perched and shallow groundwater, and lateral migration in groundwater.

The activities proposed in the RIWP are intended to address characterization data gaps associated with the BNSF Property.

2.4 Project Task/Description

This SAP/QAPP is Appendix A of the RIWP, the purpose of which is to describe the investigation activities needed to fill data gaps and identify vertical and horizontal extents of contamination in soil and groundwater using the existing data and data collected during the remedial investigation. Additional details are included in the RIWP.

2.5 Quality Objectives and Criteria for Measurement Data

2.5.1 Data Quality Objectives

The data quality objective (DQO) process, as described in EPA-QA/G-4 (USEPA, 2006), is used to establish the performance or acceptance criteria that serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support the objectives of the study. The following sections address each of the seven sequential steps in the USEPA DQO process.

Step 1: State the Problem

Previous investigations have delineated most of the vertical and horizontal extent of impacts in soil and groundwater. Additional soil and groundwater data are needed to complete characterization of the vertical and lateral extent of impacts in order to complete a Remedial Investigation and define target treatment zones as part of a Feasibility Study or interim action. One year of quarterly seasonal groundwater data for the Perched Water Bearing Zone (WBZ) and Shallow WBZ is needed to assess seasonal COPC concentration trends.

Step 2: Identify the Objective of the Study

The primary objective of this Remedial Investigation (study) is to characterize the extent of soil and groundwater impacts, where possible considering site access constraints, to bound the target treatment zone. This objective will be accomplished by obtaining necessary data of known and acceptable quality to assess constituent concentrations in soil and groundwater in the BNSF Property as described below.

Step 3: Identify Information Inputs

Information inputs include soil and groundwater data collected as part of this investigation, as detailed in Tables 1a, 1b, and 2, as well as from the following prior investigations:

- 2001 Soil Investigation (data presented in the Remedial Investigation [RI] Report by Sound Earth Strategies [SES] 2014 and Final Environmental Site Assessment: Phase II PCP/Diesel Mixing Areas [Foster Wheeler 2001]);
- 2012 Soil and Groundwater Investigation (data presented in RI Report [SES 2014]);
- 2013 Soil and Groundwater Investigation (data presented in RI Report [SES 2014]); and
- 2019 Groundwater Investigation (data presented in the Supplemental Upland Remedial Investigation and Feasibility Study by Floyd Snider 2020).

Step 4: Define the Boundaries of the Study

The BNSF AOC (study area) consists of a portion of the BNSF right-of-way (King County tax parcel #423790-0240) located adjacent to the Time Oil Properties in Seattle, Washington (RIWP Figure 2). Surface topography in the study area is generally flat, with the ground surface at an elevation of approximately 59 feet relative to the North American Vertical Datum of 1988. Steep slopes and active main-line track corridors in the BNSF right-of-way, directly to the south/southwest of wells 01MW93 through 01MW95, cannot be safely accessed and therefore these areas have been excluded from the study area. The northeastern limit of the study area is the property line between the BNSF Property and the ASKO Hydraulic Parcel. The vertical extent of the study area is between ground surface and approximately 40 feet below ground surface (bgs).

Step 5: Developing the Decision Rule

The remedial investigation will combine several sampling approaches to provide adequate spatial coverage of the study area to meet the objectives defined in Step 2 using the information inputs defined in Step 3. The following actions and decisions will be made in accordance with the RIWP:

- If soil or groundwater analytical results exceed the respective data screening levels (Tables 1a and 1b), the area and depth where the sample was collected may be defined as being within the target treatment zone. Otherwise, the location and/or depth will not be considered as a target treatment zone.

The remedial technology evaluation target treatment zone(s) will be defined utilizing analytical results from prior investigations as well as data collected during this remedial investigation.

Step 6: Specify Tolerable Limits on Decision Errors

Decision errors will be mitigated using thorough QA/QC processes described in this QAPP. Any limitations on the use of the data will be established following data validation. Laboratory-generated QC sample frequencies and QC limits are listed in Tables 2 and 3, respectively.

Step 7: Optimize the Design for Obtaining Data

Sampling of the respective media is scheduled as follows:

- Eleven soil borings (SB-BN-01 through SB-BN-11) will be advanced up to 40 feet bgs (see RIWP Table 7 and Figure 12). Borings will be logged continuously and screened every 5 feet or as lithology dictates. Soil samples will be collected for analysis from the areas with the highest apparent impact or to provide vertical delineation based on adjacent historical impacts.
- Groundwater samples will be collected from five temporary monitoring wells in the Shallow WBZ (SB-BN-03, SB-BN-05, SB-BN-06, SB-BN-08, and SB-BN-10) and two temporary monitoring wells in the Perched WBZ (SB-BN-09 and SB-BN-11, see RIWP Table 7 and Figure 12) and from 12 permanent monitoring wells (01MW92 through 01MW98 and MW-BN-01 through MW-BN-05, RIWP Figure 12) in the Shallow and Perched WBZs via low-flow sampling methodology.
- Groundwater sampling of 12 permanent monitoring wells will occur on a quarterly basis for one year.
- Analytical data and other pertinent information collected from prior investigations will be evaluated along with the data collected during this remedial investigation.

2.5.2 Data Categories

Three data categories have been defined to address various analytical data uses and the associated QA/QC effort and methods required to achieve the desired levels of quality. These categories are:

Screening Data. Screening data afford a quick assessment of site characteristics or conditions. These data collection activities involve rapid, non-rigorous methods of analysis and QA. Screening data quality objectives are generally applied to physical and/or chemical properties of samples, preliminary ecological and/or human health and safety indicators, and visual or other qualitative observations used to make rapid assessment decisions for deployment or additional assessment.

Screening Data with Definitive Confirmation. Screening data provide rapid identification and quantitation. However, because screening generally involves the use of less-precise methods of analysis with less-rigorous sample preparation, the quantitation may be relatively imprecise. Generally, at least 10% of the data are confirmed using analytical methods and QA/QC procedures and criteria associated with definitive data. This objective can also be used to verify less-rigorous laboratory-based methods. This objective of data quality is applicable to data collection activities that require qualitative and/or quantitative verification of a select portion of sample findings.

Definitive Data. Definitive data are generated using rigorous analytical methods, such as approved USEPA reference methods. Data are analyte specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data (e.g., chromatograms, spectra, digital values). Data may be generated at the site or at an off-site location, as long as the QA/QC requirements are satisfied. For data to be definitive, either analytical or total measurement error must be determined. Definitive data are used for formal site characterization, environmental monitoring, confirmation of field data, to support decision-making, and for risk assessments.

It is anticipated that both screening and definitive data categories will be used during the investigation. Screening techniques will include measurement of water quality parameters during the collection of groundwater samples and monitoring of air quality (i.e., volatile organic compound [VOC] concentration and particulate matter) during sampling. All samples submitted to the project laboratory for analysis will be determined using definitive techniques.

For this project, Level 2 reports will be provided by the laboratory.

Elements required for a Level 2 laboratory data report include documentation of the following:

- Chain of custody;
- Case narrative;
- Final parameter concentration for all samples;
- Preparation or extraction and analysis dates/times;
- Method blanks;
- Surrogate recoveries;
- Matrix spike (MS) and matrix spike duplicate (MSD) recoveries and relative percent difference (RPD);
- Laboratory duplicate RPD; and
- Laboratory control sample (LCS) recoveries.

The analytical methods to be used during the investigation are derived from the Test Methods for Evaluating Solids and Water, Physical/Chemical Methods (SW-846), Northwest NWTPH-Dx and NWTPH-Gx, and USEPA Methods and Guidance for the Analysis of Water.

Analytical results will be reported by the laboratory in both electronic data deliverable (EDD) and digital (i.e., PDF) format.

2.5.3 Data Quality Indicators

The primary QA objective is to ensure that the data are of known and acceptable quality, and that the analysis is performed with sufficient sensitivity to confidently detect target parameters. To support the overall project DQOs and to gauge measurement performance, six data quality indicators (DQI) have been defined: representativeness, comparability, completeness, precision, accuracy/bias, and sensitivity. Each DQI is defined below.

Representativeness. Representativeness is the extent to which measurements represent site conditions. It is dependent on sampling and analytical variability, and the variability (or homogeneity) of the Site itself. The sampling activities have been designed to assess the presence of the constituents at the time of sampling. This SAP/QAPP presents field sampling methodologies and laboratory analytical methodologies. The use of the prescribed field and laboratory analytical methods with associated holding times and preservation requirements are intended to provide representative data.

Comparability. Comparability is defined as the extent to which data from one data set can be compared directly to similar or related data sets and/or decision-making standards. Comparability between this investigation and, to the extent possible, with existing data, will be maintained through consistent use of the sampling and analytical methodologies set forth in this SAP/QAPP, analytical methods, stringent application of established QA/QC procedures, and utilization of appropriately trained personnel.

Completeness. Completeness is defined as a measure of the amount of usable data collected compared to the total amount of data that was expected to be obtained. This will be determined upon final assessment of the analytical results. Three measures of completeness are defined: (1) sampling completeness, defined as the number of valid samples collected relative to the number of samples planned for collection; (2) analytical completeness, defined as the number of valid sample measurements relative to the number of valid samples collected; and (3) overall completeness, defined as the number of valid sample measurements relative to the number of samples planned for collection.

Precision. Precision is a measure of agreement among repeated measurements. The goal is to maintain a level of analytical precision consistent with the project objectives. To maximize precision, sampling and analytical procedures will be followed, and work will adhere to established protocols presented in this SAP/QAPP. Analytical precision will be determined through the use of the same analytical methods to perform repeated analyses on the same sample, including the analysis of MSD samples laboratory duplicates and field duplicates. Collection of field duplicate samples allows for evaluating the precision of sample collection, handling, preservation, and storage.

Precision for laboratory and field measurements will be expressed as the RPD between two duplicate determinations. Acceptance criteria for laboratory precision are presented in Table 3.

Accuracy/Bias. Accuracy is the degree of agreement of a measured value with its true value. Accuracy can be expressed as a percent recovery or percent deviation of the measurement with respect to its known or true value. Accuracy will be determined through evaluation of spike recoveries (e.g., surrogate recoveries, LCS recoveries, MS recoveries, reference material recoveries) and instrument calibration. Acceptance percentages for spike recoveries are presented in Table 3.

Bias is defined as the constant or systematic distortion of a measurement process as a persistent positive or negative deviation from the known or true value. This may be due to improper sample collection, sample matrix, poorly calibrated analytical or sampling equipment, or limitations or errors in analytical methods and techniques. Blank samples (laboratory or field) are also used to assess contamination of samples that may bias results high.

Sensitivity. Sensitivity refers to the ability of an analytical procedure to quantify an analyte at a given concentration. The sensitivity requirements should be established such that the laboratory reporting limits (RLs) are at or below the relevant and applicable regulatory limits for each constituent of concern for the project. Method detection limit (MDL) is defined as the minimum concentration of a substance that can be identified, measured, and reported with a 99% confidence that the analyte concentration is greater than zero and is determined from repeated analysis of a sample in a given matrix containing the analyte. MDLs have been determined as required in Title 40 of the Code of Federal Regulation Part 136B. The RL is greater than or equal to the lowest standard used to establish the calibration curve. Results greater than the MDL and less than the RL will be qualified estimated by the laboratory. Non-detected results will be reported at the RL. The MDLs and RLs for the constituents of concern are provided in Tables 1a and 1b. In order to achieve the low screening levels for vinyl chloride in groundwater, an ultra-low level concentration VOC analysis is available from Pace. Since this analysis is performed on a pristine instrument, samples will be analyzed using the standard VOC method first. If a sample result using the standard VOC method is non-detect, the sample will be analyzed using the ultra-low level concentration VOC analysis.

2.6 Special Training Needs/Certification

In compliance with the Occupational Safety and Health Administration (OSHA) final rule, “Hazardous Waste: Operations and Emergency Response [29 Code of Federal Regulations 1910.120(e)],” all personnel performing sampling activities at the site will have completed the requirements for OSHA 40-Hour Hazardous Waste Operations and Emergency Response training. Persons in field supervisory positions will have also completed the additional OSHA 8-Hour Supervisory Training.

Field personnel involved with the shipping of samples to the subcontracted laboratory will have completed the United States Department of Transportation (USDOT) Hazardous Materials (HazMat) #1 – USDOT/International Air Transportation Association HazMat Shipping and Transportation training.

Arcadis’ human resources department maintains records to document management and technical training accomplished by each staff member. Training documentation records are stored in the Arcadis Training Center database.

2.7 Documents and Records

Detailed descriptions of the documentation and reporting requirements are presented below.

2.7.1 Sample Designation System

Samples will be identified with a unique designation system that will facilitate sample tracking. The sample designation system to be employed during the sampling activities will be consistent yet flexible enough to accommodate unforeseen sampling events and conditions. An alpha-numeric system is considered appropriate and will be used by field personnel to assign each sample with a unique sample identification number.

The sample type codes are as follows:

- Groundwater monitoring samples: MW-BN-XX(mmddyy), where “MW” indicates monitoring well, “BN” indicates BNSF, “XX” indicates well number, and “mmddyy” indicates the sample collection date. For example, a monitoring well sample collected from well ID MW-BN-01 on January 13, 2023 will be named MW-BN-01(011323). Groundwater samples collected from temporary wells will be identified as SB-BN-XX-GW (mmddyy), where SB” indicates soli boring, “BN” indicates BNSF, “XX” indicates soil boring number, “GW” indicates groundwater, and “mmddyy” indicates the sample collection date. For example, a groundwater sample collected from a temporary well at soil boring ID SB-BN-01 on January 13, 2023 will be named SB-BN-01-GW(011323).
- Soil samples: SB-BN-XX-depth (mmddyy), where “SB” indicates soli boring, “BN” indicates BNSF, “XX” indicates soil boring number, “depth” indicates the sample collection bottom depth, and “mmddyy” indicates the sample collection date. For example, a soil sample collected from soil boring ID SB-BN-01 at a depth of 1 to 2 feet on January 13, 2023 will be named SB-BN-01-02(011323).

Field duplicate samples will be submitted blind to the laboratory with no indication of the parent sampling location. Duplicate samples will be identified as MW-DUP-XX(mmddyy) and SB-DUP-XX(mmddyy), where “XX” indicates a sequential number for all field duplicate samples collected for each mobilization for specific media (i.e., soil or groundwater). For example, the second field duplicate sample collected in association with a first-quarter groundwater sampling event on January 13, 2023 will be named MW-DUP-02(011323), and the fourth field duplicate sample collected during the first drilling mobilization in association with soil boring sampling on January 13, 2023 will be named SB-DUP-04(011323).

Blanks will be identified as follows:

- Equipment blank: EB-XX(mmddyy) where “XX” indicates a sequential number for all equipment blank samples collected in a day. For example, the first equipment blank sample collected on January 13, 2023 will be named EB-01(011323).
- Trip blank: TB-XX(mmddyy) where “XX” indicates a sequential number for all trip blank samples submitted with each sample cooler. For example, the trip blank sample submitted to the laboratory in the second sample cooler on January 13, 2023 will be named TB-02(011323).

Detailed descriptions of the sample identifications will be recorded in the field log.

2.7.2 Field Documentation

Field personnel will provide comprehensive documentation covering various aspects of field sampling, field analysis, and sample chain of custody. This documentation creates a record that allows reconstruction of field events to aid in the data review and interpretation process. Documents, records, and information relating to the performance of the field work will be retained in the project file.

The various forms of documentation to be maintained throughout the investigation include:

- Field Notebooks/Forms. All pertinent information regarding site and sampling procedures will be documented. A field notebook consisting of a waterproof, bound notebook or electronic tablet will contain a record of all activities performed at the site. Detailed notes will be made as to the exact sampling location, physical observations, and weather conditions, as appropriate. To ensure that data collected in the field are consistent, accurate, and complete, forms may be used during repetitive data collection (e.g., depth to groundwater in monitoring wells during groundwater sampling).
- Sample Labels. Sample labels reduce the possibility of confusing sample containers and provide information necessary to complete COC forms. To the extent practical, sample containers will be pre-labeled before sample collection (with all required information except the date and time of sample collection), and the labels will be protected with a clear tape covering.
- Sample COC. COC forms provide a legal record of possession of the samples, from sample collection through submittal to the laboratory. COC forms will be filled out at each sampling site, at a group of sampling sites, or at the end of each day of sampling by field personnel designated to be responsible for sample custody. In the event that samples are relinquished by the designated sampling person to other sampling or field personnel, the COC form will be signed and dated by the appropriate personnel to document the sample transfer. The original COC form will accompany the samples to the laboratory, and copies will be forwarded to the project files. When the form is complete, it will indicate that there were no lapses in sample accountability.

A sample COC form is included in Arcadis SOP - Sample Chain of Custody, Revision 2, April 2020 (copy included in Appendix D of the RIWP).

Persons will have custody of samples when the samples are in their physical possession, in their view after being in their possession, or in their physical possession and secured so they cannot be tampered with. In addition, when samples are secured in a restricted area accessible only to authorized personnel, they will be deemed to be in the custody of such authorized personnel. A custody seal will be placed on each sample cooler during secure storage and prior to release of custody of the samples to the shipping company for delivery to the laboratory. The purpose of the custody seal is to maintain sample integrity; sample tampering or contamination may be indicated if the seal is broken during storage or transportation.

- Field Equipment, Calibration, and Maintenance Logs. To document the calibration and maintenance of field instrumentation, calibration and maintenance logs will be maintained for each piece of field equipment that is not factory calibrated.

2.7.3 Laboratory Documentation Files

- Laboratory Project Files. The laboratory will establish a file for pertinent data. The file will include all correspondence (including emails), faxed information, phone logs, and COC forms. The laboratory will retain project files and data packages for a period of not less than 5 years.
- Laboratory Logbooks. Workbooks, bench sheets, instrument logbooks, and instrument printouts will be used to trace the history of samples through the analytical process and to document important aspects of the work, including the associated QC checks. As such, all logbooks, bench sheets, instrument logs, and instrument printouts will be part of the permanent record of the laboratory.

  Each page or entry will be dated and initialed by the analyst at the time of entry. Errors in entry will be crossed out in indelible ink with a single stroke, corrected without the use of white-out or by obliterating or writing directly over the erroneous entry, and initialed and dated by the individual making the correction. Pages of logbooks that are not used will be completed by lining out unused portions.

  Information regarding the sample, analytical procedures performed, and the results of the testing will be recorded on laboratory forms or personal notebook pages by the analyst. These notes will be dated and will also identify the analyst, the instrument used, and the instrument conditions.

  Laboratory notebooks will be periodically reviewed by the laboratory group leaders for accuracy, completeness, and compliance with the laboratory SOPs and quality assurance manual. All entries and calculations will be verified by the laboratory group leader. If all entries on the pages are correct, then the laboratory group leader will initial and date the pages. Corrective action will be taken for incorrect entries before the laboratory group leader signs.
- Computer and Hard Copy Storage. All electronic files and deliverables will be retained by the laboratory for not less than 5 years; hard copy data packages (or electronic copies) will also be retained for not less than 5 years.

2.7.4 Data Reporting Requirements

- Field Data Reporting. Information collected in the field through visual observation, manual measurement, and/or field instrumentation will be recorded in field notebooks or on data sheets and/or on forms. Such data will be reviewed for adherence to the applicable field SOPs and for consistency. Concerns identified as a result of this review will be discussed with the field personnel, corrected if possible, and, as necessary, incorporated into the data evaluation process.

Where applicable, field data forms and calculations will be processed and included in appendices to the appropriate project reports (when generated). The original field logs, documents, and data reductions will be kept in the main project file.

- Laboratory Data Reporting. The laboratory is responsible for preparing Level 2 data packages (as defined previously) for all samples. Analytical results will be provided by the laboratory in a digital format (i.e., PDF) as well as an EDD. The project database is maintained in EQuIS; therefore, the EDD must be provided in the EQuIS EFWEDD four-file format (Sample, Test, Result, Batch).

  Upon receipt, the data packages will be examined to ensure that the correct analyses requested on the COC were performed for each sample submitted. If discrepancies are noted, the Quality Assurance Coordinator will be notified and will promptly follow up with the laboratory to resolve any issues.

  The data packages will be validated in accordance with the procedures presented in this SAP/QAPP. Data that do not meet the specified standards will be flagged pending resolution of the issue. The flag will not be removed from the data until the issue associated with the sample results is resolved. Although flags may remain for certain data, the use of that data may not necessarily be restricted.

  Data reports for all parameters will include, at a minimum, the following items:

  - Narrative: The narrative includes a summary of activities that took place during sample analysis, including the following information:
    - Laboratory name and address;
    - Date of sample receipt;
    - Cross-reference of laboratory identification number to sample identification;
    - Analytical methods used;
    - Deviations from specified protocol; and
    - Corrective actions taken.

  The narrative will also contain any sample handling documents, including field and internal COC forms, air bills, and shipping tags.

  - Analytical Results: Analytical results will include the following information, as applicable:
    - Sample identification number;
    - Laboratory identification number;
    - Date of collection;
    - Date of receipt;
    - Date of extraction;
    - Date of analysis;
    - Dilution factor; and
    - Detection limits.

  Sample results on the report forms will be corrected for dilutions. Soil samples will be reported on a dry weight basis. All results will be reported uncorrected for blank contamination.

The analytical reports will be expanded to include all supporting documentation necessary to provide a full data package. This additional documentation will include, at a minimum, all raw data required to recalculate any result, including printouts, chromatograms, and quantitation reports; standards used in calibration and calculation of analytical results; sample extraction, digestion, and other preparation logs; standard preparation logs; and instrument run logs.

3 Data Generation and Acquisition

3.1 Sampling Process Design

Previous investigations have identified impacted soil and groundwater at the BNSF Property.

- Groundwater sampling will include the sampling of monitoring wells, both temporary and permanent, for analysis of TPH (GRO, DRO, HO), benzene, toluene, ethylbenzene, and total xylenes (BTEX), CVOCs (1,2-dichloroethane (EDC), 1,1-dichloroethene (1,1-DCE), cis-1,2-DCE, trans-1,2-DCE, tetrachloroethene (PCE), TCE, and VC), and PCP. Total and dissolved iron, total and dissolved manganese, nitrate, sulfate, and TOC will also be evaluated in the Perched WBZ and Shallow WBZ to evaluate biodegradation and natural source zone depletion in groundwater. The groundwater sampling plan for quarterly groundwater sampling is provided in Table 5, and the temporary well sampling plan is provided in Table 6.
- Soil sampling will include soil collection for analysis of TPH (GRO, DRO, and HO), BTEX, EDC, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, PCE, TCE, VC, and PCP (Table 6). In addition, select soil samples will be analyzed for fraction of organic carbon and vertical permeability (Table 6).

3.2 Sampling Methods

Arcadis will collect all required samples. Appropriate Technical Guidance Instructions (TGIs) and SOPs will be reviewed prior to sample collection to ensure that samples are collected in accordance with the project requirements (Tables 5 and 6).

Field activities will be performed in accordance with Arcadis TGIs and SOPs (copies included in Appendix D of the RIWP). General procedures include:

- Sample Chain of Custody, Arcadis SOP, Revision 2, April 2020;
- Groundwater and Soil Sampling Equipment Decontamination, Arcadis TGI, Revision 2, June 14, 2022; and
- Investigation-Derived Waste Handling and Storage, Arcadis TGI, Revision 1, May 15, 2020.

Groundwater will be sampled in accordance with established Arcadis TGIs (copies included in Appendix D of the RIWP). Applicable procedures include:

- Manual Water-Level and NAPL Monitoring, Arcadis TGI, Revision 2, April 5, 2022;
- Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells, Arcadis TGI, Revision 2, April 5, 2022;
- Monitoring Well Development, Arcadis TGI, Revision 1, April 12, 2022;
- Monitoring Well Installation, Arcadis TGI, Revision 1, June 23, 2022; and
- Solid Slug Testing, Arcadis TGI, Revision 5, April 28, 2022; and
- Low Flow Steady State Drawdown Testing, Revision 0, March 16, 2022.

Soil will be sampled in accordance with established Arcadis TGIs (copy included in Appendix D of the RIWP). Applicable procedures include:

- Soil Drilling and Sample Collection, Arcadis TGI, Revision 2, April 8, 2022; and

- Soil Description, Arcadis TGI, Revision 4, June, 13, 2022.

Investigation-derived wastes (IDW) include purge water, decontamination water, drill cuttings, sampling supplies, and personal protective equipment generated during sampling activities. The intent of managing IDW is to ensure that impacted materials and media are not allowed to contaminate non-impacted materials and media. Where necessary to promote the safe, efficient, and environmentally protective performance of work, IDW will be managed consistent with the Arcadis TGI Investigation-Derived Waste Handling and Storage, Revision 1, May 15, 2020. Disposable equipment (including used personal protective equipment) will be containerized, appropriately labeled during the sampling events, and disposed of accordingly. Equipment will be decontaminated, as appropriate.

3.3 Sample Handling and Custody

3.3.1 Sample Containers and Preservation

Appropriate sample containers, preservation methods, and laboratory holding times for the samples are shown in Table 4.

The analytical laboratory will supply appropriate sample containers and preservatives, as necessary. The bottles will be purchased pre-cleaned to USEPA Office of Solid Waste and Emergency Response Directive 9240.05A requirements. Certificates of analysis for each lot of sample containers will be maintained by the laboratory and will be available upon request. The field personnel will be responsible for properly labeling containers and preserving samples, as appropriate.

3.3.2 Field Custody Procedures

The sampling team will maintain overall responsibility for the care and custody of the samples until they are transferred or properly dispatched to the laboratory. The objective of field sample custody is to ensure that samples are not tampered or modified from the time of collection through transport and transfer to the analytical laboratory. Persons will have “custody of samples” when the samples are in their physical possession, in their view after being in their possession, or in their physical possession and secured so they cannot be tampered with. In addition, when samples are secured in a restricted area accessible only to authorized personnel, they will be deemed to be in the custody of such authorized personnel.

- Field Logbooks. Field logbooks will provide the means of recording the data collecting activities performed. As such, entries will be described in as much detail as possible so that persons going to the site could reconstruct a particular situation without reliance on memory. Field logbooks will be bound field survey books or notebooks and have numbered, water-resistant pages. Entries will be made in ink, with no erasures. If an incorrect entry is made, the information will be crossed out with a single strike mark and initialed by the person making the correction.

  Recorded information typically includes, but may not be limited to the following:

  - Name and location of site;
  - Date and time of arrival and departure;
  - Name and signature of person keeping log;
  - Names of all persons onsite;

  - Purpose of visit;
  - Level of personal protection equipment used;
  - Field instrument identification and calibration information;
  - Location of sampling points;
  - Results of field measurements made;
  - Number of samples taken, volume of samples taken;
  - Preservation;
  - Method of sample collection and any factors that may affect its quality;
  - Name of sample collector;
  - All sample identification numbers (assigned prior to sample collection);
  - Description of samples, including, as applicable, depth at which the sample was collected;
  - Weather conditions on the day of sampling and any field observations; and
  - Number and description of photographs taken, if any.
- <u>Sample Labeling.</u> Sample labels are an important part of proper documentation because their use reduces the possibility of confusing sample containers and provides the information necessary during handling to complete COC forms. The following information is required on each sample label:
  - Site name or location;
  - Date and time collected;
  - Sample identification number;
  - Sampler’s initials;
  - Parameter sampled; and
  - Preservative.

  When possible, preprinted sample labels (i.e., preprinted with items noted above except date and time collected) will be affixed to sample bottles prior to delivery at the sampling site, and the labels themselves will be protected from the sample matrix with a clear tape covering.
- <u>Field COC Forms.</u> The COC form is intended as a legal record of possession of the sample. Completed COC forms will be required for all samples to be analyzed. COC forms will be initiated by the sampling crew in the field. The COC forms will contain the sample’s unique identification number, sample date and time, sample description, sample type, preservation (if any), and analyses required. The original COC form will accompany the samples to the laboratory. Copies of the COC will be made prior to shipment (or multiple-copy forms will be used) and placed in the project files. The COC forms will remain with the samples at all times. The samples and signed COC forms will remain in the possession of the sampling crew until the samples are delivered to the express carrier (e.g., Federal Express), hand delivered to the laboratory, picked up by a laboratory courier, or placed in secure storage.
- <u>Sample Custody Seals.</u> Custody seals are narrow strips of adhesive paper or glass fiber used to demonstrate that no tampering of the shipping container has occurred. The custody seals will be signed and dated by the sampling crew and placed across the opening of the lid and body of the shipping containers and at least on one side and the front of the container. These custody seals shall be plainly visible.

3.3.3 Packing, Handling, and Shipping Requirements

All shipping or sample transfer information will be recorded at the end of each day or collection period on COC forms. Sample packaging and shipment procedures are designed so that the samples will arrive at the laboratory with the COC intact.

It is imperative that all samples are submitted to the laboratory with ample time for the analysis to be completed within the method-specified holding time. It should be noted that the laboratory needs to be aware that missing a holding time is unacceptable and may result in unusable data if the holding time is missed.

General sample packaging and shipping requirements for COPC analyses are as follows:

- Securely affix the sample label to the container with clear packing tape.
- Check the cap on the sample container to confirm that it is properly sealed.
- Complete the COC form with the required sampling information and confirm that the recorded information matches the sample labels. NOTE: If the designated sampler relinquishes the samples to other sampling or field personnel for packing or other purposes, the sampler will complete the COC prior to this transfer. The appropriate personnel will sign and date the COC form to document the sample custody transfer.
- Using duct tape, secure the outside drain plug at the bottom of the cooler.
- Wrap glass sample containers in bubble wrap or other cushioning material.
- Place 1 to 2 inches of cushioning material at the bottom of the cooler.
- Place the sealed sample containers into the cooler.
- Put ice in double-bagged heavy duty plastic bags (i.e., place sealed bag containing ice into a second bag that is also sealed). Double-bagging the ice is intended to contain any melted water. Place the bagged ice on top of and/or between the samples to ensure uniform cooling of the samples.
- Fill the remaining space in the cooler with cushioning material.
- Place COC forms in a plastic bag and seal. Tape the forms to the inside of the cooler lid.
- Close the lid of the cooler and secure with duct tape.
- Wrap strapping tape (or equivalent) around both ends of the cooler at least twice.
- Mark the cooler on the outside with the shipping address and return address, affix “Fragile” labels, and draw (or affix) arrows indicating “this side up.” Cover the labels with clear plastic tape. Place a signed custody seal over the cooler lid. NOTE: If the samples are being delivered directly to the laboratory or will be picked up by the laboratory’s courier service, this step is eliminated.

Samples will be packaged by field personnel and transported as low-concentration environmental samples. The samples will be hand-delivered or delivered by an express carrier within 48 hours of the time of collection. In some cases, the analytical method may require analysis within a shorter holding time, and arrangements will need to be made to accommodate the laboratory requirements. Shipments will be accompanied by the COC form identifying the contents. The original form will accompany the shipment; copies will be retained by the sampler for the sampling office records. If the samples are sent by common carrier, a bill of lading will be used. Receipts or bills of lading will be retained as part of the permanent project documentation. Commercial carriers are not required to sign off on the COC form as long as the forms are sealed inside the sample cooler, and the custody seals remain intact.

Custody seals and cooler packing materials will be provided by the analytical laboratory. The filled, labeled, and sealed containers will be placed in a cooler on ice and carefully packed to eliminate the possibility of container breakage. Trip blanks of analyte-free water will be provided by the laboratory and included in each cooler containing samples to be analyzed for VOCs.

3.3.4 Laboratory Custody Procedures

Upon sample receipt, laboratory personnel will be responsible for sample custody. The original field COC form will accompany all samples requiring laboratory analysis. Samples will be kept secured in the laboratory until all stages of analysis are complete. All laboratory personnel having samples in their custody will be responsible for documenting and maintaining sample integrity.

- Sample Receipt and Storage. Upon sample receipt, the laboratory sample custodian will verify the package seal, open the package, verify the sample integrity, and compare the contents against the field COC. If a sample container is broken, the sample is in an inappropriate container or has not been preserved by appropriate means, or if there is a discrepancy between the COC and the sample shipment, Arcadis will be notified. The laboratory sample custodian will then log the samples in, assign a unique laboratory identification number to each, and label the sample bottle with the laboratory identification number. The project name, field sample code, date sampled, date received, analysis required, storage location and date, and action for final disposition will be recorded in the laboratory tracking system.
- Sample Analysis. Analysis of an acceptable sample will be initiated by a work sheet that will contain pertinent information for analysis. The analyst will sign and date the laboratory COC form when removing the samples from storage. Samples will be organized into sample delivery groups by the laboratory.
- Sample Storage Following Analysis. The remaining sample volume and extracts/digestates, if any, will be maintained by the laboratory for one month after the final report is delivered to Arcadis. After this period, the samples will be disposed of in accordance with applicable rules and regulations.

3.4 Analytical Methods

3.4.1 Field Analytical Procedures

Field analytical procedures may include the monitoring of VOCs using a photoionization detector and the measurement of water quality parameters during groundwater sampling tasks. Water quality parameters will include pH, specific conductance, oxidation reduction potential, dissolved oxygen, temperature, and turbidity. Samples will be analyzed using a multi-parameter water quality instrument equipped with a flow-through cell.

3.4.2 Laboratory Parameters and Methods

Laboratory analytical requirements presented in the sub-sections below include a general summary of requirements, specifics related to each sample medium to be analyzed, and details of the methods to be used for this project. Current approved methods will be used for all applicable parameters and sample media.

The following tables (attached at the end of this SAP/QAPP) summarize general analytical requirements:

- Table 1a: Parameters, Methods, and Target Quantitation Limits (Groundwater);

- Table 1b: Parameters, Methods, and Target Quantitation Limits (Soil)
- Table 2: Sample Quantities and Quality Control Frequencies
- Table 3: Laboratory Quality Control Limits; and
- Table 4: Sample Containers, Preservation, and Holding Times.

Laboratory analytical SOPs are provided in Attachment 1 of this document. The SOPs are based on the methodology requirements promulgated in:

- USEPA Test Methods for Evaluation Solid Waste, Physical/Chemical Methods, EPA Publication SW-846, Third Edition, Final Updates (USEPA 1993b);
- Ecology Analytical Methods for Petroleum Hydrocarbons, Publication No. ECY 97-602, June 1997 (Ecology 1997); and
- USEPA Method 300.0 Determination of Inorganic Anions by Ion Chromatography, Revision 2.1, August 1993 (USEPA 1993a).

3.5 Quality Control

3.5.1 Field Quality Control Checks

- Field Measurements. To verify the quality of data using field instrumentation, duplicate measurements will be obtained and reported for all field measurements. A duplicate measurement will involve obtaining measurements a second time at the same sampling location.
- Sample Containers. New, certified, clean sample containers will be supplied by the laboratory.
- Field Duplicates. Field duplicates will be collected to evaluate precision and sample homogeneity, and to verify the reproducibility of the sampling methods. Field duplicates are two separate samples collected from the same sampling location in the field and submitted to the laboratory as two distinct samples. In general, field duplicates will be collected at a 5% frequency (i.e., one field duplicate for every 20 samples collected) and submitted blind to the laboratory. Table 2 provides an estimated number of field duplicates to be prepared for each applicable parameter and matrix.
- Equipment Rinse Blanks. Equipment rinse blanks are used to monitor the cleanliness of the sampling equipment and the effectiveness of the cleaning procedures. Rinse blanks will be prepared and submitted for analysis at a frequency of 1 per day or once for every 20 samples collected, whichever is more frequent, when reusable sample equipment cleaning occurs. When dedicated sampling devices are used or sample containers are used to collect the samples, rinse blanks will not be necessary. Rinse blanks will be prepared by filling sample containers with analyte-free water (supplied by the laboratory), which has been poured over or routed through decontaminated field sampling equipment before the collection of environmental samples. Table 2 provides an estimated number of rinse blanks collected during the investigation activities.
- Trip Blanks. Trip blanks will be used to assess whether site samples have been exposed to non-site-related VOCs during field handling procedures and shipping. Trip blanks will be analyzed at a frequency of once per day, per cooler containing samples to be analyzed for VOCs. A trip blank will consist of a VOC vial that has been filled with analyte-free water (supplied by the laboratory), taken to the sampling site, and transported back to the laboratory without having been exposed to sampling procedures. Table 2 provides an estimated number of trip blanks collected for each matrix and parameter during the investigation activities.

- Temperature Blanks. A temperature blank will be included in each sample cooler and will be used to determine whether samples have been adequately cooled during shipment and storage. Temperature blanks will be prepared by adding water to a sample container. The temperature of the water in this container will be measured upon receipt by the analytical laboratory. Note that the laboratory will not use a field sample intended to be analyzed as the temperature blank.

3.5.2 Analytical Laboratory Quality Control Checks

Internal laboratory QC checks will be used to monitor data integrity and to document the validity of the generated data. The checks reveal information about sampling technique, analyst technique, instrument capability, possible sources of contamination, precision of the results, and difficulties with the matrix. These checks will include method blanks, LCS, MS/MSD, laboratory duplicates, internal standards, and surrogate samples. Advisory quality control limits are identified in Table 3.

- Calibration Verification. Initial calibration of instruments will be performed as required in the method and when any ongoing calibration does not meet control criteria. The number of points used in the initial calibration is defined in each analytical method. Ongoing calibration verification will be performed as specified in the analytical methods to monitor instrument performance. If an ongoing calibration does not meet control limits, analysis of samples will be suspended until the source of the control failure is either eliminated or reduced to within control specifications. Any samples analyzed while the instrument was out of control will be reanalyzed.
- Method Blanks. Sources of contamination in the analytical process, whether specific analyses or interferences, must be identified, isolated, and corrected. A method blank is an “analyte-free” matrix that is treated exactly as the sample, including exposure to all glassware, equipment solvents, reagents, labeled compounds, internal standards, and surrogates that are used with sample. The method blank is useful in identifying possible sources of contamination within the analytical process (i.e., laboratory environment, reagents, or apparatus). For this reason, it is necessary that the method blank be initiated at the beginning of the analytical process and encompass all aspects of the analytical work. One method blank will be analyzed with each analytical series associated with no more than 20 samples. Blank corrections will not be applied to the original data by the laboratory.
- MS/MSDs. An MS is an aliquot of an environmental sample to which known quantities of target analytes are added in the laboratory. An MSD is a second aliquot of the sample that is also spiked with identical concentrations of target analytes. The MS and MSD are analyzed in an identical manner as the sample. The purpose of a MS is to determine the accuracy of the overall analytical procedure for determining the analytes of concern in the sample. The MSD analysis is used to document both the precision and accuracy of the method in a sample matrix.

  To get the true benefit from MS and MSD analyses, it is necessary that the sample come from the project site so that it is possible to ascertain if the matrix itself is contributing to analytical difficulties or outliers. MS/MSD pairs will be analyzed at a 5% frequency (i.e., additional sample volume for MS and MSD analysis will be collected for every 20 field samples collected per matrix). When MS recoveries are outside QC limits, associated LCS and surrogate spike recoveries will be evaluated, as applicable, to attempt to verify the reason for the deviation and determine the effect on the reported sample results. Table 2 presents an estimated number of MS and MSD analyses for each applicable parameter.

- Laboratory Duplicates. Laboratory duplicates assess laboratory precision. Laboratory duplicates are defined as a separate aliquot of an individual sample that is analyzed as a separate sample. Table 2 presents an estimated number of laboratory duplicates for each applicable parameter.
- Laboratory Control Samples. An LCS is a blank matrix, free from the analytes of interest, spiked with verified known amounts of analytes created from a source other than that used to make up calibration standards. The LCS is carried through the analysis along with the samples. The intent of LCS analysis is to provide insight into the intra-laboratory or analyst specific accuracy and bias or to assess the performance of all or a portion of the measurement system. This includes the preparation of calibration standards, validity of calibration, sample preparation, instrument set-up, and the premises inherent in quantitation. One LCS will be analyzed with each analytical series associated with not more than 20 samples.

  A laboratory control sample duplicate (LCSD) is an additional replicate of the LCS. When the LCSD is analyzed in addition to the LCS, the precision and accuracy of the analytical process can be monitored. An LCSD may be analyzed by the laboratory if sufficient sample volume is not available in an analytical batch to perform MS/MSD or laboratory duplicate analysis in order to assess analytical precision and reproducibility.
- Surrogate Spikes. A surrogate spike is an organic non-target analyte that is unlikely to occur under natural conditions but that has similar chemical properties to the analytes of interest. The surrogate standard is added to the sample in a known amount, prior to purging or extraction, and is used to evaluate the response of the analyte to the preparation and analysis procedures. The surrogate concentration is measured using the same procedures used to measure other analytes in the sample. The surrogate spike is used to provide broader insight into the proficiency and efficiency of an analytical method on a sample-specific basis. This control reflects analytical conditions that may not be attributable to sample matrix.

  If surrogate spike recoveries exceed specified QC limits, the analytical results must be evaluated thoroughly in conjunction with other control measures. In the absence of other control measures, the integrity of the data may not be verifiable, and reanalysis of the samples with additional control may be necessary.

  Surrogate spike compounds will be selected using the guidance provided in the analytical methods and will be added to all field samples and laboratory quality control samples.
- Internal Standards. Internal standard areas and retention times will be monitored for organic analyses performed by gas chromatography/mass spectrometry (GC/MS) methods. Method-specified internal standard compounds will be spiked into all field samples, calibration standards, and quality control samples after preparation and prior to analysis. If internal standard areas in one or more samples exceed the specified tolerances, the cause will be investigated; the instrument will be recalibrated, if necessary; and all affected samples may be re-analyzed.

  The acceptability of internal standard performance will be determined using the guidance provided within the analytical methods.

3.5.3 Data Precision Assessment Procedures

Field precision is difficult to measure because of temporal variations in field parameters. However, precision will be controlled using experienced field personnel, properly calibrated meters, and duplicate field measurements. Field duplicates will be used to assess precision for the entire measurement system, including sampling, handling, shipping, storage, preparation, and analysis.

Analytical precision will be evaluated by calculating the RPD for field duplicates, laboratory duplicates, and MS/MSD samples, as follows:

$$RPD = \frac{abs(D1 - D2)}{\frac{(D1 + D2)}{2}} x\ 100$$

Where: abs = absolute value

RPD = relative percent difference

D1 = sample value

D2 = duplicate sample value

Acceptance criteria for laboratory and field precision are specified in Table 3.

3.5.4 Data Accuracy Assessment Procedures

The accuracy of field measurements will be controlled by employing experienced field personnel, using properly calibrated field meters, and adhering to established protocols. The accuracy of field meters will be assessed by review of calibration and maintenance logs.

Laboratory accuracy will be assessed by evaluating the results of spiked samples (i.e., MS/MSD, surrogate spikes, and LCS) for percent recovery (%R). %R will be calculated as follows:

$$REC = \frac{A - X}{B}\ x\ 100$$

Where: A = value measured in spiked sample or standard

X = value measured in original sample

B = amount added to sample or true value of the standard

Acceptance criteria for MS/MSD, surrogate spikes, and LCS are specified in Table 3. Note that the limits were provided by the laboratory at the time this SAP/QAPP was written. Acceptance limits are updated periodically by the laboratory, and the QC sample result will be compared to the current laboratory limits provided in the analytical data report on an analyte-by-analyte basis.

3.5.5 Data Representativeness Assessment Procedures

Representativeness will be assessed by examining sample preservation and the results of the precision and accuracy evaluation, and by adhering to method holding time. Failure of the field or laboratory personnel to properly handle samples may result in qualification of the data as estimated or unusable. The use of laboratory data from a sample with a failed holding time could render the data unusable; in particular, for VOC analysis there is a potential for loss of compounds, and the concentration may be biased low. The representativeness review will qualitatively consider whether precision and/or accuracy is sufficient to characterize the representativeness of the samples.

3.5.6 Blank Sample Assessment Procedures

Blank samples will be used to determine the existence and magnitude of contamination resulting from laboratory or field activities. The method blank is used as a check on laboratory procedures as well as possible contamination from laboratory equipment (e.g., reagents, glassware). Equipment blanks are collected in the field from the sampling equipment to check for possible residual contamination and assess potential cross-contamination during sampling tasks. Trip blanks determine the integrity of the sample container for loss or addition of analytes due to handling and transport. Detections in any blank samples will be used to qualify similar detections in associated field samples.

3.5.7 Data Completeness Assessment Procedures

Completeness of a field or laboratory data set will be calculated by comparing the number of usable measurements (i.e., all measurements except rejected data) actually obtained to the total number of usable measurements that were planned.

$$Completeness = \frac{usable\ data\ points\ obtained}{total\ data\ points\ obtained}\ x\ 100$$

As a general guideline, overall project completeness is expected to be at least 90 percent. The assessment of completeness will require professional judgment to determine data usability for the intended purposes.

3.5.8 Data Comparability Assessment Procedures

Comparability will be assessed by evaluating whether samples were collected in a manner similar to previous sampling events and analytes using analytical methodology similar to previous events.

3.5.9 Sensitivity Assessment Procedures

Sensitivity is related to the RL. In general, RLs should be less than the applicable standard. Analytical results for samples that are reported as non-detected for a particular analyte that have RLs greater than the applicable standard cannot be used to demonstrate compliance with the applicable standard. Samples that are contaminated with sufficient quantity of material, such that dilutions are performed, are a leading cause of RLs exceeding applicable criteria. However, there may be instances where such exceedances are insignificant relative to the site-specific DQOs. The sensitivity review will qualitatively consider whether the RLs are sufficiently low to compare analytical results to the applicable standards, with consideration of the project DQOs.

3.6 Instrument/Equipment Testing, Inspection, and Maintenance

Preventive maintenance schedules have been developed for both field and laboratory instruments. A summary of the maintenance activities to be performed is presented below.

3.6.1 Field Instruments and Equipment

Prior to any field sampling, each piece of field equipment will be inspected to confirm that it is operational. If the equipment is not operational, it must be serviced prior to use. All meters that require charging will be fully charged or have fresh batteries. If instrument servicing is required, it is the responsibility of the Field Sampling Manager to follow the maintenance schedule and arrange for prompt service.

Logbooks will be kept for each field instrument. Logbooks will contain records of operation, maintenance, calibration and any problems and repairs. Logbooks for each piece of equipment will be maintained in project records.

Field equipment returned from a site will be inspected to confirm it is in working order. This inspection will be recorded in the logbook or field notebooks, as appropriate. It will also be the obligation of the last user to record any equipment problems in the logbook.

Non-operational field equipment will be either repaired or replaced. Appropriate spare parts for field equipment/meters will be available from the rental companies or manufacturers. Arcadis- or subcontractor-owned or -leased equipment will be maintained in accordance with the manufacturer’s instructions.

3.6.2 Laboratory Instruments and Equipment

Laboratory instrument and equipment documentation procedures include details of any observed problems, corrective measure(s), routine maintenance, and instrument repair (including information regarding the repair and the individual who performed the repair).

Preventive maintenance of laboratory equipment generally will follow the guidelines recommended by the manufacturer. A malfunctioning instrument will be repaired immediately by in-house staff or through a service call from the manufacturer.

Maintenance schedules for laboratory equipment adhere to each manufacturer's recommendations. Records reflect the complete history of each instrument and specify the time frame for future maintenance. Major repairs or maintenance procedures are performed through service contracts with the manufacturer or qualified contractors. Paperwork associated with service calls and preventive maintenance calls will be kept on file by the laboratory.

Laboratory Systems Managers are responsible for the routine maintenance of instruments used in the laboratory. Any routine preventive maintenance carried out is logged into the appropriate logbooks. The frequency of routine maintenance is dictated by the nature of samples being analyzed, the requirements of the method used, and/or the judgment of the Laboratory Systems Manager.

All major instruments are backed up by comparable (if not equivalent) instrument systems in the event of unscheduled downtime. An inventory of spare parts is also available to minimize equipment/instrument downtime.

The operation of balances, incubators, ovens, refrigerators, and water purification systems will be checked and documented daily. Any discrepancies will be immediately reported to the appropriate laboratory personnel for resolution.

3.7 Instrument/Equipment Calibration and Frequency

3.7.1 Field Equipment Calibration Procedures and Frequency

Calibration checks of field equipment will be performed daily when used. Field equipment operation, calibration, and maintenance procedures are provided in the equipment operation manuals.

3.7.2 Laboratory Equipment Calibration Procedures and Frequency

Instrument calibration will follow the specifications provided by the instrument manufacturer or specific analytical method used. The analytical methods for chemical constituents are identified in Tables 1a and 1b.

When analyses are conducted according to USEPA methods, the calibration procedures and frequencies specified in the applicable method will be followed. Records of calibrations will be filed and maintained by the laboratory. These records will be subject to QA audit. For all instruments, the laboratory will maintain trained repair staff with in-house spare parts or will maintain service contracts with vendors.

All standards used to calibrate equipment are traceable, directly or indirectly, to the National Institute of Standards and Technology. All standards received will be logged into standard receipt logs maintained by the individual analytical groups. Each group will maintain a standards log that tracks the preparation of standards used for calibration and QC purposes.

3.8 Inspection/Acceptance of Supplies and Consumables

All supplies to be used in the field and laboratory will be available when needed. They will be free of target chemicals and interferences. All reagents will be tested prior to use in the laboratory. All standards will be verified against a second source standard. The laboratory will follow a “first in/first out” procedure for the storage and use of all consumables to minimize the risk of contamination and degradation.

3.9 Non-direct Measurements

Non-direct measurements will not be used on this project.

3.10 Data Management

The purpose of data management is to provide for the accuracy and ready accessibility of all necessary data to meet the analytical and reporting objectives of the project. The data management program established for the project includes field documentation and sample QA/QC procedures, methods for tracking and managing the data, and a system for filing all site-related information. More specifically, data management procedures will be employed to efficiently process the information collected such that the data are readily accessible and accurate. These procedures are described in detail in the following section.

The data management plan has three elements: (1) sample designation system; (2) field activities; and (3) data management system.

3.10.1 Sample Designation System

A concise and easily understandable sample designation system is an important part of the project sampling activities. It provides a unique sample number that will facilitate both sample tracking and easy resampling of select locations to evaluate data gaps, if necessary. The sample designation system to be employed during the sampling activities will be consistent yet flexible enough to accommodate unforeseen sampling events or conditions. A combination of letters and numbers will be used to yield a unique sample number for each field sample collected. The sample designation system is described in more detail in Section 2.7.1.

3.10.2 Field Activities

Field activities designed to gather the information necessary to make decisions require consistent documentation and accurate record keeping. During site activities, standardized procedures will be used for documenting field activities, data security, and QA. These procedures are described in further detail in the following subsections.

- Field Documentation. Complete and accurate record keeping is a critical component of the field activities. When interpreting analytical results and identifying data trends, investigators realize that field notes are an important part of the review and validation process. To confirm that all aspects of the field investigation are thoroughly documented, several different information records, each with its own specific reporting requirements, will be maintained, including field logs, instrument calibration records, and COC forms. A description of each of these types of field document is provided in other sections of this SAP/QAPP.
- Data Security. Measures will be taken during the field investigation to prevent samples and records from being lost, damaged, or altered. When not in use, all field notebooks will be in the possession of project personnel. Access to these files will be limited to the field personnel who use them.
- Sample Tracking and Management. A record of all field documentation will be maintained to provide verification of the validity of data used in the site analysis. To effectively execute such documentation, carefully constructed sample tracking and data management procedures will be used throughout the sampling program.

  Sample tracking will begin with the completion of COC forms. Copies of all completed COC forms will be maintained in the field office. The laboratory will verify receipt of the samples electronically (via email) on the following day.

  When analytical data are received from the laboratory, the incoming analytical data packages will be reviewed against the information on the COC to confirm that the correct analyses were performed for each sample and that results for all samples submitted for analysis were received. Any discrepancies noted will be promptly followed up with the laboratory.

3.10.3 Data Management System

In addition to the sample tracking system, a data management system will be implemented. The central focus of the data management system will be the development of a personal computer-based project database. The project database will combine pertinent geographical, field, and analytical data. Information that will be used to populate the database will be derived from surveys of sampling locations, field observations, and analytical results. Each of these sources is discussed in the following sections.

- Field Observations. An important part of the information that will ultimately reside in the data management system for use during the project will originate with observations that are recorded in the field logbook.

  The field logbook will include the locations sampled, the sampling methodologies used, QA/QC procedures, sample identification numbers, equipment decontamination procedures, personnel involved in the activity, and any other noteworthy events that occurred.

  Field logbooks are valuable tools to keep project personnel informed on the details of the field activities and are also invaluable during the development of the required reports. Each field logbook will be reviewed for accuracy and completeness by the respective sampling activity manager. As appropriate, information included in the field logbook will be used to transfer field observations into the data management system.

- Analytical Results. Analytical results will be provided by the laboratory in digital format. The data packages will be examined to confirm that the correct analyses were performed for each sample submitted and that all the analyses requested on the COC form were performed. If discrepancies are noted, the laboratory will be contacted to resolve any issues.

  Each data package will be validated. Any data that do not meet the specified standards will be flagged pending resolution of the issue. The flag will not be removed from the data until the issue associated with the sample results is resolved. Although flags may remain for certain data, the use of those data may not necessarily be restricted.

  The individual EDDs, supplied by the laboratory in EQuIS four-file format, will be loaded into the appropriate database. Any analytical data that cannot be provided by the laboratory in electronic format will be entered manually. After entry into the database, the EDD data will be compared to the field information previously entered into the database to confirm that all requested analytical data have been received. Validated data will be uploaded to the Ecology Environmental Information Management System (EIM) in accordance with Washington Administrative Code 173-340-840(5) and Ecology's Toxics Cleanup Program Policy 840: Data Submittal Requirements. Data will be entered into the EIM database within 45 days of data validation completion (Ecology 2021).

- Data Analysis and Reporting. A valuable function of the data management system will be the manual generation of tables of analytical results during report preparation. Tables of analytical data will be produced as part of data interpretation and reporting tasks and will include a comparison of the analytical results to the applicable investigation standards.

4 Assessment and Oversight

4.1 Assessment and Response Actions

Performance and systems audits will be completed in the field and the laboratory during the sampling, as described below.

4.1.1 Field Audits

The Arcadis TM will monitor field performance. Field performance audit summaries will contain an evaluation of field activities to verify that the activities are performed according to established protocols. Field performance audits may be performed by Arcadis, Ecology, or BNSF. The auditor(s) will review field reports and communicate concerns, as appropriate. The observations made during field performance audits and any recommended changes/deviations to the field procedures will be recorded and documented.

In addition, systems audits comparing scheduled QA/QC activities from this SAP/QAPP with actual QA/QC activities completed will be performed. The PM and Project Chemist may periodically confirm that work is being performed consistent with this SAP/QAPP.

4.1.2 Laboratory Audits

Internal audits are conducted by the laboratory consistent with their Quality Systems Manual. As part of the audit, the overall performance of the laboratory staff is evaluated and compared to the performance criteria outlined in the laboratory Quality Systems Manual and SOPs. The results of the audits are summarized and issued to each department supervisor, the laboratory manager, and the laboratory director. A systems audit of each laboratory may be performed by the Arcadis Project Chemist to determine whether the procedures implemented by each laboratory are following the Quality Systems Manual and SOPs.

As a participant in state and federal certification programs, the laboratory is audited by representatives of the regulatory agency issuing certification. Audits are usually conducted on an annual basis and focus on laboratory conformance to the specific program protocols for which the laboratory is seeking certification. The auditor reviews sample handling and tracking documentation, analytical methodologies, analytical supportive documentation, and final reports. The audit findings are formally documented and submitted to the laboratory for corrective action, if necessary.

4.1.3 Corrective Action

Corrective actions are required when field or analytical data are not within the objectives specified in this SAP/QAPP. Corrective actions include procedures to promptly investigate, document, evaluate, and correct data collection and/or analytical procedures. Field and laboratory corrective action procedures for the assessment are described below.

- Field Procedures. If during field work, a condition is noted by the field crew that would have an adverse effect on data quality, corrective action will be taken so as not to repeat this condition. Condition identification, cause, and the corrective action implemented will be documented on a Corrective Action Form. The PM or their designee will be responsible for follow-up and acceptance of corrective actions. Project personnel will continuously monitor ongoing work performance in the normal course of daily responsibilities. Examples of situations that would require corrective actions are provided below:

  - Protocols as defined by the SAP/QAPP have not been followed;
  - Equipment is not in proper working order or properly calibrated;
  - QC requirements have not been met; and/or
  - Issues resulting from performance or systems audits have not been addressed.

  The required corrective actions for these field-related conditions may include stopping work until the condition has been corrected, retraining field staff in the procedures included in the SAP/QAPP, discontinuing use of a piece of field equipment until a replacement unit can be obtained or the equipment can be properly calibrated, or recollecting samples in the event that the issue is deemed to result in unusable data.

- <u>Laboratory Procedures.</u> In the laboratory, when a condition is noted to have an adverse effect on data quality, corrective action will be taken so as not to repeat this condition. Condition identification, cause, and corrective action to be taken will be documented and reported to Arcadis. Corrective action may be initiated, at a minimum, under the following conditions:

  - Protocols as defined by this SAP/QAPP have not been followed;
  - Predetermined data acceptance standards have not been obtained;
  - Equipment is not in proper working order or calibrated;
  - Sample and test results are not completely traceable;
  - QC requirements have not been met; and/or
  - Issues resulting from performance or systems audits have not been addressed.

  Laboratory personnel will continuously monitor ongoing work performance in the normal course of their daily responsibilities. Corrective action will be initiated upon identification of the problem. At whatever level this occurs (analyst, supervisor, data review, or QC), it will be brought to the attention of the Laboratory QA Manager and, ultimately, the Laboratory Director. Final approval of any action deemed necessary is subject to the approval of the Laboratory Director.

  Corrective action deemed necessary based on system or performance audits, the analytical results of split samples, or the results of data review will be implemented. The corrective action may include sample re-extraction, re-preparation, reanalysis, cleanup, dilution, matrix modification, or other activities deemed necessary to ensure usable analytical data.

4.2 Reports to Management

4.2.1 Internal Reporting

The analytical laboratory will submit analytical reports to Arcadis for data validation. Supporting data (e.g., historical data, related field, or laboratory data) will also be reviewed to evaluate data quality, as appropriate. Internal reporting will include the following:

- Assessment of data accuracy, precision, and completeness for both field and laboratory data;
- Results of the performance and systems audits;
- Significant QA/QC problems, solutions, corrections, and potential consequences; and

- Analytical data validation report.

4.2.2 Reporting

Project deliverables and the associated schedule are included in the RIWP.

5 Data Validation and Usability

After field and laboratory data are obtained, the data will be subject to the following:

- Review;
- Data validation;
- Reduction or manipulation, mathematically or otherwise, into meaningful and useful forms; and
- Organization, interpretation, and reporting.

5.1 Data Review, Verification, and Validation

5.1.1 Field Data Reduction

Information collected in the field through visual observation, manual measurement, and/or field instrumentation will be recorded in field notebooks, log sheets, and/or on forms. Such data will be reviewed for adherence to this SAP/QAPP and for consistency. Any concerns identified because of this review will be discussed with the field personnel, corrected if possible, and, as necessary, incorporated into the data evaluation process.

5.1.2 Field Data Review

Field data calculations, transfers, and interpretations will be conducted by the field personnel and reviewed for accuracy. Logs and documents will be checked for:

- General completeness;
- Readability;
- Usage of appropriate procedures;
- Appropriate instrument calibration and maintenance;
- Reasonableness in comparison to present and past data collected;
- Correct sampling locations; and
- Correct calculations and interpretations.

5.1.3 Field Data Reporting

Where appropriate, field data forms and calculations will be processed and included in appendices to the reports. The original field logs, documents, and data reductions will be kept in the project file.

5.1.4 Laboratory Data Reduction

The calculations used for data reduction will be in accordance with the analytical methods. Whenever possible, analytical data will be transferred directly from the instrument to a computerized data system. Raw data will be entered into permanently bound laboratory notebooks. The data entered must be sufficient to document all factors used to arrive at the reported value.

Concentration calculations for chromatographic analyses will be based on response factors. Quantitation will be performed using internal standards for GC/MS methodology. Concentration calculations for metals and wet chemistry, if appropriate, will be based on linear regression.

Unless otherwise specified, all values will be reported uncorrected for blank contamination

5.1.5 Laboratory Data Review

Data will be subject to multi-level review by the laboratory. The group leader will review all data reports prior to release for final data report generation. The QA Manager will review the final data reports, and the Laboratory Director will review a cross-section of the final data reports prior to release.

If discrepancies or deficiencies are present in the analytical results, corrective action will be taken. Deficiencies discovered as a result of internal data review, as well as the corrective actions to be used to rectify the situation, will be documented on a Corrective Action Form.

5.2 Verification and Validation Methods

Data validation is a standardized review process for judging the analytical quality and usefulness of a discrete set of chemical data and is necessary to ensure that data of known and documented quality are used in making environmental decisions that meet the DQOs of the site. Data validation is a systematic process that compares a body of data to the requirements in a set of documented acceptance criteria to ascertain its completeness, correctness, and consistency. Data validation will be performed by the Arcadis Project Chemist (or their designee). The data validation personnel will work independently from all other project teams within the organization of Arcadis. Data validators are not associated with the field staff involved in the collection of samples or end users (project team) preparing data reports for the client. Furthermore, the project chemistry group has previous work experience in a laboratory environment and is familiar with the analytical methods and data validation guidance.

Data will be validated using the USEPA National Functional Guidelines for Organic Superfund Methods Data Review, EPA 540-R-20-005, November 2020 (USEPA 2020b) (with reference to the historical USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review, OSWER 9240.1-05A-P, October 1999 [USEPA 1999], as appropriate) and USEPA National Functional Guidelines for Inorganic Superfund Methods Data Review, EPA 540-R-20-006, November 2020 (USEPA 2020a) (with reference to the historical USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-45, October 2004 [USEPA 2004], as appropriate). These procedures and criteria may be modified, as necessary, to address project-specific and method-specific criteria, control limits, and procedures. Data validation will consist of data screening, checking, reviewing, editing, and interpretation to document analytical data quality and determine whether the quality is sufficient to meet the DQOs.

The data validator will verify that laboratory reporting of analytical parameters is in accordance with the procedures specified for each analytical method and/or as specified in this SAP/QAPP. Any deviations from the analytical method or any special reporting requirement apart from those specified in this SAP/QAPP will be detailed on COC forms.

All chemical data will be reviewed with regard to the following, consistent with a Level II validation:

- COC/documentation;

- Sample preservation and holding times;
- Method blanks, rinsate blanks, and trip blanks
- Method reporting limits and reporting units;
- Surrogate recoveries;
- MS/MSD recoveries;
- LCS recoveries;
- Laboratory duplicate RPD; and
- Field duplicate RPD.

Anomalies identified during review must be investigated. When anomalies are identified, they will be discussed with the Project Manager and/or Laboratory Manager, as appropriate.

If data appear suspect, the specific data of concern must be investigated. Calculations will be traced back to raw data. If calculations do not agree, the cause will be determined and corrected.

It should be noted that qualified results may not necessarily invalidate data. The goal to produce the best possible data does not necessarily mean that data must be produced without QC qualifiers. Qualified data can provide useful information.

During the review process, laboratory-qualified and -unqualified data are verified against the supporting documentation. Based on this evaluation, qualifier codes may be added, deleted, or modified by the data reviewer. Results will be qualified with the following codes in accordance with the National Functional Guidelines:

Qualifier	Definition
Concentration Qualifiers (Laboratory Assigned)	
U	The analyte/compound was analyzed for but not detected. The associated value is the compound reporting limit.
B	The analyte/compound has been found in the sample as well as its associated blank. Its presence in the sample may be suspect.
J	The analyte/compound was positively identified; however, the associated numerical value is an estimated concentration only.
Quantitation Qualifiers (Laboratory Assigned)	
E	The compound was quantitated above the calibration range.
D	Concentration is based on a diluted sample analysis.
Validation Qualifiers	
UJ	The analyte/compound was not detected above the reported sample quantitation limit; however, the reported limit is approximate and may or may not represent the actual reporting limit.
UB	The analyte/compound is considered non-detect at the listed value due to associated blank contamination (i.e., concentration in the sample is less than five times the concentration detected in the associated blank).
J	The analyte/compound was positively identified; however, the associated numerical value is an estimated concentration.

Qualifier	Definition
R	The sample results are rejected, and the data are unusable.

Two facts will be noted to all data users:

- The “R” qualifier means that the associated value is unusable. In other words, due to significant QC problems, the analysis is invalid and provides no information as to whether the compound is present or not. “R” values should not appear on data tables because they cannot be relied on, even as a last resort.
- No compound concentration, even if it has passed all QC tests, is guaranteed to be accurate. Strict QC serves to increase confidence in data, but any value potentially contains error.

Resolution of any issues regarding laboratory performance or deliverables will be handled between the laboratory and the data validator. Suggestions for reanalysis may be made by the Project Chemist at this point.

5.3 Reconciliation with User Requirements

The data results will be examined to determine the performance that was achieved for each DQI. The performance will then be compared with the project objective and DQOs. Of note will be samples at or near action levels. All deviations from objectives will be noted. Additional action may be warranted when performance does not meet performance objectives for critical data. Options for corrective action relating to incomplete information, questionable results, or inconsistent data may include the following:

- Retrieval of missing information;
- Request for additional explanation or clarification;
- Reanalysis of sample from extract (when appropriate); and/or
- Recalculation or reinterpretation of results by the laboratory.

These actions may improve the data quality, reduce uncertainty, and eliminate the need to qualify or reject data.

If these actions do not improve the data quality to an acceptable level, the following additional actions may be taken:

- Extrapolation of missing data from existing data points;
- Use of historical data; and/or
- Evaluation of the critical/non-critical nature of the sample.

If the data gap cannot be resolved by these actions, an evaluation of the data bias and potential for false negatives and positives can be performed. If the resultant uncertainty level is unacceptable, additional sample collection and analysis may be required.

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Tables

Table 1A
Parameters, Methods, and Target Quantitation Limits (Groundwater)
Sampling and Analysis Plan/Quality Assurance Project Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Chemicals of Interest	CAS No.	Protection of Drinking Water				Protection of Surface Water				Protection of Surface Water			Protection of Sediment
						MTCA Method B		Protection of Aquatic Life[1]		Protection of Human Health			
		MTCA Method A Cleanup Levels	MTCA Method B Cleanup Levels - Noncancer	MTCA Method B Cleanup Levels - Cancer	Washington State/Federal Maximum Contaminant Level	Noncancer	Cancer	WA WQS—Freshwater Chronic WAC 173-201A	NRWQC—Freshwater Chronic CWA Section 304	WA WQS Consumption of Water + Organisms WAC 173-201A	WA Toxics Rule Consumption of Water + Organisms 40 CFR 131.45	NRWQC - Consumption of Water + Organisms CWA Section 304	Criteria Protective of the Lesser of SMS SCO and Human Health Criteria[2]
All concentrations in micrograms per liter (µg/L)													
Total Petroleum Hydrocarbons													
Gasoline range organics	GRO	800[6]	--	--	--	--	--	1,000	1,000	--	--	--	--
Diesel range organics	DRO	500	--	--	--	--	--	150/3,000	150/3,000	--	--	--	--
Heavy Oils	HO	500	--	--	--	--	--	--	--	--	--	--	--
Diesel range organics + Heavy Oils	DRO + HO	500	--	--	--	--	--	--	--	--	--	--	--
Volatile Organic Compounds													
Benzene	71-43-2	5.0	32	0.80	5.0	2,000	23	10	10	0.44	--	0.58	--
1,2-Dichloroethane [EDC]	107-06-2	5.0	48	0.48	5.0	13,000	59	--	--	9.3	8.9	9.9	--
1,1-Dichloroethene	75-35-4	--	400	--	7.0	23,000	--	--	--	1,200	700	300	--
cis-1,2-Dichloroethene	156-59-2	--	16	--	70	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethene	156-60-5	--	160	--	100	33,000	--	--	--	600	200	100	--
Ethylbenzene	100-41-4	700	800	--	700	6,900	--	12	12	200	29	68	--
Tetrachloroethene	127-18-4	5.0	48	21	5.0	500	100	--	--	4.9	2.4	10	--
Toluene	108-88-3	1,000	640	--	1,000	19,000	--	53	53	180	72	57	
Trichloroethene	79-01-6	5.0	4.0	0.54	5.0	120	4.9	--	--	0.38	0.30	0.60	--
Vinyl chloride	75-01-4	0.20	24	0.029	2.0	6,600	3.7	--	--	0.020	--	0.022	--
Total Xylenes	1330-20-7	1,000	1,600	--	10,000	--	--	57	57	--	--	--	
Semivolatile Organic Compounds													
Pentachlorophenol	87-86-5	--	80	0.22	1.0	1,200	1.5	13	15	0.046	0.0020	0.030	0.87
Metals													
Total and Dissolved Iron	7439-89-6	--	--	--	--	--	--	--	--	--	--	--	--
Total and Dissolved Manganese	7439-96-5	--	--	--	--	--	--	--	--	--	--	--	--
Nutrients and Total Organic Carbon													
Nitrate	14797-55-8	--	--	--	--	--	--	--	--	--	--	--	--
Sulfate	14808-78-8	--	--	--	--	--	--	--	--	--	--	--	--
Chloride	16887-00-6	--	--	--	--	--	--	--	--	--	--	--	--
Total Organic Carbon	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 1A
Parameters, Methods, and Target Quantitation Limits (Groundwater)
Sampling and Analysis Plan/Quality Assurance Project Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Chemicals of Interest	CAS No.	Protection of Indoor Air		Adjustment Factors		Most Stringent Risk-Based Criteria	Proposed PCUL^{5}
		MTCA Method B Groundwater Criteria Protective of Volatilization to Soil Vapor then Indoor Air - Nonancer	MTCA Method B Groundwater Criteria Protective of Volatilization to Soil Vapor then Indoor Air - Cancer	Practical Quantitation Limit^{3,4}	Method Detection Limit^{3,4}		
		All concentrations in micrograms per liter (µg/L)					
Total Petroleum Hydrocarbons							
Gasoline range organics	GRO	--	--	100	32	1000	1,000
Diesel range organics	DRO	--	--	100	33	500	500
Heavy Oils	HO	--	--	250	83	500	500
Diesel range organics + Heavy Oils	DRO + HO	--	--	350	116	500	500
Volatile Organic Compounds							
Benzene	71-43-2	100	2.4	1 / 0.04	0.0941 / 0.016	0.44	0.44
1,2-Dichloroethane [EDC]	107-06-2	120	3.5	1 / 0.1	0.0819 / 0.019	0.48	0.48
1,1-Dichloroethene	75-35-4	130	--	1 / 0.1	0.188 / 0.020	7.0	7.0
cis-1,2-Dichloroethene	156-59-2	180	--	1 / 0.1	0.126 / 0.0276	16	16
trans-1,2-Dichloroethene	156-60-5	77	--	1 / 0.2	0.149 / 0.0572	77	77
Ethylbenzene	100-41-4	2,800	--	1 / 0.1	0.137 / 0.0212	12	12
Tetrachloroethene	127-18-4	48	25	1 / 0.1	0.300 / 0.028	2.4	2.4
Toluene	108-88-3	15,000	--	1 / 0.2	0.278 / 0.050	53	53
Trichloroethene	79-01-6	3.9	1.4	1 / 0.04	0.190 / 0.016	0.30	0.30
Vinyl chloride	75-01-4	54	0.33	1 / 0.1	0.234 / 0.0273	0.020	1 / 0.1
Total Xylenes	1330-20-7	320	--	3 / 0.26	0.174 / 0.191	57	57
Semivolatile Organic Compounds							
Pentachlorophenol	87-86-5	--	--	1.0	0.313	0.0020	0.313
Metals							
Total and Dissolved Iron	7439-89-6	--	--	100	18	--	--
Total and Dissolved Manganese	7439-96-5	--	--	10	0.93	--	--
Nutrients and Total Organic Carbon							
Nitrate	14797-55-8	--	--	100	48	--	--
Sulfate	14808-78-8	--	--	5,000	594	--	--
Chloride	16887-00-6	--	--	1,000	379	--	--
Total Organic Carbon	--	--	--	1.0	0.10	--	--

Notes:

1. Implementation Memo #23 provides Aquatic Life Protective Values (Ecology 2021). DRO values are either for unweathered/weathered substances.
2. Criteria for protection of sediment via groundwater discharge are based on a modified MTCA fixed parameter three-phase partitioning model (WAC 173-340-747, equation 747-1). The lower of the sediment criteria for protection of human health direct contact (including beach play, clamming, and net fishing pathways), bioaccumulation, and benthic species was selected as the target concentration.
3. Practical quantitation limit and method detection limit values from Pace National Center for Testing and Innovation (Pace) of Mt. Juliet, Tennessee.
4. Practical quantitation limits for ultra-low level VOC analysis are provided. Note that this analysis is performed on a pristine instrument so any impacted samples will need to be analyzed by the standard VOC method.
5. Preliminary cleanup level is based on the lowest of the protection of direct contact, terrestial receptors, and protection of groundwater leaching, as appropirate.
6. Benzene has been detected at the site (see Table 4), so the lower cleanup level is applicable.

Acronyms and Abbreviations:

-- = not applicable
BNSF = BNSF Railway Company
CAS = Chemical Abstracts Service
CFR = Code of Federal Regulations
CWA = Clean Water Act
Ecology = Washington Department of Ecology
MTCA = Model Toxics Control Act
NRWQC = National Recommended Water Quality Criteria
PCUL = preliminary cleanup level
SCO = Sediment Cleanup Objective
SMS = Sediment Management Standards
WAC = Washington Administrative Code
WA WQS = Washington Water Quality Standards

References:

Washington State Department of Ecology. 2013. *Model Toxics Control Act Regulation and Statute* . Publication No. 94-06.

Washington State Department of Ecology. 2021. Implementation Memorandum No. 23: Concentrations of Gasoline and Diesel Range Organics Predicted to be Protective of Aquatic Receptors in Surface Waters. August.

Table 1B
Parameters, Methods, and Target Quantitation Limits (Soil)
Sampling and Analysis Plan/Quality Assurance Project Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Chemicals of Interest	CAS No.	MTCA Method A Cleanup Levels	Protection of Direct Contact		Protection of Terrestial Ecological Receptors		Protection of Groundwater Leaching		Adjustment Factors		Most Stringent Risk-Based Criteria	Preliminary Cleanup Level[5]
			MTCA Method B Cleanup Levels - Noncancer	MTCA Method B Cleanup Levels - Cancer	Terrestrial Ecological Indicator Soil Concentrations[1]	Site Specific Terrestrial Ecological Evaluation[2]	Protective of Groundwater Saturated[3]	Protective of Groundwater to Surface Water Saturated (Fresh Water)[3]	Practical Quantitation Limit[4]	Method Detection Limit[4]		
All units in milligrams per kilogram (mg/kg)												
Total Petroleum Hydrocarbons												
Gasoline-range organics	GRO	30[6]	--	--	100	--	--	--	0.10	0.0339	30	30
Diesel-range organics	DRO	2,000	--	--	200	570	--	--	4.0	1.33	200	570[7]
Heavy Oils	HO	2,000	--	--	--	1,600	--	--	10	3.33	1,600	1,600[7]
Diesel-range organics + Heavy Oils	DRO + HO	2,000	--	--	--	--	--	--	14	4.66	2,000	2,000
Volatile Organic Compounds												
Benzene	71-43-2	0.030	320	18	--	--	0.0017	0.00015	0.0010	0.00047	0.00015	0.0010
1,2-Dichloroethane [EDC]	107-06-2	--	480	11	--	--	0.0016	0.0029	0.0025	0.00065	0.0016	0.0025
1,1-Dichloroethene	75-35-4	--	4,000	--	--	--	0.0025	0.11	0.0025	0.00061	0.0025	0.0025
cis-1,2-Dichloroethene	156-59-2	--	160	--	--	--	0.0052	--	0.0025	0.00073	0.0052	0.0052
trans-1,2-Dichloroethene	156-60-5	--	1,600	--	--	--	0.032	0.032	0.0050	0.0010	0.032	0.032
Ethylbenzene	100-41-4	6.0	8,000	--	--	--	0.34	0.0059	0.0025	0.00074	0.0059	0.0059
Tetrachloroethene	127-18-4	0.050	480	480	--	--	0.0028	0.0013	0.0025	0.00090	0.0013	0.0025
Toluene	108-88-3	7.0	6,400	--	--	--	0.27	0.023	0.0050	0.0013	0.023	0.023
Trichloroethene	79-01-6	0.030	40	12	--	--	0.0015	1.1E-04	0.0010	0.00058	0.00011	0.0010
Vinyl chloride	75-01-4	--	240	0.67	--	--	9.0E-05	6.2E-06	0.0025	0.0012	6.2E-06	0.0025
Total Xylenes	1330-20-7	9.0	16,000	--	--	--	0.83	0.030	0.0065	0.00088	0.030	0.030
Semivolatile Organic Compounds												
Pentachlorophenol	87-86-5	--	400	2.5	3.0	--	8.8E-04	1.8E-06	0.333	0.00896	1.80E-06	0.00896

Notes:

1. The TEEs are based on MTCA Table 749-3 with the lowest of the plant, soil biota, and wildlife screening levels selected.
2. The cleanup levels are based on the site specific Terrestrial Ecological Evaluation summarized in the Upland Ecological Risk Assessment (Ecology 2020).
3. Criteria for protection of groundwater and surface water are based on the MTCA fixed parameter three-phase partitioning model (WAC 173-340-747, equation 747-1). Default values used.
4. Practical quantitation limit and method detection limit values from Pace National Center for Testing and Innovation (Pace) of Mt. Juliet, Tennessee.
5. Preliminary cleanup level is based on the lowest of the protection of direct contact, terrestial receptors, and protection of groundwater leaching, as appropirate.
6. Benzene has been detected at the site, so the lower cleanup level is applicable.
7. PCUL based on site specific Terrestrial Ecological Evaluation.

Acronyms and Abbreviations:

🟧 = PCUL based on the practical quantitation limit (reporting limit) provided by the laboratory
🟨 = PCUL based on the method detection limit provided by the laboratory
-- = not applicable
CAS = Chemical Abstracts Service
MTCA = Model Toxics Control Act
PCUL = preliminary cleanup level

References:

Washington State Department of Ecology. 2013. *Model Toxics Control Act Regulation and Statute* . Publication No. 94-06.
Washington State Department of Ecology. 2020. Time Oil Site: Upland Ecological Risk Assessment, Memo to Mark Adams, LHG, Toxic Cleanup Program. June 26.

Table 2
Sample Quantities and Quality Control Frequencies
Sampling and Analysis Plan/Quality Assurance Project Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

ARCADIS

Parameter	Estimated Environmental Sample Quantity	Field QC Analyses [1]						Laboratory QC Sample [1,2]						Total
		Trip Blank		Rinse Blank		Field Duplicate		MS		MSD		Lab Duplicate		
		Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	Freq.	No.	
Groundwater														
VOCs (SW-846 8260C)	11	1/cooler	TBD	1/20	1	1/20	1	1/20	1	1/20	1	NC	--	15
SVOCs (SW-846 8270D-SIM)	11	NC	--	1/20	1	1/20	1	1/20	1	1/20	1	NC	--	15
TPH GRO (NWTPH-Gx)	11	NC	--	1/20	1	1/20	1	1/20	1	1/20	1	NC	--	15
TPH DRO and HO (NWTPH-Dx)	11	NC	--	1/20	1	1/20	1	1/20	1	1/20	1	NC	--	15
Total and Dissolved Fe and Mn (SW-846 6010D)	11	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	11
Anions (Nitrate as N, Chloride, Sulfate) (EPA 300.0)	11	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	11
TOC (SW-846 9060A)	11	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	11
Soil														
VOCs (SW-846 8260C)	24	1/cooler	TBD	1/20	2	1/20	2	1/20	2	1/20	2	NC	--	32
SVOCs (SW-846 8270D-SIM)	24	NC	--	1/20	2	1/20	2	1/20	2	1/20	2	NC	--	32
TPH GRO (NWTPH-Gx)	24	NC	--	1/20	2	1/20	2	1/20	2	1/20	2	NC	--	32
TPH DRO and HO (NWTPH-Dx)	24	NC	--	1/20	2	1/20	2	1/20	2	1/20	2	NC	--	32
FOC	8	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	8
Soil Permeability	8	NC	--	NC	--	NC	--	NC	--	NC	--	NC	--	8

Notes:

1. A minimum of one rinse blank, field duplicate, and MS/MSD will be collected per sampling event, even if fewer than 20 parent samples are collected.
2. Additional sample volume will not be provided to the laboratory for site-specific QC samples related to metals, anions, and TOC. The laboratory will be expected to perform method-required QC sample analysis, whether using a site sample or a batch sample.

Abbreviations and Acronyms:

-- = not applicable
BNSF = BNSF Railway Company
DRO = Diesel Range Organics
EPA = United States Environmental Protection Agency
Fe = Iron
FOC = fraction of organic carbon
Freq. = Frequency
GRO = Gasoline Range Organics
HO = Heavy Oil
Lab = Laboratory
Mn = Manganese
MS = Matrix Spike
MSD = Matrix Spike Duplicate
NC = Not Collected
No. = Number
QC = Quality Control
SVOCs = Semivolatile Organic Compounds
TBD = To Be Determined
TOC = Total Organic Carbon
TPH = Total Petroleum Hydrocarbons
VOCs = Volatile Organic Compounds

Table 3
Laboratory Quality Control Limits
Sampling and Analysis Plan/Quality Assurance Project Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Parameter	Accuracy - Percent Recovery			Precision - Relative Percent Difference			
	Surrogate	MS/MSD	LCS/LCSD	MS/MSD	LCS/LCSD	Laboratory Duplicate	Field Duplicate
Groundwater							
VOCs (SW-846 8260C)							
Benzene	--	17-158%	70-123%	27%	20%	--	35%
1,2-Dichloroethane	--	29-151%	70-128%	27%	20%	--	35%
1,1-Dichloroethene	--	11-160%	71-124%	29%	20%	--	35%
cis-1,2-Dichloroethene	--	10-160%	73-120%	27%	20%	--	35%
trans-1,2-Dichloroethene	--	17-153%	73-120%	27%	20%	--	35%
Ethylbenzene	--	30-155%	79-123%	27%	20%	--	35%
Tetrachloroethene	--	10-160%	72-132%	27%	20%	--	35%
Toluene	--	26-154%	79-120%	28%	20%	--	35%
Trichloroethene	--	10-160%	78-124%	25%	20%	--	35%
Vinyl chloride	--	10-160%	67-131%	27%	20%	--	35%
Total Xylenes	--	29-154%	79-123%	28%	20%	--	35%
Toluene-d8	80-120%	--	--	--	--	--	--
Dibromofluoromethane	75-120%	--	--	--	--	--	--
4-Bromofluorobenzene	77-126%	--	--	--	--	--	--
1,2-Dichloroethane-d4	70-130%	--	--	--	--	--	--
SVOCs (SW-846 8270D)							
Pentachlorophenol	--	35-138%	35-138%	20%	20%	--	35%
Phenol-d5	10-67%	--	--	--	--	--	--
2-Fluorophenol	19-119%	--	--	--	--	--	--
2,4,6-Tribromophenol	43-140%	--	--	--	--	--	--
Total Petroleum Hydrocarbon (NWTPH-Gx and NWTPH-Dx)							
Gasoline Range Organics	--	10-155%	70-124%	21%	20%	--	35%
a,a,a,-Trifluorotoluene	78-120%	--	--	--	--	--	--
Diesel Range Organics and Heavy Oil	--	50-150%	50-150%	20%	20%	--	35%
o-Terphenyl	31-160%	--	--	--	--	--	--
Metals (SW-846 6010D)							
Iron	--	75-125%	80-120%	20%	20%	20%	35%
Manganese	--	75-125%	80-120%	20%	20%	20%	35%
Anions (EPA 300.0)							
Nitrate as N	--	80-120%	80-120%	15%	15%	15%	35%
Sulfate	--	80-120%	80-120%	15%	15%	15%	35%
Chloride	--	80-120%	80-120%	15%	15%	15%	35%
Total Organic Carbon (SW-846 9060A)							
Total Organic Carbon	--	80-120%	85-115%	20%	20%	20%	35%

Table 3
Laboratory Quality Control Limits
Sampling and Analysis Plan/Quality Assurance Project Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Parameter	Accuracy - Percent Recovery			Precision - Relative Percent Difference			
	Surrogate	MS/MSD	LCS/LCSD	MS/MSD	LCS/LCSD	Laboratory Duplicate	Field Duplicate
Soil							
VOCs (SW-846 8260C)							
Benzene	--	10-149%	70-123%	37%	20%	--	50%
1,2-Dichloroethane	--	10-148%	65-131%	35%	20%	--	50%
1,1-Dichloroethene	--	10-155%	65-131%	37%	20%	--	50%
cis-1,2-Dichloroethene	--	10-149%	73-125%	37%	20%	--	50%
trans-1,2-Dichloroethene	--	10-150%	71-125%	37%	20%	--	50%
Ethylbenzene	--	10-160%	74-126%	38%	20%	--	50%
Tetrachloroethene	--	10-156%	70-136%	39%	20%	--	50%
Toluene	--	10-156%	75-121%	38%	20%	--	50%
Trichloroethene	--	10-156%	76-126%	38%	20%	--	50%
Vinyl chloride	--	10-160%	63-134%	37%	20%	--	50%
Total Xylenes	--	10-160%	72-127%	38%	20%	--	50%
Toluene-d8	75-131%	--	--	--	--	--	--
Dibromofluoromethane	65-129%	--	--	--	--	--	--
4-Bromofluorobenzene	67-138%	--	--	--	--	--	--
1,2-Dichloroethane-d4	70-130%	--	--	--	--	--	--
SVOCs (SW-846 8270D)							
Pentachlorophenol	--	10-160%	29-120%	31%	25%	--	50%
Phenol-d5	10-120%	--	--	--	--	--	--
2-Fluorophenol	12-120%	--	--	--	--	--	--
2,4,6-Tribromophenol	10-127%	--	--	--	--	--	--
Total Petroleum Hydrocarbon (NWTPH-Gx and NWTPH-Dx)							
Gasoline Range Organics	--	50-150%	71-124%	27%	20%	--	50%
a,a,a,-Trifluorotoluene	77-120%	--	--	--	--	--	--
Diesel Range Organics and Heavy Oil	--	50-150%	50-150%	20%	20%	--	50%
o-Terphenyl	18-148%	--	--	--	--	--	--
Others							
Fraction of Organic Carbon	--	--	--	--	--	--	--
Soil Permeability	--	--	--	--	--	--	--

Notes:

1. The listed QC limits are based on the laboratory-provided limits at the time of this document. The limits are updated periodically by the laboratory, and the current limits at the time of analysis will be reported

Abbreviations and Acronyms:

– = Not Applicable
BNSF = BNSF Railway Company
EPA = United States Environmental Protection Agency
LCS = Laboratory Control Sample
LCSD = Laboratory Control Sample Duplicate
MS = Matrix Spike
MSD = Matrix Spike Duplicate
SVOCs = Semivolatile Organic Compounds
VOCs = Volatile Organic Compounds

Table 4
Sample Containers, Preservation, and Holding Times
Sampling and Analysis Plan/Quality Assurance Project Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Parameter	Method	Bottle Type[1]	Preservation	Holding Time[2]
Groundwater				
VOCs	SW-846 8260C	Two 40-mL glass vials with Teflon®-lined lid	HCl to pH<2; Cool to <6°C	14 days to analysis
SVOCs	SW-846 8270D	Two 1-L amber glass bottles	Cool to <6°C	7 days to extraction 40 days to analysis
TPH GRO	NWTPH-Gx	Two 40-mL glass vials with Teflon®-lined lid	HCl to pH<2; Cool to <6°C	14 days to analysis
TPH DRO and HO	NWTPH-Dx	One 1-L amber glass bottle	HCl to pH<2; Cool to <6°C	14 days to extraction 40 days to analysis
Metals - Total	SW-846 6010D	One 250-mL plastic bottle	HNO_3 to pH<2; Cool to <6°C	180 days to analysis
Metals - Dissolved	SW-846 6010D	One 250-mL plastic bottle	Cool to <6°C	180 days to analysis
Anions	EPA 300.0	One 250-mL plastic bottle	Cool to <6°C	Nitrate as N: 48 hours to analysis Chloride and Sulfate: 28 days to analysis
TOC	SW-846 9060A	One 250-mL glass bottle	H_2SO_4 to pH<2; Cool to <6°C	28 days to analysis
Soil				
VOCs	SW-846 8260C	High Level: Two 40-mL glass vials with Teflon®-lined lid (5-gram soil sample)	MeOH; Cool to <6°C	14 days to analysis
		Low Level: Two 40-mL glass vials with Teflon®-lined lid (5 gram soil sample)	Water; Cool to <6°C; freeze within 48 hours of collection	14 days to analysis
TPH GRO	NWTPH-Gx	Two 40-mL glass vials with Teflon®-lined lid (5-gram soil sample)	MeOH; Cool to <6°C	14 days to analysis
		One 4-oz. wide-mouth glass jar	Cool to <6°C	
TPH DRO and HO	NWTPH-Dx	One 8-oz. glass jar with Teflon®-lined lid	Cool to <6°C	14 days to extraction 40 days to analysis
SVOCs	SW-846 8270D	One 8-oz. glass jar with Teflon®-lined lid	Cool to <6°C	14 days to extraction 40 days to analysis
TOC	SW-846 9060A	One 250-mL glass bottle	H_2SO_4 to pH<2; Cool to <6°C	28 days to analysis
FOC	Walkley-Black[3]	Plastic bottle or plastic bag	--	--
Soil permeability	ASTM-D5856[3]	Undisturbed, brass sleeve ~2"x6"	--	--

Notes:

1. The laboratory should be consulted prior to sample collection because it may be possible to combine sample volume for multiple analyses in one sample container.
2. All holding times are measured from date of collection. It is imperative that all samples be submitted to the laboratory with ample time for the analysis to be completed within the holding time. Missing a holding time is unacceptable and may result in unusable data.
3. Equivalent laboratory methods may be used, depending on the laboratory's cabability

Abbreviations and Acronyms
° = Degree
< = Less than
" = inch
BNSF = BNSF Railway Company
C = Celsius
DRO = Diesel Range Organics
EPA = United States Environmental Protection Agency
FOC = fraction of organic carbon
GRO = Gasoline Range Orgar
HCl = Hydrochloric Acid
HNO_3 = Nitric Acid
HO = Heavy Oil
H_2SO_4 = Sulfuric Acid
L = Liter
MeOH = methanol
mL = milliliter
oz. = ounce
SVOCs = Semivolatile Organic Compounds
TOC = Total Organic Carbon
TPH = Total Petroleum Hydrocarbons
VOCs = Volatile Organic Compounds

Table 5
Quarterly Groundwater Sampling Plan
Sampling and Analysis Plan/Quality Assurance Project Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Sampling Location	Water Bearing Zone	Existing or Proposed Screened Interval (feet below top of casing)	Existing or Proposed Screen Interval below Top of Casing (feet NAVD88)[1]	Laboratory Analysis[2]	Relevant Technical Guidance Instructions[3]
Existing Wells					
01MW92	Perched	6 to 16	53 to 43	CVOCs, BTEX, TPH, geochemical parameters (standard TAT)	SOP - Sample Chain of Custody TGI - Investigation-Derived Waste Handling and Storage TGI - Groundwater and Soil Sampling Equipment Decontamination TGI - Manual Water-Level and NAPL Monitoring TGI - Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells
01MW93	Shallow	23.5 to 38.5	35.5 to 20.5	CVOCs, TPH, geochemical parameters (standard TAT)	
01MW94	Shallow	28 to 40	31 to 19	CVOCs, TPH, geochemical parameters (standard TAT)	
01MW95	Shallow	27 to 37	32 to 22	CVOCs, geochemical parameters (standard TAT)	
01MW96	Perched	5 to 15	54 to 44	CVOCs, BTEX, TPH, PCP[4], geochemical parameters (standard TAT)	
01MW97	Perched	5 to 15	54 to 44	CVOCs, TPH, , geochemical parameters (standard TAT)	
01MW98	Perched	5 to 15	54 to 44	CVOCs, TPH, geochemical parameters (standard TAT)	
Proposed Wells					
MW-BN-01	Perched	5 to 15	54 to 44	CVOCs, TPH, geochemical parameters (standard TAT)	SOP - Sample Chain of Custody TGI - Investigation-Derived Waste Handling and Storage TGI - Groundwater and Soil Sampling Equipment Decontamination TGI - Monitoring Well Installation TGI - Monitoring Well Development TGI - Manual Water-Level and NAPL Monitoring TGI - Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells
MW-BN-02	Perched	5 to 15	54 to 44	CVOCs, TPH, geochemical parameters (standard TAT)	
MW-BN-03	Shallow	25 to 35	34 to 24	CVOCs, BTEX, geochemical parameters (standard TAT)	
MW-BN-04	Perched	5 to 15	54 to 44	CVOCs, BTEX, TPH, PCP, geochemical parameters (standard TAT)	
MW-BN-05	Perched	5 to 15	54 to 44	CVOCs, BTEX, TPH, PCP, geochemical parameters (standard TAT)	

Notes:

1. Assumed surface elevation is 59 feet NAVD88 based on the 2019 survey (Floyd Snider 2020).
2. See Table 4 for additional analytical details.
3. Included as Remedial Investigation Work Plan Appendix D.
4. If detected at MW-BN-04 in the perched zone groundwater, PCP will be analyzed in the perched zone groundwater at 01MW96.

Acronyms and Abbreviations:

BNSF = BNSF Railway Company
BTEX = benzene, toluene, ethylbenzene, and total xylenes
CVOC = chlorinated volatile organic compound
NAPL = non-aqueous phase liquid
NAVD88 = North American Vertical Datum of 1988
PCP = pentachlorophenol
SOP = Standard Operating Procedures
TAT = turnaround time
TGI = Techincal Guidance Instructions
TPH = total petroleum hydrocarbons

References:

Floyd Snider. 2020. Supplemental Upland Remedial Investigation and Feasibility Study, Time Oil Bulk Terminal, Seattle, WA. Prepared for Cantera Development Group, LLC. September.

Table 6
Proposed Boring and Temporary Well Sampling Plan
Sampling and Analysis Plan/Quality Assurance Project Plan
Time Oil Bulk Terminal - BNSF Property
Seattle, Washington

Sampling Location	Approximate Sample Depths (feet bgs)	Approximate Sample Elevations (feet NAVD88)[1]	Approximate Total Depth (feet bgs)	Proposed Temporary Screen Interval below Top of Casing (feet bgs)	Proposed Temporary Screen Interval below Top of Casing (feet NAVD88)[1]	Laboratory Analysis[2]	Relevant Technical Guidance Instructions[3]
Soil Borings							
SB-BN-01	2.5, 5, 10, 15	56.5, 54, 49, 44	20	--	--	CVOCs, TPH, FOC*, Permeability* (standard TAT)	SOP - Sample Chain of Custody TGI - Investigation-Derived Waste Handling and Storage TGI - Groundwater and Soil Sampling Equipment Decontamination TGI - Soil Description TGI - Soil Drilling and Sample Collection
SB-BN-02	5, 10, 15, 19	54, 49, 44, 40	20	--	--	CVOCs, BTEX, TPH (standard TAT)	
SB-BN-03	2.5, 10, 20, 35	56.5, 49, 39, 24	40	--	--	CVOCs, TPH (standard TAT)	
SB-BN-04	2.5, 5, 10, 15	56.5, 54, 49, 44	20	--	--	CVOCs, BTEX (only at 5 feet bgs interval), TPH (standard TAT)	
SB-BN-05	2.5, 10, 20, 35	56.5, 49, 39, 24	40	--	--	CVOCs (standard TAT)	
SB-BN-06	2.5, 10, 20, 35	56.5, 49, 39, 24	40	--	--	CVOCs (standard TAT)	
SB-BN-07	2.5, 10, 20, 35	56.5, 49, 39, 24	40	--	--	CVOCs, BTEX, PCP[4] (standard TAT)	
SB-BN-08	2.5, 10, 20, 35	56.5, 49, 39, 24	40	--	--	CVOCs, BTEX, TPH, PCP (standard TAT)	
SB-BN-09	2.5, 5, 10, 15	56.5, 54, 49, 44	20	--	--	CVOCs, BTEX, TPH, PCP (standard TAT)	
SB-BN-10	2.5, 10, 20, 35	56.5, 49, 39, 24	40	--	--	CVOCs, BTEX, TPH, PCP, FOC*, Permeability* (standard TAT)	
SB-BN-11	2.5, 5, 10, 15	56.5, 54, 49, 44	20	--	--	CVOCs, BTEX, TPH, PCP (standard TAT)	
Temporary Wells							
SB-BN-03	30	29	--	25 to 35	34 to 24	CVOCs (standard TAT)	SOP - Sample Chain of Custody TGI - Investigation-Derived Waste Handling and Storage TGI - Groundwater and Soil Sampling Equipment Decontamination TGI - Monitoring Well Installation TGI - Monitoring Well Development TGI - Manual Water-Level and NAPL Monitoring TGI - Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells
SB-BN-05	30	29	--	25 to 35	34 to 24	CVOCs (standard TAT)	
SB-BN-06	30	29	--	25 to 35	34 to 24	CVOCs (standard TAT)	
SB-BN-08	30	29	--	25 to 35	34 to 24	CVOCs (standard TAT)	
SB-BN-09	8	51	--	5 to 15	54 to 44	CVOCs, TPH, PCP[5] (standard TAT)	
SB-BN-10	30	29	--	25 to 35	34 to 24	CVOCs (standard TAT)	
SB-BN-11	8	51	--	5 to 15	54 to 44	CVOCs, TPH, PCP[5] (standard TAT)	

Notes:

1. Assumed surface elevation is 59 feet NAVD88 based on the 2019 survey (Floyd Snider 2020).
2. See Table 4 for additional analytical details.
3. Included as Remedial Investigation Work Plan Appendix D.
4. If detected at SB-BN-08 in soil, PCP will be analyzed in soil at SB-BN-07.
5. If detected at MW-BN-04 or MW-BN-05, CVOCs and PCP will be analyzed in the perched groundwater from SB-BN-09 and SB-BN-11 temporary wells.

Acronyms and Abbreviations:

-- = Not applicable
* = samples collected at intervals representative of unique soil types
bgs = below ground surface
BTEX = benzene, toluene, ethylbenzene, and total xylenes
BNSF = BNSF Railway Company
CVOC = chlorinated volatile organic compound
FOC = fraction of organic carbon
NAPL = non-aqueous phase liquid
NAVD88 = North American Vertical Datum of 1988
SOP = Standard Operating Procedure
PCP = pentachlorophenol
Permeability = hydraulic permeability (conductivity)
TAT = turnaround time
TGI = Techincal Guidance Instructions
TPH = total petroleum hydrocarbons

References:

Floyd Snider. 2020. Supplemental Upland Remedial Investigation and Feasibility Study, Time Oil Bulk Terminal, Seattle, WA. Prepared for Cantera Development Group, LLC. September.

Attachment 1

Laboratory Standard Operating Procedures

Document Information

Document Number: ENV-SOP-MTJL-0081	**Revision:** 04
Document Title: Semi-volatile Organics by GCMS using Capillary Column (EPA Methods 8270C, EPA 8270D, EPA Method 625, SM 6410B), Including Provisions for Analysis in SIM Mode	
Department(s): SVOA	

Date Information

Effective Date: 14 May 2021

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Document Notes:

All Dates and Times are listed in: Central Time Zone

Signature Manifest

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All dates and times are in Central Time Zone.

ENV-SOP-MTJL-0081

QM Approval

Name/Signature	Title	Date	Meaning/Reason
Elizabeth Turner (007857)	Manager - Quality Program	14 May 2021, 08:34:12 AM	Approved

Management Approval

Name/Signature	Title	Date	Meaning/Reason
Christopher Johnson (006487)	Manager - Operations	13 May 2021, 11:46:22 AM	Approved
James Burns (006456)	Manager - EHS	13 May 2021, 12:26:03 PM	Approved
Shakir Wani (010007)	Manager	13 May 2021, 03:14:35 PM	Approved

1.0 SCOPE AND APPLICATION

STATE NOTE: For samples analyzed in conjunction with the Ohio Voluntary Action Program (VAP) please utilize SOP #330345OH.

1.1 This method is used to determine the concentration of semi-volatile organic compounds in extracts prepared from many types of solid waste matrices, soils, and water samples. The lists of compounds that are routinely determined by this method are listed in Attachment II. This table represents a default list to be used in the absence of a project-specific list, which would take precedence. See section 13.4.

1.2 This method is used to quantitate most neutral, acidic and/or basic organic compounds that are soluble in methylene chloride and capable of being eluted, without derivatization, from a gas chromatographic fused-silica column coated with a slightly polar methyl silicone phase. Such compounds include polynuclear aromatic hydrocarbons, chlorinated hydrocarbons and pesticides, phthalate esters, organophosphate esters, nitrosamines, haloethers, aldehydes, ethers, ketones, anilines, pyridines, quinolines, aromatic nitro compounds, and phenols, including nitrophenols.

1.3 In general, this method is not appropriate for the quantitation of multi-component analytes (i.e. Toxaphene, Chlordane, Aroclors, etc.) because of the limited sensitivity for those analytes; however when those analytes are identified using another analytical technique, this procedure is appropriate for confirmation pending sufficient analyte concentration is present in the extract.

1.4 Detection limits, sensitivity and optimum ranges of organic compounds vary with sample matrices, extraction technique, detector parameters, and model of GC/MS.

1.5 Qualifier ions are method specified and can be found in Attachment IV.

1.6 Use of this method is restricted to analysts who are knowledgeable in the interpretation of Mass Spectrometry and use of GC/MS systems.

1.7 The use of selected ion monitoring (SIM) is acceptable for applications requiring limits below the normal range of electron impact mass spectrometry. However, SIM may provide a lesser degree of confidence in the compound identification unless multiple ions are monitored for each compound.

1.8 An MDL study must be completed at least annually or more frequently if major instrumentation changes occur. Method Detection Limits (MDLs) are performed based on ESC SOP #030206. Updated MDL records are filed and stored on ESC's intranet.

1.8.1 Limit of Detection (LOD) and Limit of Quantitation (LOQ) studies are completed at the frequency required by the TNI standard per the procedure identified in the ESC SOP #030206, *Method Detection Limits (MDL), Limits of Detection (LOD) and Limits of Quantitation (LOQ).* Should the procedure be utilized for DOD support; then the frequency of these studies must meet the requirements of the current DOD QSM (see Attachment IX).

1.8.2 Lower Limit of Quantitation (LOQ) – For analyses performed per the requirements of Method 8000D, the LLOQ is established at concentrations where both quantitative and qualitative requirements can consistently be met (see Sections 2.10 and 10.4).

2.0 METHOD SUMMARY AND DEFINITIONS

2.1 Field samples are prepared for analysis by gas chromatography/mass spectrometry (GC/MS) using the appropriate sample extraction technique. See ESC SOPs 330702/330702A/330702B/330705/330707/330708/330709/330754 for extraction and extract concentration methods. A measured volume or weight of sample is extracted using the appropriate extraction technique. Liquid samples are extracted at neutral pH with methylene chloride using a separatory funnel (SOP #330702) per EPA method 3510C. Reduced volume (RV) extraction using EPA method 3510C that requires a smaller volume (usually 100mL) of field sample is also available for use where applicable. Large volume injection (LVI) extraction using EPA method 3511 that requires a smaller volume (usually 40mL) of field sample is also available for use where applicable. See section 13.5 of this procedure and ESC SOP #330702B. Soil analysis using the same technology can also be performed with extraction as noted in ESC SOP #330707 and no concentration performed on the extract. This process is termed throughout this SOP as non-concentrated soil. Solid samples can also be extracted traditionally using methylene chloride-acetone (1:1) and a sonication process (SOP #330705) or with methylene chloride using the microwave process (SOP #330707), where permitted. These extracts are denoted in this procedure using the terminology “concentrated soil” extracts.

2.2 The semi-volatile compounds are introduced into the GC/MS by directly injecting a volume of the sample extract into a gas chromatograph oven (GC) equipped with a narrow-bore fused-silica capillary column. The oven, containing the capillary column, is temperature and pressure programmed to separate the analytes by molecular composition. The capillary column transfers the eluting analytes to the detector (MS) connected to a computer that then collects and stores the information for each injection.

2.3 Identification of target analytes is accomplished by comparing the mass spectra of each peak with the reference spectra of authentic standards.

2.4 Quantitation of the analytes of interest is accomplished by comparing the response of a major (quantitation) ion, present in the target analyte, relative to an internal standard in each extract, in conjunction with the response factor generated from a calibration curve.

2.5 Proper quantitation ions for each compound must be selected so that no interferences are present from adjoining (or co-eluting) analytes with common ions. Proper GC conditions must be used to resolve compounds with similar mass spectra. Background subtraction of mass spectra may be necessary when matrix interference is present.

2.6 <u>Qualitative</u> - The identification of compounds based on retention time and comparison of the sample mass spectra, after background correction, with characteristic ions in the reference mass spectra. The reference mass spectra must be generated by the laboratory using the same analytical conditions used for the analysis of field samples. The characteristic ions from the reference mass spectra are defined as the three ions of greatest relative intensity or any ions over 30% relative intensity if less than three such ions occur in the reference spectra.

2.7 <u>Quantitative</u> – Following qualitative identification, the quantitation of the identified compound is based on the integrated abundance of the primary characteristic ion from the Extracted Ion Current Profile (EICP).

2.8 <u>Relative Retention Time (RRT)</u> – The process of normalizing the response (peak area) of the target compound to the response of the internal standard.

2.9 Isotope dilution calibration - Isotope dilution calibration is essentially a special case of internal standard calibration. In isotope dilution, the internal standards are stable isotopically-labeled analogs of the target analytes *and* they are added to the sample prior to any sample handling steps, including sample extraction. Because the spiked compounds differ from the target compounds only in the presence of the stable isotopes, the physical and chemical behavior of each labeled compound is virtually the same as its unlabeled "native" analog. Thus, any losses of the target compound that may occur during any of the sample preparation, extraction, cleanup, or determinative steps will be mirrored by a similar loss of the labeled standard.

2.10 Lower Limit of Quantitation (LLOQ) – For analyses performed according to the requirements of Method 8000D, the lowest concentration at which the laboratory has demonstrated target analytes can be reliably measured and reported with a certain degree of confidence, which must be greater than or equal to the lowest point in the calibration curve.

2.11 Large Volume Injection (LVI): any injection volume >5µL. Technique is dependent upon type of GC inlet used and sensitivity of detection.

2.12 Minimum Level (ML): A term used in Method 625.1 which refers to either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the MDL, whichever is higher. Minimum levels may be obtained in several ways: They may be published in a method; they may be based on the lowest acceptable calibration point used by a laboratory; or they may be calculated by multiplying the MDL in a method, or the MDL determined by a laboratory, by a factor of 3. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: ‘‘quantitation limit,’’ ‘‘reporting limit,’’ and ‘‘minimum level.’’

2.13 See the current Quality Assurance Manual for other definitions associated with terms found in this document.

3.0 HEALTH AND SAFETY

3.1 The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

3.2 The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets (SDS) for all hazardous chemicals are available to all personnel. Employees must abide by the environmental, health, and safety (EHS) policies and procedures specified in this SOP and in the Pace National Chemical Hygiene / Safety Manual.

3.3 Personal protective equipment (PPE) such as safety glasses and/or side shields, gloves, a laboratory coat, and shoes that are not cloth, canvas, and/or perforated must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure. When handling glass, needles, knives, or any material with a potential sharp edge, employees must use cut-resistant gloves.

3.4 Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids, bases, or oxidizers in a fume hood whenever possible with the appropriate PPE designed for handing these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

3.5 Spill kits are located in each laboratory department. Employees are to familiarize themselves with the location and contents of each spill kit in their area.

3.6 Universal precautions should be observed when performing any tests or procedures. Hard surfaces, instrument surfaces may be contaminated and should be handled according to good laboratory practices.

3.7 Contact your supervisor or local EHS coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure. Any accidents involving personnel or sample supplies are to be reported immediately to either the Manager and/or to the Safety Officer.

4.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

4.1 All samples must have been collected using a sampling plan that addresses the considerations of this method.

4.2 Requirements for sample extraction are detailed in SOP numbers 330702, 330702A, 330702B, 330705, 330707, 330708, 330709, and 330754.

4.3 The sample holding time for solid samples is 14 days to extraction and, for aqueous samples, the holding time is 7 days. Holding time begins when (date and time) the samples are collected and ends either 14 or 7 days following sampling, at the time sampled.

4.4 The holding time for each extract is 40 days from sample preparation to analysis.

4.5 The container for aqueous samples and liquid sludge being extracted using the traditional 1L EPA 3510 method are 1L amber glass bottles. For the reduced volume extraction process using the EPA 3510 method, 100mL amber glass bottles are utilized. The containers for aqueous samples being extracted using EPA Method 3511 are 40mL amber glass bottles. Add 0.008% $Na_2S_2O_3$ per liter, if residual chlorine is expected or present.

4.6 Collect solid sample materials in 4 oz. jars or larger, depending on the weight and density of the sampled materials.

4.7 All samples and extracts must be shipped and stored at <6°C (not frozen).

4.8 Samples submitted for analysis that do not meet the requirements contained within this section must be addressed before performing the logging process within the laboratory. In some cases, exceeding the appropriate preservation and storage criteria can cause significant bias in the resulting data. Clients may need to resubmit samples where the conditions during shipment cause uncertainty regarding sample integrity. If samples do not meet the requirements for preservation, sampling, shipment and storage and the client approves the completion of the analytical process, sample results can be qualified and possible bias is narrated per the ESC SOP #030201, *Data Handling and Reporting*.

5.0 INTERFERENCES

5.1 Raw GC/MS data from all method blanks, samples, and spikes is evaluated for interferences. Determine if the source of interference is in the preparation and/or cleanup of samples and take corrective action to eliminate the problem.

5.2 Contamination by carryover can occur whenever high-concentration and low-concentration samples are sequentially analyzed. To reduce carryover, the sample syringe is rinsed between sample injections. Whenever an unusually concentrated sample is encountered, it should be followed by analysis of solvent to check for cross-contamination. Clean/replace injector liner or clip column, check with solvent blanks, and repeat samples if necessary.

5.3 Choice of quantitative ions and qualifier ions: Some compounds may co-elute, so the selection of quantitation ions and qualifier ions must be made carefully so these ions are specific to each of the compounds that co-elute. Qualifier ions that are most commonly used are listed in Attachment IV and are recommended from the published 8270 methods. There is no method stated ions for the following: Pyridine, 1-Methylnaphthalene, Biphenyl, Carbazole. Aniline Bis (2-Chloroethyl)ether and Tetraethyllead quantitation ions may vary due to chromatographic conditions causing co-elution of the shared primary ion. Targets have strongly-responding, analyte-specific secondary ions suitable for quantitative use. Refer to Attachment IV for ESC ions.

5.4 Problematic Compounds:

5.4.1 Benzidine may be subject to oxidative losses during solvent concentration and exhibits poor chromatographic behavior.

5.4.2 Hexachlorocyclopentadiene is subject to thermal decomposition in the GC inlet, as well as photochemical decomposition.

5.4.3 N-nitrosodimethylamine may be difficult to separate from the solvent using the chromatographic conditions listed in this method.

5.4.4 N-nitrosodiphenylamine decomposes in the GC inlet and can’t be separated from diphenylamine.

5.4.5 Pentachlorophenol, 2,4-Dinitrophenol, 4-Nitrophenol, Benzoic Acid, 4,6-Dinitro-2-methylphenol, 4-Chloro-3-methylphenol, 2-Nitroaniline, 3-Nitroaniline, 4-Chloroaniline, and Benzyl Alcohol are subject to erratic chromatographic behavior, especially when there is high boiling material contamination of the GC system.

5.4.6 Pyridine may perform poorly at the GC injection port temperatures listed in this method. The amount of degradation may be reduced by lowering the injection port temperature. Modification of the injection port temperature may adversely affect the performance of other target analytes.

5.4.7 Benzenethiol, or thiophenol, can be found in refinery wastes at caustic pH values. Benzenethiol is unstable in water/soils of neutral or acidic pH values. Benzenethiol rapidly degrades in organic solvents used to prepare the instrument calibration standards. Benzenethiol is part of Appendix VIII and the 1985 Skinner List, but was never included in Appendix IX to 40 CFR 264, due to its instability in the environment

5.4.8 Tetraethyllead may be subject to decomposition or other losses as processed using microwave digestion, 3546.

6.0 EQUIPMENT AND SUPPLIES

6.1 Gas chromatograph/mass spectrometer system.

6.1.1 Gas chromatograph (HP 6890/7890 or equivalent)- An analytical system complete with a temperature- programmable gas chromatograph suitable for split-less injection and all required accessories, including, auto sampler, syringes, analytical columns, and gases. The capillary column is directly coupled with the source.

6.1.2 Column 1 - 30m x 0.25mm ID with a 0.25µm film thickness silicon-coated fused silica capillary column (Phenomonex ZB-5MS or equivalent).

6.1.3 Column 2 – J&W 30m x 0.25mm x 0.5um film DB5MS or an equivalent is used. Ultrapure (99.999%) Helium gas is used for a mobile phase.

6.1.4 Syringes: Agilent (or equivalent) syringes sizes 10µL, 25µL, 50µL, 100µL and 1.0mL.

6.2 Mass spectrometer (HP-5973/5975 or equivalent) capable of scanning from 35 to 550 amu every 1 second, using 70 volts (nominal) electron energy in the electron impact ionization mode. The mass spectrum for decafluorotriphenylphosphine (DFTPP) must meet the applicable criteria in method 8270C, 8270D, 8270E or 525 when 50ng of DFTPP GC/MS tuning standard is injected.

6.3 GC/MS interface - The interface is capillary-direct into the mass spectrometer source.

6.4 Data system (HP Chemstation with Enviroquant) - A computer system is interfaced to the mass spectrometer. The system allows the continuous acquisition and storage of machine-readable media of all mass spectra obtained throughout the duration of the chromatographic program. The computer has software that can search any GC/MS data file for ions of a specific mass and that can plot such ion abundances versus time or scan number. This type of plot is defined as Extracted Ion Current Profile (EICP). The most recent version of the EPA/NIST Mass Spectral Library is also available

6.5 Volumetric flasks, Class A - Appropriate sizes with ground-glass stoppers.

6.6 Balance - Analytical, capable of weighing 0.0001g

7.0 REAGENTS AND STANDARDS

7.1 All reagents and standards must be recorded in the appropriate preparation log and assigned a unique number. See SOP #030230, *Standard Logger – Tree Operation*. Additional information regarding reagent preparation can be found in the Standards Logger (Tree) digital archive system. All spiking solutions and surrogate standard solutions should be replaced at least every 6 months or sooner if a problem is detected unless otherwise noted.

7.2 Reagent grade inorganic chemicals are used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.3 Organic-free reagent water - all references to water in this method refer to organic-free reagent water (ASTM II or equivalent).

7.4 Burdick & Jackson Omni Solv Dichloromethane Dx0831-1 (or equivalent).

7.5 Stock standard solutions - Standard solutions are purchased as certified solutions. Commercially–prepared stock standards are used at concentrations that are certified by the manufacturer or by an independent source.

7.6 Stock standard solutions

7.6.1 Restek 8270 MegaMix – 31850, or equivalent, at 1000ppm

7.6.2 Agilent ULTRAgold Custom Standard – CUS-28559, at 1000ppm

7.6.3 NSI Lab Solutions Custom BNA Mix – Q6330, or equivalent, at 2000ppm

7.6.4 Restek Custom a-Terpineol/Quinoline Standard – 572011, or equivalent, at 2000ppm

7.6.5 Restek 8270 Benzidines Mix #2 – 31852, or equivalent, at 1000ppm

7.6.6 Restek Benzoic Acid Mix – 31879, or equivalent, at 2000ppm

7.6.7 NSI Lab Solutions 8270 BNA Mix – C-701, or equivalent, at 1000ppm

7.6.8 Phenova Custom 8270 Appendix IX Mix – ALO-130094, or equivalent, at 1000ppm

7.6.9 Phenova Benzidines Standard – ALO-101244, or equivalent, at 2000ppm

7.6.10 Phenova Benzoic Acid Mix – ALO-101246, or equivalent, at 2000ppm

7.6.11 Phenova Custom Appendix IX Mix 2 – ALO-130203, or equivalent, at 2000ppm

7.6.12 Phenova Methapyrilene – ALO-130204, or equivalent, at 2000ppm

7.6.13 Phenova Hexachlorophene – ALO-130233, or equivalent, at 4000ppm

7.6.14 Phenova Custom Appendix IX Mix 1 – ALO-130202, or equivalent, at 2000ppm

7.6.15 Phenova 8270 OP Pesticides Mix – ALO-101256, or equivalent, at 2000ppm

7.6.16 Phenova 1,4-Dioxane – ALO-101313, or equivalent, at 2000ppm

7.6.17 Restek 1,4-Dioxane – 31853, or equivalent, at 2000ppm

7.6.18 Phenova Benezenethiol – ALO-130085, or equivalent, at 1000ppm

7.6.19 Phenova Sulfolane Mix – ALO-130201, or equivalent, at 800ppm

7.6.20 Restek Sulfolane Standard – 36413, or equivalent, at 800ppm

7.6.21 Restek Custom BNA Subgroup Standard #1 – 574999, or equivalent, at 200ppm

7.6.22 Agilent ULTRAgold Custom Standard – CUS-23897, or equivalent, at 1000ppm

7.6.23 Agilent ULTRAgold Custom Standard – CUS-23952, or equivalent, at 1000ppm

7.6.24 Restek TX TPH Calibration Mix – 569373, or equivalent, at 10000ppm

7.6.25 AccuStandard Tetraethyl Lead – S-1263, or equivalent at 200ppm

7.7 Transfer the stock standard solutions into bottles with PTFE-lined screw caps. Store, protected from light, at –10°C or less or as recommended by the standard manufacturer. Stock standards should be checked frequently for signs of degradation or evaporation, especially just prior to preparing calibration standards from them. Stock standards are assigned a 6-month expiration date from the day that a sealed ampoule is opened. Standards are discarded if signs of degradation are apparent when compared to a second source standard.

STANDARD NAME	TOTAL VOLUME (mL)	RECIPE
BNA INTERNAL STANDARD	10	Open Ampule - No dilution required, Custom BNA Internal Standard, NSI Lab Solutions, Cat. No. Q-6343-O
1,4-DIOXANE-D8 IS @ 50ppm	10	250uL 1,4-Dioxane-d8 Standard, Restek, 30614 9.75mL Methylene Chloride
NDMA-D6 IS @ 50ppm	10	500uL 521 Surrogate Std., Restek, Cat. No. 33910 9.5mL Methylene Chloride
TUNE @ 50ppm	10	500uL GC/MS tuning std, Accu Standard, Cat. No. M-625-TS-20X 9.5mL Methylene Chloride
TUNE @ 10ppm	10	100 uL GC/MS tuning std, Accu Standard, Cat. No. M-625-TS-20X 9.9 mL Methylene Chloride
8270 PRIMARY INT @ 200ppm	10	2mL 8270 MegaMix, Restek, Cat. No. 31850 2mL ULTRAgold Custom Standard, Agilent, Cat. No. CUS-28559 6mL Methylene Chloride
8270 TCL INT @ 200ppm	10	1mL Custom BNA Mix, NSI Lab Solutions, Cat. No. Q6330 1mL Custom a-Terpineol/Quinoline Standard, Restek, Cat. No. 572011 1mL 8270 Benzidines Mix #2, Restek, Cat. No. 31852 1mL Benzoic Acid Mix, Restek, Cat. No. 31879 6mL Methylene Chloride
8270 SVMS SSCV @ 10ppm	1	10uL 8270 BNA Mix, NSI Lab Solutions, Cat. No. C-701 10uL ULTRAgold Custom Standard, Agilent, CUS-28559 980uL Methylene Chloride
8270 TCL SSCV @ 200ppm	10	2mL Custom 8270 Appendix IX Mix, Phenova, Cat. No. ALO-130094 1mL Benzidines Standard, Phenova, ALO-101244 1mL Benzoic Acid Mix, Phenova, ALO-101246 1mL Custom Appendix IX Mix 2, Phenova, Cat. No. ALO-130203 5mL Methylene Chloride
8270 TCL SSCV @ 10ppm	1	100uL 8270 TCL SSCV @ 200ppm, 900uL Methylene Chloride
SVAM INT @ 200ppm	10	1mL Custom Appendix IX Mix 2, Phenova, ALO-130203 1mL Methapyrilene, Phenova, Cat. No. ALO-130204 1mL Hexachlorophene, Phenova, Cat. No. ALO-130233 7mL Methylene Chloride
SVAP INT @ 200ppm	10	1mL Custom Appendix IX Mix 1, Phenova, Cat. No. ALO-130202 9mL Methylene Chloride
SVOP INT @ 200ppm	10	1mL 8270 OP Pesticides Mix, Phenova, Cat. No. ALO-101256 9mL Methylene Chloride

NDMA/1,4-DIOXANE INT @ 20ppm	10	100uL 1,4-Dioxane, Phenova, Cat. No. ALO-101313 1mL 8270 Primary Int. @ 200ppm, 8.9mL Methylene Chloride
NDMA/1,4-DIOXANE INT @ 2ppm	5	500ul NDMA/1,4-Dioxane Int @ 20 4.5mL Methylene Chloride
1,4-DIOXANE SSCV @ 200ppm	10	1mL 1,4-Dioxane, Restek, Cat. No. 31853 9mL Methylene Chloride
1,4-DIOXANE SSCV @ 10ppm	10	500uL 1,4-Dioxane SSCV @ 200pm 9.5mL Methylene Chloride
NDMA SSCV @ 10ppm	10	100uL 8270 BNA Mix, NSI Lab Solutions, Cat. No. C-701 9.9mL Methylene Chloride
BENZENETHIOL CAL INT @ 100ppm	10	1mL Benzenethiol, Phenova, Cat. No. ALO-130085 1mL Ultragold Custom Standard, Agilent, CUS-28559 8mL Methylene Chloride
BENZENETHIOL SSCV @ 100ppm	10	1mL Benzenethiol, Phenova, Cat. No. ALO-130085 9mL Methylene Chloride
SULFOLANE CAL INT @ 50ppm	10	625uL Sulfolane Mix, Phenova, Cat. No. ALO-130201 500uL Ultragold Custom Standard, Agilent, CUS-28559 8.875mL Methylene Chloride
SULFOLANE SSCV @ 50ppm	10	625uL Sulfolane, Restek, Cat. No. 36413 9.375mL Methylene Chloride

7.8 Internal standards solutions- the internal standards are naphthalene-d8, acenaphthene-d10, phenanthrene-d10, chrysene-d12, perylene-d12 and 1-4 dichlorobenzene-d4. Purchase from NSI (Cat # Q-6343-O) as certified stock solution at 800µg/mL. Alternative internal standard concentrations may be used for LVI work. Internal standard intermediates at 16µg/mL and 4µg/mL are prepared for spiking, RV/LVI 8270PAHand RV/LVI 8270SIM analyses, respectively.

7.8.1 For all concentrated soil and 8270 full run water reduced volume extracts, use the 8000µg/mL internal standard solution. Each sample extract undergoing analysis is spiked with 5µL of internal standard intermediate solution, resulting in a concentration of 8µg/mL of each internal standard.

7.8.2 For non-concentrated soil, reduced volume water and 3511 water analyses, including PAH and DROMO, use the 16µg/mL ISTD intermediate. For non-concentrated soil, reduced volume and EPA 3511 water extracts being analyzed by the SIM process, use the 4µg/mL ISTD intermediate. Each sample extract undergoing analysis is spiked with 10µL of the appropriate internal standard intermediate solution, resulting in a concentration of 160µg/L and 40µg/L, respectively, for each internal standard.

7.9 Using a volumetric syringe, measure each of the solutions listed in Section 7.9 and place into a 10mL volumetric flask.

7.10 Preparation of Working Standards

Standards must be stored at ≤6°C. The expiration date of any working standard will be 6 months unless the manufacturer’s stock expires prior to that date or if the standard starts showing signs of degradation. See section 7.11.1 through 7.11.6 for preparation instructions. Concentrations of standards used are subject to change depending on instrument condition, client needs and sample preparation method of the variety of analysis being performed. A minimum of five calibration levels is required for Method 8270C and 8270D, while a minimum of 3 calibration levels is required for Method 625.

7.10.1 8270C/D/E Calibration standards for concentrated soil and 1L concentrated water extractions: A minimum of five calibration standards is prepared at different concentrations. At least one of the calibration standards must correspond to a sample concentration at or below the laboratory's reporting limit (RL). The remaining standards correspond to the working range of the GC/MS system. Each standard contains each analyte for detection. Working standards are made directly from the intermediate stock standard described in section 7.10 give solutions at concentrations of 0.2µg/mL up to 50µg/mL. Surrogates are included at the same concentrations. Internal standards are spiked at a constant concentration per extraction method for quantitation purposes.

SVOC mix (200ppm) µL	ISTD mix uL	Final volume	Final conc. ppm	Level
1	10	1.0mL	0.2	1
5	10	1.0mL	1	2
10	10	1.0mL	2	3
25	10	1.0mL	5	4
50	10	1.0mL	10	5
75	10	1.0mL	15	6
100	10	1.0mL	20	7
150	10	1.0mL	30	8
200	10	1.0mL	40	9
250	10	1.0mL	50	10

A minimum of 5 points are used to construct the calibration curve.

7.10.2 Calibration standards for 8270C/D/E reduced volume and EPA 3511 (soil and water) extracted samples: A minimum of five calibration standards is prepared at different concentrations. At least one of the calibration standards must correspond to a sample concentration at or below the laboratory-reporting limit (RL). The remaining standards correspond to the working range of the GC/MS system. Each standard contains each analyte for detection. Working standards are made directly from the intermediates described in section 7.9 to give solutions at concentrations of 0.01µg/mL up to 1µg/mL. Surrogates are included at the same concentrations. Internal standards are spiked at a constant of 160µg/L for quantitation purposes.

SVOC mix (2ppm) µL	ISTD mix uL	Final volume	Final conc. ppb	Level
5	10	1.0mL	10	1
25	10	1.0mL	50	2
50	10	1.0mL	100	3
100	10	1.0mL	200	4
200	10	1.0mL	400	5
300	10	1.0mL	600	6
400	10	1.0mL	800	7
500	10	1.0mL	1000	8

7.10.3 For SIM analyses concentrated soil and 1L water extractions**,** calibration standards are diluted from the intermediate standard solution (section 7.9.1) to give a calibration at the following concentrations: 20, 50, 100, 500, 1000, 2000, 4000, 10,000µg/L. A minimum of five calibration standards is prepared at different concentrations. At least one of the calibration standards must correspond to a sample concentration at or below the laboratory-reporting limit (RL). The calibration levels may change based on the working range of the GC/MS system. Surrogates are included at the same concentrations. The internal standards are at a constant 8µg/mL.

SIM Standard Concentration (ug/L)	Amount Added (uL) 5µg/mL Int.	Final Volume (mL)
20	2.0	1.0
50	5.0	1.0
100	10.0	1.0
500	50.0	1.0
1000	100.0	1.0
2000	200.0	1.0
4000	400.0	1.0
10000	1000.0	1.0

7.10.4 For SIM analyses using reduced volume, non-concentrated soil, or EPA 3511 extracts**,** calibration standards are diluted from the intermediate standard solution (section 7.9.3) to give a calibration at the following concentrations: 1, 5, 10, 20, 40, 80, 200µg/L. A minimum of five calibration standards is prepared at different concentrations. At least one of the calibration standards must correspond to a sample concentration at or below the laboratory-reporting limit (RL). The calibration levels may change based on the working range of the GC/MS system. Surrogates are included at the same concentrations. The internal standards are at a constant 40µg/L.

SIM RV 3511 Standard Concentration (ug/L)	Amount Added (uL) 200µg/L Int.	Final Volume (mL)
1	5	1.0
5	25	1.0
10	50	1.0
20	100	1.0
40	200	1.0
80	400	1.0
200	1000	1.0

7.10.5 For Missouri DRO analysis by 3511 and non-concentrated soil, prepare the working calibration curve as reflected in the following table.

DROMO mix (200ppb) µL	Final Volume	Final conc. (ppb)
25	1.0 mL	5
50	1.0 mL	10
100	1.0 mL	20
200	1.0 mL	40
400	1.0 mL	80
600	1.0 mL	120
800	1.0 mL	160

8.0 PROCEDURE

STATE NOTE: For samples analyzed in conjunction with the Ohio VAP program, the criteria found and itemized in this procedure for EPA method 8270C must be utilized. Alternative GCMS tuning criteria from that specified in EPA 8270C is acceptable as permitted in Section 7 of the published method.

8.1 GC Conditions: The GC conditions are listed in each instrument maintenance log and are updated as necessary.

8.1.1 Due to the tuning and calibration requirements outlined in this method, a liner change is necessary prior to beginning an analytical sequence. Any additional maintenance performed on the instrumentation will be documented as performed in the specific instrument maintenance log. (i.e., column clip/change, septa change, inlet cleaning, detector cleaning/maintenance, etc.)

8.2 Mass Spectrometer Tuning Criteria: The GC/MS is hardware-tuned using a 50ng (or less) injection of DFTPP. Analyses must not begin until the tuning criteria are met. It is recommended that each initial tune verification utilize the “Autofind” function and be set up to look at three scans (the apex & ±1 scan) and average the three scans then perform background subtraction. If Autofind is not utilized, select the mass spectrum at the peak apex for evaluation, or use an average mass spectrum across the entire DFTPP peak. Background subtraction is required prior to the start of the peak but no more than 20 scans prior. Background correction cannot include any parts of the target peak. The scans must be averaged and background corrected.

The mass spectrometer must be tuned every 12 hours if samples, standards, etc. are to be analyzed for Methods 8270C, 8270D and 625.1. The mass spectrometer must be tuned prior to initial calibration only when samples, standards, etc. are to be analyzed for Method 8270E. ESC uses 8270D evaluation criteria per method allowances.

TABLE 8.2
Method 8270D
DFTPP Key Ions And Ion Abundance Criteria[a, b]

Mass	Ion Abundance Criteria
51	10-80% of mass 198
68	<2% of mass 69
70	<2% of mass 69
127	10-80% of mass 198
197	<2% of mass 198
198	Base peak, or >50% of mass 442
199	5-9% of mass 198
275	10-60% of mass 198
365	>1% of mass 198
441	Present, but <24% of mass 442
442	Base peak, or >50% of mass 198
443	15-24% of mass 442

(a) Data taken from Table 3 in SW-846 Method 8270D.
(b) Alternate tuning criteria may be used (e.g., CLP, Method 525, or manufacturers' instructions), providing that method performance is not adversely affected.

STATE NOTE: All South Carolina samples require a tune every 12 hours, regardless of which method is being utilized.

The GC/MS tuning standard solution must also be used to assess GC column performance and injection port inertness. Degradation of DDT to DDE and DDD is used to assess breakdown occurring in the injection port. The calculation for the determination of the breakdown occurring is found in section 9.1 and must include both DDD and DDE. Breakdown must not exceed 20%. Benzidine and pentachlorophenol total ion chromatogramsl are used to assess tailing occurring within the analytical system and both analytes should be present at their normal responses with no obvious peak tailing. To determine the tailing factor for benzidine and pentachlorophenol, use the calculation found in section 9.2. For EPA Methods 625 and 8270C, benzidine must have a tailing ratio of <3 and pentachlorophenol must have a tailing ratio of <5. For EPA Method 8270D and 625.1, benzidine and pentachlorophenol must have a tailing ratio of <2. The Missouri diesel method does not require tailing or degradation checks prior to or during analysis.

8.3 The use of selected ion monitoring (SIM) is acceptable for applications requiring quantitation limits below the normal range of electron impact mass spectrometry. However, SIM may provide a lesser degree of confidence in the compound identification since less mass spectral information is available. Using the primary ion for quantitation and the secondary ions for confirmation set up the collection groups based on their retention times. The selected ions are nominal ions and most compounds have small mass defect, usually less than 0.2 amu, in their spectra. These mass defects should be used in the acquisition table. The dwell time may be automatically calculated by the laboratory’s GC/MS software or manually calculated using the following formula. The total scan time should be less than 1,000 msec and produce at least 5 to 10 scans per chromatographic peak. The start and stop times for the SIM groups are determined from the full scan analysis using the formula below: Additional guidance for performing SIM analyses, in particular for PAHs and phenol target analyte compounds, can be found in the most recent CLP semivolatile organic methods statement of work (SOW). See the SIM sections from the following CLP SOW for further details: EPA CLP Organics SOW. (Reference 14)

SIM Groups for PAHs and including pentachlorophenol, hexachlorobenzene and tetraethyllead

SIM Group	1	2	3	4	5	6	7	8
RT start	Solvent delay	Before 2-Methyl naphthalene	Before Acenaph-thalene	Before Fluorene	Before Fluor-anthene	Before Benzo (a)-anthracene	Before Benzo (b)-fluoranthene	Before Dibenz (a,h-)anthracene
Ions	82, 128, 129, 136, 137, 237, 295	127, 141, 142, 162, 171, 172	139, 151, 152, 153, 154, 162, 164, 168	94, 165, 166, 176, 178, 179, 188, 264, 266, 268, 282, 284, 286	200, 202, 203, 244, 245	226, 228, 229, 240, 241	252, 253, 260, 264	138, 139, 276, 277, 278, 279
Dwell	40	35	25	30	40	50	75	50

8.4 Calibration

8.4.1 Initial Calibration

EPA Method 8270C: The working standards prepared in section 7.10 are injected and average response factors are calculated. The calibration curve is typically constructed of six to nine standards, however, this may change depending on instrument conditions and/or client needs (see Section 13.4). See section 8.3.2 for information regarding use and deletion of calibration points.

The calibration check compounds (CCCs) listed in Section 8.3.1a must have an average percent relative standard deviation (%RSD) of less than or equal to 30%. Any target analyte that has a %RSD >15% for the RF must be calculated by linear or quadratic regression instead of RF. If the RSD of any target analyte is <u><</u>15%, the average response factor may be used for quantitation. When any compound does not meet the calibration criteria for RF, the analyst MUST use linear regression or quadratic curve fit. The calibration curve cannot be forced through zero and does not include a method blank. It must also meet a correlation coefficient of 0.995 or better. If a quadratic curve fit is used, a minimum of 6 calibration standards must be utilized to obtain a working calibration curve.

The system performance check compounds (SPCCs) in Table 8.3.1b must have an average RF of ≥0.05. When these criteria are met, samples can be analyzed.

Table 8.3.1a: Calibration Check Compounds (CCC)

Base/Neutral Fraction	Acid Fraction
Acenaphthene	4-Chloro-3-methylphenol
1,4-Dichlorobenzene	2,4-Dichlorophenol
Hexachlorobutadiene	2-Nitrophenol
n-Nitrosodiphenylamine	Phenol
Di-n-octyl phthalate	Pentachlorophenol
Fluoranthene	2,4,6-Trichlorophenol
Benzo(a)pyrene	

Table 8.3.1b: System Performance Check Compounds (SPCC)

Compound	*Minimum Average Response Factor*
n-Nitroso-di-n-propylamine	>0.05
Hexachlorocyclopentadiene	>0.05
2,4-Dinitrophenol	>0.05
4-Nitrophenol	>0.05

EPA Method 8270D/E: The working standards prepared in section 7.10 are injected and average response factors are calculated. The calibration curve is typically constructed of six to nine standards, however, this may change depending on instrument conditions and/or client needs (see section 13.4). At least five standards are required for Response Factor and linear regression calibration. If a quadratic curve fit is used, a minimum of 6 calibration standards must be utilized to obtain a working calibration curve. See section 8.3.2 for information regarding use and deletion of calibration points.

Target analytes must have an average RSD of ≤20%. Any target analyte that has a %RSD >20% for the RF must be calculated by linear or quadratic regression instead of RF. If the RSD of any target analyte is ≤20%, the average response factor may be used for quantitation. When any compound does not meet the calibration criteria for RF, the analyst MUST use linear regression or, if permitted, quadratic curve fit. The calibration curve cannot be forced through zero. It must also meet a correlation coefficient of 0.995 or better.

8270D RF evaluation: In addition to the minimum %RSD criteria, it is recommended that a minimum response factor for the most common target analytes be demonstrated for each individual calibration level to ensure that these compounds are performing as expected. See Table 8.3.1c. Meeting the minimum response factor criteria for the lowest calibration standard is critical in establishing and demonstrating the desired sensitivity.

8270E RF evaluation: In addition to the minimum %RSD criteria, it is recommended that a minimum response factor for the most common target analytes be demonstrated for each individual calibration level to ensure that these compounds are performing as expected. See Table 8.3.1c. Because the minimum RFs in Table 8.3.1c were determined using specific ions and instrument conditions that may vary, it is neither expected nor required that all analytes meet these minimum RFs. The information is provided as guidance only. The laboratory should establish procedures in its SOP (e.g., laboratory established minimum RFs, signal-to-noise (S/N) checks, etc.) to ensure that the instrument is working properly and that calibration standards were correctly prepared.

Table 8.3.1c: Recommended Minimum Response Factors for Each Calibration Level (Initial and Continuing Calibration)

Compound	***Minimum Response Factor***	***Compound***	***Minimum Response Factor***
Benaldehyde	0.010	Bis(2-chloroethoxy)methane	0.300
Phenol	0.800	2,4-Dichlorophenol	0.200
Bis(2-chloroethyl)ether	0.700	Naphthalene	0.700
2-Chlorophenol	0.800	4-Chloroaniline	0.010
2-Methylphenol	0.700	Hexachlorobutadiene	0.010
2,2-Oxybis-(1-chloropropane)	0.010	Caprolactam	0.010
Acetophenone	0.010	4-Chloro-3-methylphenol	0.200
4-Methylphenol	0.600	2-Methylnaphthalene	0.400
n-Nitroso-di-n-propylamine	0.500	Hexachlorocyclopentadiene	0.050
Hexachloroethane	0.300	2,4,6-Trichlorophenol	0.200
Nitrobenzene	0.200	2,4,5-Trichlorophenol	0.200
Isophorone	0.400	1,1-Biphenyl	0.010
2-Nitrophenol	0.100	2-Chloronaphthalene	0.800
2,4-Dimethylphenol	0.200	2-Nitroaniline	0.010

Compound	***Minimum Response Factor***
Dimethyl phthalate	0.010
2,6-Dinitrotoluene	0.200
Acenaphthylene	0.900
3-Nitroaniline	0.010
Acenaphthene	0.900
2,4-Dinitrophenol	0.010
4-Nitrophenol	0.010
Dibenzofuran	0.800
2,4-Dinitrotoluene	0.200
Diethyl phthalate	0.010
1,2,4,5-Tetrachlorobenzene	0.010
4-Chlorophenyl-phenyl ether	0.400
Fluorene	0.900
4-Nitroaniline	0.010
4,6-Dinitro-2-methylphenol	0.010
4-Bromophenyl-phenyl ether	0.100
n-Nitrosodiphenylamine	0.010
Hexachlorobenzene	0.100
Atrazine	0.010
Pentachlorophenol	0.050

Compound	***Minimum Response Factor***
Phenanthrene	0.700
Anthracene	0.700
Carbazole	0.010
Di-n-butyl phthalate	0.010
Fluoranthene	0.600
Pyrene	0.600
Butyl Benzyl phthalate	0.010
3,3-Dichlorobenzidine	0.010
Benzo(a)anthracene	0.800
Chrysene	0.700
Bis (2-ethylhexyl)phthalate	0.010
Di-n-octyl phthalate	0.010
Benzo(b)fluoranthene	0.700
Benzo(k)fluoranthene	0.700
Benzo(a)pyrene	0.700
Indeno(1,23-c,d)pyrene	0.500
Dibenz(a,h)anthracene	0.400
Benzo(g,h,i)perylene	0.500
2,3,4,6-Tetrachlorophenol	0.010

EPA 8270C GC/MS SIM: When analyzing samples using SW-846 8270C SIM, all target compounds must be treated as CCCs and must have an average RSD of ≤30%.

EPA 8270D GC/MS SIM: If analyzing samples by EPA 8270D SIM, follow the initial calibration criteria for the specified referenced method as found in section 8.3.1 (EPA Method 8270D).

EPA 8270E GC/MS SIM: If analyzing samples by EPA 8270E SIM, follow the initial calibration criteria for the specified referenced method as found in section 8.3.1 (EPA Method 8270E).

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EPA Method 625.1: One of the calibration standards should be at a concentration at or below the reporting limit. The resulting calibration must meet all applicable acceptance criteria in Section 10, based on the RSD, RSE, or r^2. The concentrations of the other calibration standards should correspond to the expected range of concentrations found in real samples or should define the working range of the GC/MS system for full-scan and/ or SIM operation, as appropriate. A minimum of six concentration levels is required for a second order, non-linear (i.e., quadratic) calibration.

Calculate the mean (average) and relative standard deviation (RSD) of the responses factors. If the RSD is less than 35%, the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to fit a linear or quadratic regression of response ratios, As/Ais, vs. concentration ratios Cs/Cis. If used, the regression must be weighted inversely proportional to concentration. The coefficient of determination (r^2) of the weighted regression must be greater than 0.920 (this value roughly corresponds to the RSD limit of 35%). Alternatively, the relative standard error (RSE) may be used as an acceptance criterion. As with the RSD, the RSE must be less than 35%. If an RSE less than 35% cannot be achieved for a quadratic regression, system performance is unacceptable and the system must be adjusted and re-calibrated.

All Published Methods: Reference spectra must be updated upon analysis of each new calibration curve.

Linear Regression Weighting: As an alternative to calculating mean response factors and applying the RSD test, use the GC/MS data system software or other available software to generate a linear or second order regression calibration curve, by plotting A/A(is) vs. Q(x) using the equations found in section 9.4. Either equal weighting factors or 1/x regressions may be used.

STATE NOTE: For all Minnesota sample analyses, the RL level standard is re-injected and quantitated against the newly updated calibration curve or the applicable standards are reprocessed (re-quantitated) using the completed calibration curve and is evaluated for the ±40% deviation criterion with the exception of the listed poor performers in this procedure.

STATE NOTE: For all Wisconsin sample analyses, analysts must evaluate the %RSD of calibrations to ensure that they do not have unacceptable curvature. The %RSD limit criteria, as found in the specific methods listed above, applies to calibrations using average RF calibrations. For linear and quadratic curve fits, a limit of 40% RSD is used for normal target analytes and 50% RSD is utilized for known poor performing compounds.

STATE NOTE: When analyzing samples in conjunction with the Ohio VAP or South Carolina DHEC programs, the calibration model must be RSD or linear. Quadratic curve modeling is not permitted unless historical performance of analytes exhibited a nonlinear response (i.e., Benzoic Acid and problematic phenols). Quadratic models cannot be used to extend the calibration range or bypass instrument maintenance.

8.4.2 CALIBRATION POINTS – Usage and Deletion

When the appropriate number of calibration standards is used, all points must be considered in the average response factor calculation or linear regression calculation. The deletion of the highest point is acceptable when necessary, with the analyst noting that the high end of the calibration has been lowered. The deletion of the lowest calibration point is acceptable, when necessary, provided that the analyst notes the deletion on the injection log and raises the reporting limit, if necessary, for that compound.

8.4.3 **EPA Method 8270D/E:** LINEAR REGRESSION USE – The method of linear regression calibration has the potential for a significant bias to the lower portion of the calibration model. This bias is not normally seen in relative percent difference methods. When utilizing linear regression fits, a minimum quantitation check on the viability of the lowest calibration point should be performed by re-fitting the response from the lowest concentration standard back into the completed calibration curve. It is not necessary to re-analyze a low concentration standard, but using the analytical system software, the low standard can be re-quantitated as if it were a field sample. The recalculated concentrations of the analytes utilizing the linear regression curve fit must be within ±50% of the true standard concentration.

STATE NOTE: For the analysis of South Carolina samples, all target analytes, including Hexachlorophene, is required to utilize linear regression. Quadratic curve fit is not allowed. To achieve this, the calibration curve may be modified by the removal of the lowest two levels and will utilize calibration levels of 60, 80, 100, 120, and 140 for quantitation of this analyte in South Carolina samples. The reporting limit (RL) for South Carolina will routinely be 100ppb for water samples.

8.4.4 Quadratic Regression: Quadratic regression may be used for the following compounds: Pentachlorophenol, 4-Nitrophenol, 2,3,4,6-Tetrachlorophenol, 4,6-Dinitro-2-methylphenol, 2,4-Dinitrophenol. Plots must have a minimum of 6 points and a correlation coefficient of 0.995 or better.

STATE NOTE: Quadratic curve modeling is not permitted for samples originating in South Carolina or for samples reported for the Ohio VAP unless historical performance of analytes exhibited a nonlinear response (e.g., Benzoic Acid).

8.4.5 Second Source Calibration Verification – the initial calibration for each target analyte must be checked with a standard from a source that is different from those used for initial calibration.

8.4.6 **Daily Tuning and Continuing Calibration**

8270E: Daily analysis of the GC/MS tune check solution is not required as part of the CCV. The analyst should, however, closely monitor chromatography as well as target and IS responses in the CCV for deterioration in the system.

8270C/D, 625.1: As with the initial calibration, the system must be tuned with 50ng of DFTPP or less to meet the acceptance criteria found in section 8.1. Following successful tuning, the midpoint level standard (CCV) is analyzed. Calibration verification for each method, as listed below, must be met prior to the analysis of field samples and every 12 hours for 8270C/D and every 24 hours for EPA 625 (see the method note in Section 8.2 for Method 625.1 requirements).

EPA Method 8270C: The percent difference of the CCCs (see Table 8.3.1a & b) in the mid-level standard must be ≤20% and the SPCCs must have an RF ≥0.05. The retention time of the internal standards must be within ±30 seconds from the mid-point standard level of the last initial calibration curve and the area response must be within –50% to +100%. Once these criteria are met, samples can be analyzed.

EPA Method 625.1: The RF or calibration curve must be verified immediately after calibration and at the beginning of each 12-hour shift, by analysis of a standard at or near the concentration of the mid-point calibration standard. The standard(s) must be obtained from a second manufacturer or a manufacturer's batch prepared independently from the batch used for calibration. Include the surrogates in this solution. It is necessary to verify calibration for the analytes of interest only.

Compare the recoveries for the analytes of interest against the acceptance criteria for recovery (Q) in Attachment VII and the recoveries for surrogates against the acceptance criteria in Attachment VIII. If recovery of the analytes of interest and surrogates meet acceptance criteria, system performance is acceptable and analysis of samples may continue. If any individual recovery is outside its limit, system performance is unacceptable for that analyte.

EPA Methods 8270C and 625 (analyzed concurrently): The CCV must be evaluated for CCC and SPCCs as per EPA Method 8270C requirements. All non-CCC and other target analytes must meet the criteria established in Method 625 for all analytes (±20%). For analytes not contained in the Method 625 analyte list, the analyst evaluates the CCV and the experience of the analyst weighs heavily in determining the usability of the data.

STATE NOTE: For all Wisconsin sample analyses, non-CCC compounds for 8270C requires a ±50% criteria for the CCV.

EPA 8270C GC/MS SIM: When analyzing samples using SW-846 EPA 8270C SIM, all compounds in the CCV must be treated as CCCs and must meet the minimum requirements of ≤20% difference.

EPA 8270D GC/MS SIM: If analyzing samples by EPA 8270D SIM, follow the initial calibration criteria for the specified referenced method as found in section 8.3.6 (EPA Method 8270D below).

EPA 8270E GC/MS SIM: If analyzing samples by EPA 8270E SIM, follow the initial calibration criteria for the specified referenced method as found in section 8.3.6 (EPA Method 8270E below).

EPA Method 8270D: Each of the most common target analytes in the CCV must meet the minimum response factors in Table 8.3.1c. When using the average RF, the percent difference for each target compound in the CCV must be ≤20%. When using regression fit calibration, the percent drift of the CCV must be ≤20%. The retention time of the internal standards must be within ±30 seconds from the mid-point standard level of the last initial calibration curve and the area response must be within –50% to +100%.

EPA Method 8270E: Each of the most common target analytes in the CCV may but is not required to meet the minimum response factors in Table 8.3.1c. When using the average RF, the percent difference for each target compound in the CCV must be ≤20%. When using regression fit calibration, the percent drift of the CCV must be ≤20%. The retention time of the internal standards must be within ±30 seconds from the mid-point standard level of the last initial calibration curve and the area response must be within –50% to +100%.

8.4.7 For corrective action regarding tuning and calibration, see sections 11.1 and 11.2.

8.5 Method Blank Analysis – A method blank should be analyzed prior to any field sample analysis to verify that the analytical system is free from contaminants. If the method blank indicates that contamination may be present in the analytical system, it may be necessary to analyze a solvent blank to demonstrate the source of the contamination is not carryover from standards or lingering field sample artifacts.

8.6 GC/MS analysis of field samples and preparation QC.

8.6.1 It is highly recommended that the extracts be screened on a GC/FID or GC/PID using the same type of capillary column used in the GC/MS system. This will minimize contamination of the GC/MS system from unexpectedly high concentrations of organic compounds.

8.6.2 Allow the extracts to warm to room temperature. Just prior to analysis, add 10µL of the internal standard solution to the 1mL concentrated extract or 5µL of the internal standard solution to the 0.5mL extract obtained from sample preparation.

8.6.3 If the response for any quantitation ion exceeds highest level of the initial calibration range, the extract must be diluted and re-analyzed. Additional internal standard must be added to the diluted extract to maintain the same concentration as in the calibration standards (0.04, 0.16 or 8ng/uL, unless a more sensitive GC/MS system is being used). For example, if performing a 1:10 dilution on a concentrated extract, take 100uL of the extract and dilute to a volume of 1mL with the appropriate solvent. Add 9uL of the appropriate internal standard solution to the diluted extract and inject on the analytical system. It can be assumed that 1uL of internal standard was contained in the 100uL extract used for the initial dilution.

8.6.4 Internal standard area counts and retention times must be monitored in all samples, spikes and method blanks to monitor system performance, check for drifting, ensure effective autosampler performance, etc. If the area of the Extracted Ion Current Profile (EICP) changes by a factor of 2 (-50% to +100%) from the areas in the daily CCV, corrective action is required. The RRT of the internal standard in the extract must be within ± 0.06RRT units of the RRT of the daily CCV.

STATE NOTE: With each new calibration curve, a reporting limit verification (RLV) standard must be analyzed for samples analyzed from Minnesota. This standard consists of either re-injecting the low calibration standard(s) or re-processing the low standard(s) utilized in the construction of the calibration curve. The RLV must recover within ±40% of the expected concentration. See section 11.10 for additional information.

8.7 Qualitative Identification

8.7.1 The qualitative identification of compounds determined by this method is based on retention time and on comparison of the sample mass spectrum, after background correction, with characteristic ions in a reference mass spectrum. The reference mass spectrum must be generated by the laboratory using the conditions of this method. The characteristic ions from the reference mass spectrum are defined as the three ions of greatest relative intensity, or any ions over 30% relative intensity if less than three such ions occur in the reference spectrum. Retention time windows for internal standards and target compounds integrations are updated with each calibration curve and after any instrument maintenance occurs that causes a shift that may affect ChemStation integrations.

8.7.1.1 The intensities of the characteristic ions of a compound must maximize in the same scan or within one scan of each other. Selection of a peak by a data system target compound search routine where the search is based on the presence of a target chromatographic peak containing ions specific for the target compound at a compound-specific retention time will be accepted as meeting this criterion.

8.7.1.2 The RRT of the sample component is within ± 0.06RRT units of the RRT of the standard component.

8.7.1.3 The relative intensities of the characteristic ions agree within 30% of the relative intensities of these ions in the reference spectrum.

(EXAMPLE: For an ion with an abundance of 50% in the reference spectrum, the corresponding abundance in a sample spectrum can range between 20% and 80%). Analyst experience is vital in this determination when interferences are present.

8.7.1.4 Structural isomers that produce very similar mass spectra should be identified as individual isomers if they have sufficiently different GC retention times. Sufficient GC resolution is achieved if the height of the valley between the two isomers is <50% of the average of the two peak heights (for Method 8270D/E) and <25% of the sum of the two peak heights (for Methods 8270C & 625). Otherwise, structural isomers are identified as isomeric pairs.

8.7.1.5 Identification is hampered when sample components are not resolved chromatographically and produce mass spectra containing ions contributed by more than one analyte. When gas chromatographic peaks obviously represent more than one sample component (i.e., a broadened peak with shoulder(s) or a valley between two or more maxima), appropriate selection of analyte spectra and background spectra is important.

8.7.1.6 Examination of extracted ion current profiles of appropriate ions can aid in the selection of spectra, and in qualitative identification of compounds. When analytes co-elute (i.e., only one chromatographic peak is apparent), the identification criteria can be met, but each analyte spectrum will contain extraneous ions contributed by the co-eluting compound.

8.7.1.7 Absolute retention times are used for compound identification in all GC methods that do *not* employ internal standard calibration. Retention time windows are established to compensate for minor shifts in absolute retention times as a result of sample loadings and normal chromatographic variability. The width of the retention time window should be carefully established to minimize the occurrence of both false positive and false negative results. Tight retention time windows may result in false negatives and/or may cause unnecessary reanalysis of samples when surrogates or spiked compounds are erroneously not identified. Overly wide retention time windows may result in false positive results that may not be confirmed.

8.7.1.7.1 Before establishing retention time windows, make sure that the chromatographic system is operating reliably and that the system conditions are optimized for the target analytes and surrogates in the sample matrix to be analyzed. Make three injections of all standard mixtures over the course of a 72-hour period. Serial injections or injections over a period of less than 72 hours may result in retention time windows that are too tight.

8.7.1.7.2 Record the retention time (in minutes) for each single component analyte and surrogate to three decimal places. Calculate the mean and standard deviation of the three absolute retention times for each single component analyte and surrogate. For multi-component analytes, choose three to five major peaks (see the determinative methods for more details) and calculate the mean and standard deviation of those peaks.

8.7.1.7.3 If the standard deviation of the retention times for a target compound is 0.000 (i.e., no difference between the absolute retention times), then either collect data from additional injections of standards or use a default standard deviation of 0.01 minutes.

8.7.1.7.4 The width of the retention time window for each analyte, surrogate, and major constituent in multi-component analytes is defined as ± 3 times the standard deviation of the mean absolute retention time established during the 72-hour period or 0.03 minutes, whichever is greater.

8.7.1.7.5 Establish the center of the retention time window for each analyte and surrogate by using the absolute retention time for each analyte and surrogate from the calibration verification standard at the beginning of the analytical shift. For samples run during the same shift as an initial calibration, use the retention time of the mid-point standard of the initial calibration.

8.7.1.7.6 Calculate absolute retention time windows for each analyte and surrogate on each chromatographic column and instrument. New retention time windows must be established when a new GC column is installed or if a GC column has been shortened during maintenance.

8.8 TICs – Tentatively Identified Compounds

Periodically, clients may request the tentative identification of compounds present in the field sample that are not normal target compounds and are not normally calibrated. This identification is limited to the compounds in the current NBS (National Bureau of Standards) mass spectral library employed by ESC.

Library Search Identification – For samples containing components not associated with the calibration standards, a library search may be made for the purpose of a tentative identification. Data system library searches must not use normalization routines that would misrepresent the library or unknown spectra when making comparisons. For example, the RCRA permit or waste delisting requirements may require the reporting of non-target analytes. The analyst may only assign tentative identifications after visual comparison of sample spectra with the nearest library searches.

Guidelines for tentative identification are:

- Relative intensities of major ions in the reference spectrum (ions >10% of the most abundant ion) should be present in the sample spectrum.
- The relative intensities of the major ions should agree within ±20%. (EXAMPLE: For an ion with an abundance of 50% in the standard spectrum, the corresponding sample ion abundance must be between 30% and 70%).
- Molecular ions present in the reference spectrum should be present in the sample spectrum.
- Ions present in the sample spectrum but not in the reference spectrum should be reviewed for possible background contamination or presence of co-eluting compounds.
- Ions present in the reference spectrum but not in the sample spectrum should be reviewed for possible subtraction from the sample spectrum because of background contamination or co-eluting peaks. Data system library reduction programs can sometimes create these discrepancies.

Routinely, ESC employs a minimum Q value of 80 for tentative identifications and a minimum concentration of 10ppb. Peaks below a Q value of 80 but above 10ppb are reported as “Unknown”. Any identified peaks below 10ppb are removed as these could result from baseline noise or other interferences, not necessarily attributable to the field sample or reliably quantifiable using GCMS technology. Additionally, any peaks that are attributable to instrument contamination (I.e., siloxanes) are also removed.

8.9 Quantitative analysis

8.9.1 Once a compound has been identified, the quantitation of that compound will be based on the integrated abundance of the primary characteristic ion from the EICP.

8.9.1.1 It is recommended to use the integrations produced by the software if the integration is correct because the software will produce more consistent integrations of peaks in chromatograms. Manual integrations may be necessary in some cases and must be performed in conjunction with ESC SOP #030215, *Manual Integration*.

DOD samples must include a reason for each integration performed on the manual integration documentation.

8.9.2 If the RSD of a compound's response factor meets method requirements, then the concentration in the extract may be determined using the average response factor (average RF) from initial calibration data.

8.9.3 Where applicable, the concentration of any tentatively identified compounds in the sample should be estimated. The same formula as is used to calculate target analyte concentrations is used with the following modifications: The areas A_x and A_{is} must be from the total ion chromatograms and the RF for the compound is assumed at 1. See section 9.7 for calculation.

8.9.4 The resulting concentration must be reported indicating that the value is an estimate. Use the nearest internal standard free of interferences for estimated concentration calculations.

8.9.5 Quantitation of multi-component compounds (e.g., Toxaphene, Aroclors, etc.) is beyond the scope of Method 8270. Normally, quantitation is performed using a GC/ECD, by Methods 8081or 8082. However, Method 8270 may be used to confirm the identification of these compounds, when the concentrations are at least 10ng/µL in the concentrated sample extract.

8.9.6 **Peak Resolution:** Structural isomers that produce very similar spectra must be quantitated as individual isomers if they have sufficiently different GC retention times. Sufficient GC resolution is achieved if the height of the valley between the two isomers is <50% of the average of the two peak heights (for Method 8270D/E) and <25% of the sum of the two peak heights (for Methods 8270C & 625). Otherwise, structural isomers should be identified as isomeric pairs.

STATE NOTE: Minnesota MPCA requires that peak resolution of all co-eluters, analyzed using Method 8270C, must be resolved as close to 75% as possible. Resolution must be adequate at lower levels and not worsen as concentration increases.

8.9.7 Indeno(1,2,3-cd)pyrene and dibenz(a,h)anthracene share a similar structure and physical properties. Under routine analytical production conditions it is very difficult to achieve resolved chromatographic separation. The mass-spectra of these compounds exhibit base peaks separated by 2 AMUs (276 and 278 respectively) and these unique ions are used for quantitation of the respective compounds as defined by Method 8270. It has been found that the major base ion, 276, for indeno(1,2,3-cd)pyrene includes a significant contribution from dibenz(a,h)anthracene when the targets are present together at equal concentrations; however, indeno(1,2,3-cd)pyrene presence *does not* contribute significant ion 278 abundance to dibenz(a,h)anthracene quantitation at equal concentrations. For these reasons when dibenz(a,h)anthracene is found to be present at similar or lesser concentrations than indeno(l,2,3-cd)pyrene, the results are normalized by the calibration conditions and considered to be non-impacted. Alternatively, when dibenz(a,h)anthracene is found to be present at relatively greater concentrations than indeno(l ,2,3-cd)pyrene, the indeno(1,2,3-cd)pyrene results are considered to be elevated and may be confirmed by a secondary acquisition and analysis utilizing a technique for chromatographic separation of the targets. Concentrations shall be considered similar up to a factor of two.

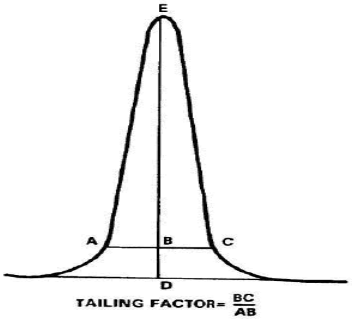
9.0 DATA ANALYSIS AND CALCULATIONS

9.1 GC/MS Tune: DDT Breakdown Determination during Tuning:

$$\%\text{ breakdown of DDT} = \frac{\text{sum of degradation peak areas (DDD + DDE)}}{\text{sum of all peak areas (DDT + DDE + DDD)}} \times 100$$

9.2 GC/MS Tune: Benzidine and Pentachlorophenol Tailing Factor

$$\text{TailingFactor} = \frac{BC}{AB}$$



where: BC is the width of the back ½ of the peak at 10% of the peak height
AB is the width of the front ½ of the peak at 10% of the peak height.

9.3 Internal Calibration Equations (Response Factors):

$$RF = \frac{[A_s][C_{is}]}{[A_{is}][C_s]}$$

where:
A_s = Peak area (or height) of the analyte or surrogate.
A_{is} = Peak area (or height) of the internal standard.
C_s = Concentration of the analyte or surrogate, in µg/L.
C_{is} = Concentration of the internal standard, in µg/L.

- Percent Relative Standard Deviation (%RSD)

$$\overline{RF} = \frac{\sum_{i=1}^{n} RF_i}{n} \qquad SD = \sqrt{\frac{\sum_{i=1}^{n}(RF_i - \overline{RF})^2}{n-1}} \qquad RSD = \frac{SD}{\overline{RF}} x100\%$$

where:
RSD = Relative standard deviation.
RF = Mean of 5 initial RFs for a compound.
SD = Standard deviation of average RFs for a compound.

- Concentration of an analyte in an extract using RF (on column):

$$X_s = \frac{(Conc_{.IStd})(Area_{Analyte})}{(Average\,RF_{analyte})(Area_{IStd})}$$

where:
X_s = Calculated raw concentration of analyte (in ppb)

- Quantitation Report Multiplier”

$$M_a = \frac{(V_t)(D)}{(V_s)} \quad or \quad M_s = \frac{(V_t)(D)}{(W_s)}$$

where:
M_a = Quantitation Report Multiplier for Aqueous Samples
M_s = Quantitation Report Multiplier for Solid Samples
V_t = Total volume of concentrated extract (in mL)
D = Dilution factor. If no dilution, D=1. Always dimensionless
V_s = Volume of aqueous sample extracted (in mL)
W_s = Weight sample extracted (in grams)

- Sample concentration by volume (ug/L) for aqueous samples:

$$Concentration\ in\ \frac{\mu g}{L} = (X_s)(M_a)$$

- Sample concentration by weight (ug/kg) for solid samples and non-aqueous liquids:

$$Concentration\ in\ \frac{\mu g}{kg} = \frac{(X_s)(M_s)}{(\%S)}$$

where:
%S = Percent solids expressed as a decimal

9.4 Relative Retention Time (RRT):

$$RRT = \frac{RT\ of\ Target\ Analyte}{RT\ of\ Internal\ Standard}$$

9.5 Percent Error (%Error)

$$\%Error = \frac{x_i - x'_i}{x_i} * 100$$

where:
x'_i = Measured amount of analyte at the calibration level *i*, in mass or concentration units
x_i = True amount of analyte at calibration level *i*, in mass or concentration units

9.6 Relative Standard Error (%RSE) – As an alternative to using the average response factor when using Method 625.1, the quality of the calibration may be evaluated using the Relative Standard Error (RSE). The acceptance criterion for the RSE is the same as the acceptance criterion for Relative Standard Deviation (RSD), in the method. RSE is calculated as:

$$\%RSE = 100 \times \frac{\sum_{i=1}^{n}\left[\frac{x'_i - x_i}{x_i}\right]^2}{(n-p)}$$

where:
x'i = Calculated concentration at level i
xi = Actual concentration of the calibration level i
n = Number of calibration points
p = Number of terms in the fitting equation (average = 1; linear = 2; quadratic = 3)

9.7 See the current Quality Assurance Manual for other equations associated with common calculations.

10.0 QUALITY CONTROL AND METHOD PERFORMANCE

10.1 All analysts must meet the qualifications specified in SOP #030205, *Technical Training and Personnel Qualifications* before approval to perform this method. Analysts must complete an initial demonstration of proficiency before being approved to perform this method. Continuing proficiency must be demonstrated using proficiency testing, laboratory control sample analysis and/or MDL studies. Method performance is assessed per analyst. Updated method performance records are filed and stored in a central location within the department.

10.1.1 Method 625.1 Demonstration of Capability (DOC) Requirements

10.1.1.1 For the DOC, a QC check sample (LCS) concentrate containing each analyte of interest is prepared in a water miscible solvent. The QC check sample concentrate must be prepared independently from those used for calibration, but may be from the same source as the second-source standard used for calibration verification. The concentrate should produce concentrations of the analytes of interest in water at the midpoint of the calibration range, and may be at the same concentration as the LCS.

10.1.1.2 Prepare four QC check samples by adding an appropriate volume of the concentrate and of the surrogate(s) to each of four aliquots of reagent water and mix well. The volume of reagent water must be the same as the volume that will be used for the sample, blank, and MS/MSD.

10.1.1.3 Extract and analyze the four LCSs samples.

10.1.1.4 Calculate the average percent recovery ($\overline{X}$) and the standard deviation (s) of the percent recovery for each analyte using the four results.

10.1.1.5 For each analyte, compare s and $\overline{X}$ with the acceptance criteria for precision and recovery presented in Attachment VII. For analytes that are not listed, QC acceptance criteria must be developed by the laboratory.

If s and $\overline{X}$ for all analytes of interest meet the acceptance criteria, system performance is acceptable and analysis of blanks and samples can begin. If any individual s exceeds the precision limit or any individual $\overline{X}$ falls outside the range for recovery, system performance is unacceptable for that analyte.

10.1.1.6 When one or more of the analytes tested fail at least one of the acceptance criteria, repeat the test for only the analytes that failed. If results for these analytes pass, system performance is acceptable and analysis of samples and blanks may proceed. If one or more of the analytes again fail, system performance is unacceptable for the analytes that failed the acceptance criteria. Correct the problem and repeat the test.

10.2 Use the designated Run log to record batch order and standards/reagents used during analysis. See SOP #030201, *Data Handling and Reporting*.

10.3 Batches:

Batches are defined as sets of 1 - 20 samples. Batch analysis must include the following: 1 method blank, 1 Laboratory Control Sample (LCS), 1 Laboratory Control Sample Duplicate (LCSD), 1 Matrix Spike/Spike Duplicate (MS/MSD) (if client has supplied sufficient sample volume). All batch information must be maintained in the preparation documentation assigned to the department.

10.4 For sample analyzed per the requirements of Method 8000D, the LLOQ (see Section 1.8.2) must be verified at least annually, and whenever significant changes are made to the preparation and/or analytical procedure, to demonstrate quantitation capability at lower analyte concentration levels

10.4.1 The LLOQ verification (to be performed after the initial calibration) is prepared by spiking a clean control material with the analyte(s) of interest at 0.5-2 times the LLOQ concentration level(s).

10.4.2 The LLOQ check is carried through the same preparation and analytical procedures as environmental samples and other QC samples.

10.4.3 It is recommended to analyze the LLOQ verification on every instrument where data is reported; however, at a minimum, the lab must rotate the verification among similar analytical instruments such that all are included within 3 years.

10.4.4 Recovery of target analytes in the LLOQ verification must be within established in-house limits or within other such project-specific acceptance limits to demonstrate acceptable method performance at the LLOQ. Until the laboratory has sufficient data to determine acceptance limits, the LCS criteria ± 20% (i.e., lower limit minus 20% and upper limit plus 20%) may be used for the LLOQ acceptance criteria.

10.5 For acceptance criteria for calibration standards, QC samples and field samples and corrective actions, see section 11.0.

11.0 DATA VALIDATION AND CORRECTIVE ACTION

11.1 A successful DFTPP tune must be achieved prior to initial calibration or daily calibration verification(daily tuning prior to CCV not required for 8270E). If a tune does not meet the acceptance criteria in section 8.2, then re-inject the tuning solution. If the failure persists, instrument maintenance or detector adjustment is required. The instrument is equipped with detector adjustments in routines called “Autotunes” that can make minor adjustments to m/z ratios and detector setting and can align the analytical system to return the system to peak performance. If after performing the Autotune routine, the injected tuning standard still fails, the system may require injector and/or detector cleaning, column cutting or replacement, injection liner cleaning or replacement, or other maintenance as specified by the manufacturer.Following successful tuning of the DFTPP solution, the DDT degradation and Benzidine/Pentachlorophenol tailing must be assessed using the total ion chromatograms for each. If either fail to meet the required acceptance criteria, instrument maintenance is required. The DDT degradation is most likely an inlet or column condition and corrective action entails clipping 6-12” from the injector end of the column, changing the injection port liner, possibly changing the gold inlet seal and re-injecting the tuning solution. The tailing issue is most likely caused by the same type of inlet issues and the same corrective action steps should occur when the tailing criteria is not met. Tailing may also be caused by incorrect column positioning in the inlet and the correct position of the column should be verified prior to performing more involved corrective action processes.

A successful instrument tune, including degradation and tailing acceptability, must be achieved prior to the analysis of calibration standards and sample extracts by methods 8270C/D and 625.1. 8270E does not require tuning at any time other than prior to initial calibration

11.2 Initial or Continuing Calibration:

Method 8270C, SM 6410B & Method 625.1: If the calibration curve or daily calibration verification fails to meet the applicable method verification criteria for RSD, the analyst MUST use linear regression or quadratic curve fit. Quadratic models cannot be used to extend the calibration range or bypass instrument maintenance. If the method criteria are still not met when using the alternate curve fits, samples may not be quantitated using the calibration curve and a new calibration curve must be analyzed. Instrument maintenance and/or new standard preparation may also be required prior to the analysis of the new calibration curve. Following maintenance, the new calibration curve can be generated. The system may require injector and/or detector cleaning, column cutting or replacement, injection liner cleaning or replacement, or other maintenance as specified by the manufacturer. Additional actions that can be taken to address failures in calibration are included in section 8.3.

Method 8270D/E: Due to the large number of compounds that may be analyzed by this method, some compounds in the initial and/or daily calibration verification will fail to meet the initial and continuing calibration acceptance criteria. For these instances, failing compounds may not be critical to specific project needs and therefore may be utilized as qualified data or estimated values for screening purposes. If more than 10% of the compounds in the initial or continuing calibration exceed the 20% RSD limit and/or do not meet the minimum correlation coefficient (0.99) for alternate curve fits, then the chromatographic system is considered too reactive for analysis. Instrument maintenance must be performed and the calibration process must be repeated. The system may require injector and/or detector cleaning, column cutting or replacement, injection liner cleaning or replacement, or other maintenance as specified by the manufacturer. Additional actions that can be taken to address failures in calibration are included in section 8.3.

TNI: If the ICV or CCV results obtained are outside the established acceptance criteria and analysis of a second consecutive (immediate) calibration verification fails to produce results within acceptance criteria, corrective actions shall be performed. The laboratory shall demonstrate acceptable performance after the final round of corrective action with two consecutive calibration verifications, or a new initial instrument calibration shall be performed.

Method 8000D: To determine calibration function acceptability, refit the initial calibration data back to the calibration model and calculate %Error (see Section 9.5). Percent error between the calculated and expected amounts of an analyte must be ≤30% for all standards. (≤50% is acceptable for the lowest calibration point.)

Method 625.1: The RF or calibration curve must be verified immediately after calibration and at the beginning of each 12-hour shift, by analysis of a standard at or near the concentration of the mid-point calibration standard. The standard(s) must be obtained from a second manufacturer or a manufacturer's batch prepared independently from the batch used for calibration.

When one or more analytes fail acceptance criteria, analyze a second aliquot of the calibration verification standard and compare ONLY those analytes that failed the first test with their respective acceptance criteria. If these analytes now pass, system performance is acceptable and analysis of samples may continue. A repeat failure of any analyte that failed the first test, however, will confirm a general problem with the measurement system. If this occurs, repair the system and repeat the test, or prepare a fresh calibration standard and repeat the test. If calibration cannot be verified after maintenance or injection of the fresh calibration standard, re-calibrate the instrument.

11.3 The method blank must be extracted and analyzed with each set of samples at a frequency of at least 5% and must be free of the analytes of interest at the method detection limit. If the method blank contains target analytes at a detectable concentration, it may be necessary to analyze a solvent blank to demonstrate the source of the contamination is not carryover from standards or lingering field sample artifacts. Following verification that the analytical system is free from interferences, the method blank can be re-analyzed once. A passing method blank must be analyzed before any samples are analyzed; otherwise corrective action is required. Corrective action can take the form of checking the original calculations to ensure accuracy or instrument maintenance (i.e. column clipping or changing, inlet liner cleaning/replacement, etc.) or re-calibration. The surrogate recoveries in the method blank must meet the established control criteria (see the LIMS). If not, the recovery demonstrates an analytical system that is in an out-of-control mode and the batch must be re-extracted/re-analysis unless directed otherwise by the client.

General guidelines for qualifying sample results with regard to method blank quality are as follows:

- If the method blank concentration is less than the MDL and sample results are greater than the RL, then no qualification is required.
- No qualification is necessary when an analyte is detected in the method blank but not in the associated samples.
- If the concentration in a sample is more than ten times the concentration in the method blank, then no qualification is required.
- If the method blank concentration is greater than the MDL but less than the RL and sample results are greater than the MDL, then qualify associated sample results to indicate that analyte was detected in the method blank.
- If the method blank concentration is greater than the RL, further corrective action and qualification is required. An analyst should consult their supervisor for further instruction.

11.4 Second Source Calibration Verification

Method 8270D/E: The value determined from the second source calibration verification (SSCV) should be within +30% drift of the expected concentration. Alternative recovery limits may be appropriate based on analyte performance and project specific requirements. Quantitative analysis cannot proceed for analytes that fail the SSCV, except for screening purposes or estimated values only.

Method 8270C/SM6410B: The value determined from the second source calibration verification (SSCV) must be <50% drift for non-CCC compounds; <20% drift for CCC compounds and meet the minimum response factor criteria for SPCC compounds as in the initial calibration construction. Historical performance weighs heavily in the acceptability of those analytes that are known to perform poorly. Corrective action can take the form of checking the original calculations to ensure accuracy, re-analysis of the SSCV to verify initial results, instrument maintenance (i.e. column clipping or changing, inlet liner cleaning/replacement, etc.) or re-calibration.

STATE NOTE: If the samples are analyzed in conjunction with South Carolina DHEC, alternate recovery limits can only be used if they are more stringent than method criteria.

Method 625.1: Method 625.1 utilizes CCV limits for evaluation.

11.5 Surrogates: If the surrogate recoveries in the samples do not fall within the appropriate acceptance criteria presented in the LIMS, ensure that there were no errors in calculations, internal standard, or instrument performance. If the recovery of any one surrogate is critically low (, then the sample must be re-extracted unless otherwise directed by the client or a clear, documented matrix interference is exhibited. If two of three acid and two of three base/neutral surrogates are within acceptance criteria, then the sample may be reported. If surrogate recoveries present a high bias, and samples are BDL, then data is not impacted and may be reported. If re-extraction is required and there is no more sample available or it has exceeded holding times, the data must be flagged with a “J1" (surrogate high) or a “J2” (surrogate low). See SOP #030201, *Data Handling and Reporting*, for more information on qualifying out of control data.

STATE NOTE: If the sample is from North Carolina, two of the three acid and two of the three base/neutral surrogates must pass. If two of the three acid or base/neutral surrogates fail, the sample must be re-extracted. For all other samples, one of the three surrogates must pass from both the acid and base/neutral sides. If any surrogates have less than a 10% or greater than 200% recovery, and matrix interferences are not confirmed as the cause of the failure, the sample must be re-extracted.

STATE NOTE: If field samples are analyzed in conjunction with the Ohio VAP program, surrogate outliers in batch QC samples, including the method blank, LCS/LCSD, MS/MSD require re-extraction of the entire batch, if sufficient volume has been submitted by the client and an obvious matrix interferent is not present.

STATE NOTE: If the sample is analyzed in conjunction with the Ohio VAP, corrective action for failing QC (i.e. method blank, surrogate, MS/MSD, LCS/LCSD, ISTD, etc.) must be performed prior to flagging data, if sufficient sample volume was submitted by the client. Corrective action can include reanalysis, if instrument malfunction is suspected, or re-preparation and re-analysis, if the failure is suspected as either extraction or sample related.

11.6 Internal Standard: The internal standard area counts must be monitored for all ICVs. ISTDs must recover within –50% to +100% of the area counts from the internal standard area counts of the midpoint standard of the most recent initial calibration sequence. If any internal standard response is beyond the acceptable recovery, corrective action is required. Corrective action can take the form of checking the original calculations to ensure accuracy, re-analysis of the ICV to verify initial results, instrument maintenance (i.e. column clipping or changing, inlet liner cleaning/replacement, etc.) or re-calibration.

The internal standard responses and retention times in the check calibration standard must be evaluated immediately after or during data acquisition. If the retention time for any internal standard changes by more than 30 seconds from the last calibration verification, the chromatographic system must be inspected for malfunctions and corrections must be made, as required. When corrections are made, re-analysis of the CCV or a complete re-calibration is necessary, depending on the impact of the correction on the analytical system.

Internal standards must be monitored for each sample. ISTDs in samples must meet the –50% to +100% criteria when compared to the ISTDs in the daily CCV or mid-level of the calibration curve, on 12h shifts when full calibration is performed. Possible corrective actions include: re-analysis, if instrument malfunction is suspected, or re-preparation and re-analysis, if the failure is suspected as either extraction or sample related. If the sample has an obvious matrix interferent and the internal standard recovery is greater than +100%, the sample can be diluted (if acceptable reporting limits can be achieved) to minimize the interference or the sample must be re-extracted and re-analyzed to confirm the original results. ISTD failures <50% of daily ICV may be reported if all corresponding analytes are BDL as the high quantitation bias created by the reduced internal standard recovery has not adversely impacted the reported analyte results.

11.7 LCS/LCSD and MS/MSD: The laboratory control sample, laboratory control sample duplicate, matrix spike and matrix spike duplicate recoveries must be evaluated against the acceptance criteria given in the LIMS. The LCS/LCSD and MS/MSD are spiked with the same list of compounds for which the instrument is calibrated. Due to the large number of compounds analyzed using these methods, it is statistically likely that accuracy and precision failures will occur.

LCS or LCSD samples that do not pass the acceptable QC criteria must be re-analyzed. LCS/LCSD failures must meet the marginal exceedance criteria below. The normal compound list for 8270/625 typically contains 90 analytes; therefore only 5 analytes can be considered as marginally exceeding the acceptance criteria. If more than 5 failures occur or if the failures demonstrate a pattern that is causing the outliers, the entire sample batch with associated QC must be re-extracted and re-analyzed. Marginal exceedances must be random events.

Upper and lower marginal exceedance (ME) limits are established by +/- four times the standard deviation of historical accuracy data and the number of marginal exceedances allowed is based on the number of analytes spiked in the LCS.

Number of allowable marginal exceedances:

90 analytes, 5 analytes allowed in the ME limit
71 – 90 analytes, 4 analytes allowed in the ME limit.

51 – 70 analytes, 3 analytes allowed in the ME limit.
31 – 50 analytes, 2 analytes allowed in the ME limit.
11 – 30 analytes, 1 analyte allowed in the ME limit.
< 11 analytes, no analyte allowed in the ME limit.

If the MS/MSD fails to meet recovery limits listed in the LIMS, the data on the unspiked field sample for that compound must be flagged with a “J5” (high recovery) or a “J6” (low recovery). If the MS/MSD fail to pass precision limits (%RSD), the data on the unspiked field sample for that compound must be flagged with a “J3” qualifier.

STATE NOTE: For South Carolina or Ohio VAP samples, marginal exceedances do not apply. All outliers in QC require corrective action when possible and the data must be flagged when necessary.

STATE NOTE: For all samples from South Carolina, the LCS/LCSD recovery must be evaluated within 70-130% and the MS/MSD recoveries must be within in-house derived recovery limits; however, if the limits given in Method 625 Table 6 are more stringent, then those limits must be used. The following are the current limits:

Parameter	LCS/LCSD	MS/MSD
1,2,4-TRICHLOROBENZENE	70 - 130%	44 – 104%
2,4,6-TRICHLOROPHENOL	70 - 130%	37 - 132%
2,4-DICHLOROPHENOL	70 - 130%	39 - 117%
2,4-DIMETHYLPHENOL	70 - 119%	32 - 119%
2,4-DINITROPHENOL	70 - 130%	10 - 141%
2,4-DINITROTOLUENE	70 - 130%	45.4 - 139%
2,6-DINITROTOLUENE	70 - 130%	50 - 134%
2-CHLORONAPHTHALENE	70 - 118%	60 - 118%
2-CHLOROPHENOL	70 - 130%	23 - 111%
2-NITROPHENOL	70 - 130%	29 - 135%
3,3-DICHLOROBENZIDINE	70 - 130%	10 - 143%
4,6-DINITRO-2-METHYLPHENOL	70 - 130%	10 - 143%
4-BROMOPHENYL-PHENYLETHER	70 - 127%	53 - 127%
4-CHLORO-3-METHYLPHENOL	70 - 130%	38.4 - 123%
4-CHLOROPHENYL-PHENYLETHER	70 - 130%	49.8 -127%
4-NITROPHENOL	70 - 130%	10 - 52.8%
ACENAPHTHENE	70 - 130%	47 - 141%
ACENAPHTHYLENE	70 - 130%	40 - 132%
ANTHRACENE	70 - 130%	44.5 - 130%
BENZO(A)ANTHRACENE	70 - 130%	46.4 - 130%
BENZO(A)PYRENE	70 - 130%	34.6 - 129%
BENZO(B)FLUORANTHENE	70 - 130%	36.3 - 137%
BENZO(G,H,I)PERYLENE	70 - 130%	10 - 140%
BENZO(K)FLUORANTHENE	70 - 130%	30.3 - 136%
BENZYLBUTYL PHTHALATE	70 - 130%	44.8 - 152%
BIS(2-CHLORETHOXY)METHANE	70 - 130%	39.2 - 128%
BIS(2-CHLOROETHYL)ETHER	70 - 130%	14.8 - 131%
BIS(2-CHLOROISOPROPYL)ETHER	70 - 130%	36 - 117%
BIS(2-ETHYLHEXYL)PHTHALATE	70 - 130%	12.6 - 153%
CHRYSENE	70 - 130%	40 - 133%
DIBENZ(A,H)ANTHRACENE	70 - 130%	10 - 143%
DIETHYL PHTHALATE	70 - 114%	50.4 - 114%
DIMETHYL PHTHALATE	70 - 112%	9.1 - 112%
DI-N-BUTYL PHTHALATE	70 - 118%	53.3 - 118%

Parameter	LCS/LCSD	MS/MSD
DI-N-OCTYL PHTHALATE	70 - 130%	13.3 - 146%
FLUORANTHENE	70 - 130%	42.9 - 137%
FLUORENE	70 - 121%	59 - 121%
HEXACHLORO-1,3-BUTADIENE	70 - 116%	28.9 - 116%
HEXACHLOROBENZENE	70 - 130%	47 - 121%
HEXACHLOROCYCLOPENTADIENE	70 - 130%	10 - 128%
HEXACHLOROETHANE	70 - 113%	40 - 109%
INDENO(1,2,3-CD)PYRENE	70 - 130%	10 - 141%
ISOPHORONE	70 - 130%	31.9 - 118%
NAPHTHALENE	70 - 130%	29 - 115%
NITROBENZENE	70 - 130%	35 - 118%
N-NITROSODI-N-PROPYLAMINE	70 - 130%	35.4 - 129%
PENTACHLOROPHENOL	70 - 130%	14 - 128%
PHENANTHRENE	70 - 130%	54 - 120%
PHENOL	70 - 112%	10 - 55.7%
PYRENE	70 - 115%	52 - 115%

Method 625.1: For LCS analyses, repeat the test only for those analytes that failed to meet the acceptance criteria (PS). If these analytes now pass, system performance is acceptable and analysis of blanks and samples may proceed. Repeated failure, however, will confirm a general problem with the measurement system. If this occurs, repeat the test using a fresh LCS or an LCS prepared with a fresh QC check sample concentrate, or perform and document system repair. Subsequent to analysis of the LCS prepared with a fresh sample concentrate, or to system repair, repeat the LCS test. If failure of the LCS indicates a systemic problem with samples in the batch, re-extract and re-analyze the samples in the batch.

The large number of analytes tested in performance tests in this method present a substantial probability that one or more will fail acceptance criteria when many analytes are tested simultaneously, and a retest is allowed if this situation should occur. If, however, continued re-testing results in further repeated failures, the laboratory must document and report the failures (e.g., as qualifiers on results), unless the failures are not required to be reported as determined by the regulatory/control authority. Results associated with a QC failure for an analyte regulated in a discharge cannot be used to demonstrate regulatory compliance. QC failures do not relieve a discharger or permittee of reporting timely results.

NOTE: To maintain the validity of the test and re-test, system maintenance and/or adjustment is not permitted between the pair of tests.

For MS/MSD analyses, compare the percent recoveries (P1 and P2) and the RPD for each analyte in the MS/MSD aliquots with the corresponding QC acceptance criteria in Attachment VII. A laboratory may develop and apply QC acceptance criteria more restrictive than the criteria in Attachment VII, if desired.

If any individual P falls outside the designated range for recovery in either aliquot, or the RPD limit is exceeded, the result for the analyte in the unspiked sample is suspect. The large number of analytes tested in performance tests in this method present a substantial probability that one or more will fail acceptance criteria when many analytes are tested simultaneously, and a retest is allowed if this situation should occur. If, however, continued re-testing results in further repeated failures, the laboratory must document and report the failures (e.g., as qualifiers on results), unless the failures are not required to be reported as determined by the regulatory/control authority. Results associated with a QC failure for an analyte regulated in a discharge cannot be used to demonstrate regulatory compliance. QC failures do not relieve a discharger or permittee of reporting timely results.

11.8 Calibration Range: For any compound found in a sample at a level above the highest standard, the extract must be diluted and re-analyzed to allow quantitation within the range of instrument calibration. Whenever an extract dilution is made, the appropriate amount of internal standard must be added to bring the ISTD concentrations back to the concentrations consistent with the calibration standards.

STATE NOTE: For all samples analyzed from Minnesota, the reporting limit must be verified at least monthly, with each new initial calibration, or when there has been significant change to the instrument (column replacement, cleaning source, etc.) whichever is more frequent. The reporting limit verification can be performed by either re-injecting the low standard or by re-processing the low standard that was analyzed in the calibration curve. The reporting limit verification (RLV) must recovery within ±40% of the expected concentration. If this criterion is not met, the RLV may be re-analyzed once, instrument maintenance can be performed, a higher concentration standard can be injected, or a new calibration curve must be generated. If a higher concentration standard is utilized, the reporting limit must be raised to the higher level verified.

11.9 All data must undergo a primary review by the analyst. The analyst must check the performance of the initial calibration, check standard, and continuing calibrations to ensure that they meet the criteria of the method. The analyst must review any sample that has quantifiable compounds and make sure that they have been confirmed, if necessary. The analyst must also verify that reported results are derived from quantitation between the RL and the highest standard of the initial calibration curve. All calculations must be checked (any dilutions, %solids, etc.). Data must be checked for the presence or absence of appropriate flags. Comments must be noted when data is flagged.

11.10 All data must undergo a second analyst review. The analyst checking the data must check the performance of the initial calibration, mid-point check standard, and continuing calibrations to ensure that they meet the criteria of the method.

11.10.1 The analyst should must review any sample that has quantifiable compounds and make sure that they have been confirmed.

11.10.2 All surrogate recoveries must be checked to ensure that they are within QC acceptance criteria or that corrective action has occurred.

11.10.3 Blanks must be free of all interfering peaks.

11.10.4 Quality control criteria must be checked for the LCS, LCSD, MS, and MSD.

11.10.5 Data must be checked to determine the need for appropriate flags. Comments are noted when results are flagged.

11.10.7 All manual integrations must be verified through checking the before/after shot of the sample, method blank, and/or QC (LCS/LCSD/MS/MSD).

11.10.8 See SOP #030201, *Data Handling and Reporting* and SOP #030227*, Data Review*.

12.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

12.1 The EPA requires that laboratory waste management practice to be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner. See *ESC Waste Management Plan.*

12.2 See SOP #030302, *Environmental Sustainability & Pollution Prevention*.

13.0 METHOD MODIFICATIONS/CLARIFICATIONS

13.1 The **Missouri Department of Natural Resources requires** that **DRO** be analyzed by GC/MS. Tuning and frequency requirements are the same as 8270C, omitting DDT, pentachlorophenol, and benzidine assessments. Extract samples the same as 8270PAH using the appropriate extraction method. Only base/neutral surrogates are needed. GC/MS mass range should be 35-550amu. Prepare a five-point calibration curve with 1:1 unleaded gasoline and #2 diesel fuel at 10,000 µg/mL each in methylene chloride. Calibration standards range from 200 to 10,000ug/mL for concentrated soil or 1L water extractions and calibration levels for EPA 3511 extracted water samples and non-concentrated Soil range from 5-200ppm from a 200ppm intermediate. Retention time windows are set using C_{10}, C_{21}, and C_{35}. For DRO, set RT 0.1 minutes after C_{10} to 0.1 minutes after C_{21}. For ORO, set RT 0.1 minutes after C_{21} to 0.1 minutes after C_{35}. Verify RT windows daily (24 hours) by running component standard. Quantitate using baseline-to baseline, not valley–to-valley. The total ion chromatogram must be used to quantitate. DRO is quantitated using external standard method. The response factor determined for DRO (C_{10}-C_{21}) **must** be used for C_{21}-C_{35}. Subtract area for any internal standard and surrogates. %RSD <20. Run a CCV every 12 hours near mid-point of calibration, %D <20. Run a method blank, LCS and MS/MSD every extraction batch. May re-process files to quantitate PAH analytes, if needed. Quantitation of DRO must be performed using the external standard process.

13.4 The reduction of the size of the field sample used in this procedure is performed in accordance with section 7.1 of the published EPA 3510C/625method. The reduction in volume extracted along with increased sensitivity at detection and/or analysis of the resulting extract using large volume injection (>5uL) on each GCMS allows for low detection limits typical of those obtained using a 1L extraction. Complete method validation is performed for each method prior to utilizing the reduced volume extraction. This validation is maintained by the Regulatory Affairs Department and is regularly verified using LCS/LCSD, MDL studies and DOCs.

13.5 **Low level NDMA and 1,4-Dioxane by SIM scan/isotope dilution.** Tuning and frequency requirements are the same as 8270C. Extract samples the same as 8270BNA using the appropriate extraction method. 250ng of N-nitrosodimethylamine-d6 or 1,4Dioxane-d_8 is added to each sample per every 0.5mL of final extract volume prior to extraction resulting in a true value of 500ppb in extract. Only base/neutral surrogates monitoring is necessary. GC/MS is set to scan for masses 42, 43, 46, 48, 54, 74, 80, 82, 115, 128, 150 and 152 for NDMA-d_6 or masses 57, 58, 62, 64, and 88 for 1,4-Dioxane-d_8 in SIM mode. Calibrate at least 5 points using 8270BNA mega mix or 1,4-Dioxane ICAL standard. 500ng of N-nitrosodimethylamine-d_6 is added per every 1mL of calibration standard to each level of the calibration resulting in a true value of 500ppb. Calibration standards range from 5ppb to 10,000ppb for 3510RV extracted water samples. Quantitate using Chemstation auto-integration software unless a significant discrepancy is noted in which case manually adjust integrations to best represent the calibration.

Select ion monitoring should be used for acquisition and quantitation. NDMA and 1,4-Dioxane are quantitated using the isotope dilution method as described in 8000C. The %RSD determined for NDMA RFs **must** be <15% in order to use the average of response factors for quantitation, otherwise linear regression is to be used. Run a DFTPP tune and CCV every 12 hours near mid-point of calibration, %Diff must be <20% for the calibration to be deemed in control and sample analysis to proceed. Run a method blank, LCS and LCSD with every extraction batch. MS/MSDs will be processed with batches when requested by the client as matrix spiking and duplication does not yield reliable precision data when analyzed by the isotope dilution method. Quantitation of low level NDMA and 1,4-Dioxane should be performed using the isotope dilution process.

13.6 **Tetraethyllead by SIM analysis**. Tetraethyllead is analyzed by standard SIM operating procedures. Ions 237 and 295 are added to the routine SIM acquisition methods in SIM group 1. All calibration and analytical procedures are mirrored from analysis of PAH by SIM.

14.0 REFERENCES

14.1 *Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)*, SW846 Method 8270C, Revision 3, December 1996.

14.2 *Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)*, SW846 Method 8270D, Revision 4, February 2007.

14.3 *Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)*, SW846 Method 8270E, Revision 6, February 2017.

14.4 *Determinative Chromatographic Separations*, SW846 Method 8000B, Revision 2, December 1996.

14.5 *Determinative Chromatographic Separations*, SW846 Method 8000C, Revision 3, March 2003.

14.6 *Determinative Chromatographic Separations*, SW846 Method 8000D, Revision 4, July 2014.

14.6 *Base/Neutrals and Acids*, 40 CFR Part 136, Appendix A, EPA Method 625, October 1991.

14.7 *Extractable Base/Neutrals and Acids*, Standard Methods for the Examination of Water and Wastewater, Method 6410B-2000.

14.8 *Extractable Base/Neutrals and Acids*, Standard Methods for the Examination of Water and Wastewater, Method 6410B-1997 (20th Ed).

14.9 *Base/Neutrals and Acids by GC/MS*, EPA Method 625.1, Federal Register, Volume 82, Number 165, August 28, 2017.

Attachment I: Revision History

Current Version (Pace National):

Date	Description of Revisions
5/13/2021	Review and revision in response to South Carolina DHEC comments to add 8270E requirements. Revised title as well as Sections 6.2, 7.10.1, 7.10.2, 8.2, 8.4.1, 8.4.3, 8.4.6, 8.7.1.4, 8.9.6, 11.1, 11.2, and 11.4. Added Section 14.3.

Superseded Versions (ESC Lab Sciences SOP #330345):

Version	Date	Description of Revisions
0	4/27/95	Origination
1	7/13/95	
2	8/22/96	
3	8/20/99	
4	4/18/00	
5	8/21/00	
6	12/20/00	
7	9/3/01	
8	7/30/02	
9	7/9/03	
10	3/25/04	
11	8/7/06	Technical and Quality Review and update.
12	2/11/09	Addition of 8270D requirements; Addition of State Notes; Update of standards information; Technical and Quality Review and update. Ohio VAP approval 2/11/09.
13	11/23/10	Technical and Quality Review and update. Revised sections 2.1, 2.10, 4.2 through 4.6, 7.1, 7.6, 7.8, 7.10.2, 7.12, 7.13, 8.3, 8.6, 9.3, 9.4, 9.5, 9.10 through 9.13, 11.3, 11.6, 12.1; Added sections 2.27 through 2.30, 4.7, 7.14, state note following section 11.9, 11.10, and 13.4; Removed section 1.2.
14	2/24/12	Technical and Quality Review and update. Revised sections 2.1, 4.2, 4.5, 5.3, 6.1.4, 6.2, 7.8, 7.9, 7.10, 7.13, 8.2, 8.3, 8.5, 8.6, 8.8, 11.2, 11.10, 13.1 and Attachment IV; Added state note to section 1.0; Added sections 1.8.1, 2.31, 2.32, and 13.5.
15	6/12/12	Technical and Quality Review and update. Revised sections 2.1, 7.9, 7.10, 8.3.2, 9.9, 9.14, 11.2, 11.3, 11.4, and 11.11; Added sections 2.19, 2.34, 4.8, 11.9 through 11.10, and 11.11.4 through 11.11.7.
16	3/26/13	Technical and Quality Review and update. Revised title, Attachment IV and sections 2.1, 7.8, 7.9, 7.10, 8.0 (state note), 8.3, 11.6, and 13.1; Added sections 7.13, 14.6 and state notes in sections 1.0 and 11.4; Removed sections 7.10.5 and 8.5.3.
17	6/10/14	Technical and Quality Review and update. Revised Attachments II, IVc through IVk, and V along with sections 5.3, 8.3.1, 8.3.6; 11.7; Added sections 5.4.7, 7.5.10 through 7.5.13, 7.7, 8.3.4; Removed sections 6.1.4 and 11.11.2.
18	8/14/14	Technical and Quality Review and update. Added sections 2.35, 7.5.14, and 13.6.

STANDARD OPERATING PROCEDURE
TITLE: Semivolatile Organics by GCMS using Capillary Column (EPA Methods 8270C, 8270D, 8270E, 625.1 and SM6410 B) Including Provisions for Analysis in SIM Mode
ISSUER: Pace National – Mt. Juliet, Tennessee

Version	Date	Description of Revisions
19	11/17/2015	Technical and quality review and update. Header and signature block re-formatting. Revised Sections 1.5, 1.8.1, 5.3, 7.9.1, 7.11.1, 8.1.1, 8.4.1, 8.4.4, 8.4.6, 8.7.1, 8.8, 8.9.1.1, 11.3, 11.5, 11.7, 11.11.4, 11.11.5, and 13.5. Added Section 8.6.1.7, 8.6.1.7.1 through 8.6.1.7.6, and Attachment VI. Deleted Attachment Iva, Attachment IVb, Attachment IVc, Attachment IVd, Attachment IVe, Attachment IVf, Attachment IVg, Attachment IVh, Attachment IVi, Attachment IVj, and Attachment IVk.
20	4/1/2016	Technical and quality review and update. Revised Sections 1.8.1, 2.8, 2.9, 2.10, 4.8, 7.1, 9.4, 9.5, 11.2, 11.4, 11.11.7, 12.2, and 13.6. Deleted Sections 2.11 through 2.35 and 9.6 through 9.13. Added Sections 7.5.16, 7.5.17, 7.5.18, and 8.9.7.
21	10/24/16	Technical and quality review and update to satisfy the requirements of SC DHEC (see correspondence dated 6/24/16) Header and signature block re-formatting. Revised Sections 11.2, 11.3, 11.4, 11.7, 14.1, 14.2, 14.3, 14.4, 14.6, 14.7, 14.8, and Attachment VII Table 2. Added Sections 1.8.2, 2.10, 9.5, 10.4 and all subsections, and 11.11.7.1.
22	6/19/2017	Technical and quality review and update. Revised Sections 1.8, 3.1, 7.5.14, 7.8, 7.11.1, 8.4.1, 8.8, 9.3, 10.3, 11.7, and Attachment III.
23	7/10/2017	Technical and quality review and update. Revised Sections 2.1, 2.11, 2.12, 7.9.2, 7.10.2, 7.10.3, 7.10.4, 7.11.4, 7.11.5, 9.3, 13.1, 13.5
24	10/6/2017	Technical and quality review and update. Revised Sections 7.9.2, 11.5, and Attachment IV. Added Table 8 in Attachment VII.
25	11/29/2017	Update in response to A2LA audit finding CAR2872. Revised Attachment IV.
26	3/22/2018	Technical and quality review and update. Added 625.1 requirements. Revised SOP Title and Sections 1.8.1, 2.11, 8.2, 8.4.1, 8.4.6, 9.7, 10.6, 11.1, 11.2, 11.3, 11.4, 11.5, 11.6, and 11.7. Added Sections 2.12, 9.6, 10.1.1 and all subsections, 10.5 and all subsections, 14.9, Attachment VII, and Attachment VIII.

Revised Versions (Pace National):

Date	Description of Revisions
9/19/2019	Technical and quality review and revision. Additional update in response to SC DHEC 8/29/2019 technical review letter. Replaced existing header and footer with corporate header and footer. Revised Sections 4.7, 7.61 through 7.6.24, 7.7, 7.8 and all subsections, 7.9, 7.10 and all subsections, 8.2, 8.4.1, 8.4.3, 8.4.6, 10.5, 11.1, 11.2, 11.3, 11.4, 11.5, 11.6, and 11.7. Deleted all subsections of 10.5 as well as Sections 11.10.2, 11.10.7, 11.10.9, 11.10.10, 11.10.11, 11.11 and all subsections, 13.2, 13.3, 13.4, and re-numbered as appropriate.
10/8/2020	Technical and quality review and revision. Removed date from header. Replaced section 3.0, Health and Safety.
2/27/2021	Technical and quality review and revision. Revised header. Revised sections 5.3 and 8.3. Added sections 5.4.8, 7.6.25 and 13.6.

Attachment II: 8270/625 Common Calibration List & Reporting Limits *(may be updated without notice)**

Analyte	Water mg/L	Soil mg/Kg
Acenaphthene	0.001	0.033
Acenaphthylene	0.001	0.033
Acetophenone	0.01	0.33
Anthracene	0.001	0.033
Atrazine	0.01	0.33
Benzaldehyde	0.01	0.33
Benzidine	0.05	0.33
Benzo(a)anthracene	0.001	0.033
Benzo(b)fluoranthene	0.001	0.033
Benzo(k)fluoranthene	0.001	0.033
Benzo(g,h,i)perylene	0.001	0.033
Benzo(a)pyrene	0.001	0.033
Bis(2-chlorethoxy)methane	0.01	0.33
Bis(2-chloroethyl)ether	0.01	0.33
Bis(2-chloroisopropyl)ether	0.01	0.33
4-Bromophenyl-phenylether	0.01	0.33
Caprolactam	0.01	0.33
2-Chloronaphthalene	0.01	0.33
4-Chlorophenyl-phenylether	0.01	0.33
Chrysene	0.001	0.033
Dibenz(a,h)anthracene	0.001	0.033
3,3-Dichlorobenzidine	0.01	0.33
2,4-Dinitrotoluene	0.01	0.33
2,6-Dinitrotoluene	0.01	0.33
Fluoranthene	0.001	0.033
Fluorene	0.001	0.033
Hexachlorobenzene	0.01	0.33
Hexachloro-1,3-butadiene	0.01	0.33
Hexachlorocyclopentadiene	0.01	0.33
Hexachloroethane	0.01	0.33
Indeno(1,2,3-cd)pyrene	0.001	0.033
Isophorone	0.01	0.33
Naphthalene	0.001	0.033
Nitrobenzene	0.01	0.33
n-Nitrosodimethylamine	0.01	0.33
n-Nitrosodiphenylamine	0.01	0.33
n-Nitrosodi-n-propylamine	0.01	0.33
Phenanthrene	0.001	0.033

Analyte	Water mg/L	Soil mg/Kg
Benzylbutyl phthalate	0.003	0.033
Bis(2-ethylhexyl)phthalate	0.003	0.033
Di-n-butyl phthalate	0.003	0.033
Diethyl phthalate	0.003	0.033
Dimethyl phthalate	0.003	0.033
Di-n-octyl phthalate	0.003	0.033
Pyrene	0.001	0.033
1,2,4-Trichlorobenzene	0.01	0.33
4-Chloro-3-methylphenol	0.01	0.33
2-Chlorophenol	0.01	0.33
2,4-Dichlorophenol	0.01	0.33
2,4-Dimethylphenol	0.01	0.33
4,6-Dinitro-2-methylphenol	0.01	0.33
2,4-Dinitrophenol	0.01	0.33
2-Methylphenol	0.01	0.33
4-Methylphenol	0.01	0.33
2-Nitrophenol	0.01	0.33
4-Nitrophenol	0.01	0.33
Pentachlorophenol	0.01	0.33
Phenol	0.01	0.33
2,4,6-Trichlorophenol	0.01	0.33
1-Methylnapthalene	0.001	0.033
2-Methylnapthalene	0.001	0.033
4-Chloroaniline	0.01	0.33
2-Nitroaniline	0.01	0.33
3-Nitroaniline	0.01	0.33
4-Nitroaniline	0.01	0.33
1,2,3,4-Tetrachlorobenzene	0.05	1.65
1,2,3,5-Tetrachlorobenzene	0.05	1.65
1,2,4,5-Tetrachlorobenzene	0.05	1.65
1,2,4,5-Tetrachlorobenzene	0.05	1.65
1,2-diphenylhydrazine	0.01	0.33
1,3-Dinitrobenzene	0.05	1.65
1,4-Naphthoquinone	0.05	1.65
1-Chloronaphthalene	0.05	1.65
1-Naphthylamine	0.05	1.65
2,3,4,6-Tetrachlorophenol	0.05	1.65
2,3-Dichloroaniline	0.01	0.33

Analyte	Water mg/L	Soil mg/Kg
2,6-Dichlorophenol	0.05	1.65
2-Acetylaminofluorene	0.05	1.65
2-Naphthylamine	0.05	1.65
2-Picoline	0.05	1.65
3,3'-Dimethylbenzidine	0.05	1.65
3-Methylcholanthrene	0.05	1.65
4-Aminobiphenyl	0.05	1.65
4-Nitroquinoline-1-oxide	0.05	1.65
5-Nitro-o-toluidine	0.05	1.65
7,12-Dimethylbenz(a)anthracene	0.05	1.65
7H-Dibenzo (c,g) carbazole	0.05	1.65
a,a-Dimethylphenethylamine	0.05	1.65
Acetophenone	0.01	0.33
Alpha-terpineol	0.01	0.33
Aniline	0.01	0.33
Aramite	0.05	1.65
Benzal Chloride	0.05	1.65
Benzo (j) fluoranthene	0.05	1.65
Benzotrichloride	0.05	1.65
Benzyl Chloride	0.05	1.65
Chlorobenzilate	0.05	1.65
Diallate (cis)	0.05	1.65
Diallate (trans)	0.05	1.65
Dibenz (a,e) pyrene	0.05	1.65
Dibenz (a,h) acridine	0.05	0.33
Dibenz (a,h) pyrene	0.05	1.65
Dibenz (a,i) pyrene	0.05	1.65
Dimethoate	0.05	1.65
Dinoseb	0.05	1.65
Diphenylamine	0.05	1.65
Disulfoton	0.05	1.65
Ethyl methanesulfonate	0.05	1.65
Famphur	0.05	1.65
Hexachlorophene	0.05	1.65
Hexachloropropene	0.05	1.65
Isodrin	0.05	1.65
Isosafrole (cis)	0.05	1.65
Isosafrole (trans)	0.05	1.65
Kepone	0.05	1.65

Analyte	Water mg/L	Soil mg/Kg
Methapyriline	0.05	1.65
Methyl methanesulfonate	0.05	1.65
Methyl parathion	0.05	1.65
N-Nitrosodiethylamine	0.05	1.65
n-nitrosodi-n-butylamine	0.01	0.33
N-Nitrosodi-n-butylamine	0.05	1.65
N-Nitrosomethylethylamine	0.05	1.65
N-Nitrosomorpholine	0.05	1.65
N-Nitrosopiperidine	0.05	1.65
N-Nitrosopyrrolidine	0.05	1.65
o,o,o-Triethylphoshorothioate	0.05	1.65
o-cresol	0.01	0.33
o-Toluidine	0.05	1.65
Parathion	0.05	1.65
p-cresol	0.01	0.33
p-Dimethylaminoazobenzene	0.05	1.65
Pentachlorobenzene	0.05	1.65
Pentachloroethane	0.05	1.65
Pentachloronitrobenzene	0.05	1.65
Phenacetin	0.05	1.65
Phorate	0.05	1.65
p-Phenyleneamine	0.05	1.65
Pronamide	0.05	1.65
Safrole	0.05	1.65
Sulfotepp	0.05	1.65
sym-Trinitrobenzene	0.05	1.65
Thionazin	0.05	1.65
2-nitrodiphenylamine	0.01	0.33
n-decane	0.01	0.33
n-octadecane	0.01	0.33
Pentachlorphenol (SIM)	0.001	-
Sulfolane	0.0002	0.33
Mirex	0.02	NA
Dicofol	0.02	NA
Quinoline	0.05	0.33
Indene	NA	0.33
Benzenethiol	0.02	3.3

*Alternate reporting levels may be possible using different technologies (i.e. SIM, LVI, etc.).

STANDARD OPERATING PROCEDURE

TITLE: Semivolatile Organics by GCMS using Capillary Column (EPA Methods 8270C, 8270D, 8270E, 625.1 and SM6410 B) Including Provisions for Analysis in SIM Mode

ISSUER: Pace National – Mt. Juliet, Tennessee

Please contact the laboratory for additional information.

Attachment III – Appropriate Extraction Methods by Analyte *(printed from SW-846 Method 8270C)*

ANALYTE:	3510*	3520	3540/3541	3550*	3580*	CAS #(a)
Acenaphthene	X	X	X	X	X	83-32-9
Acenaphthylene	X	X	X	X	X	208-96-8
Acetophenone	X	ND	ND	ND	X	98-86-2
2-Acetylaminofluorene	X	ND	ND	ND	X	53-96-3
1-Acetyl-2-thiourea	LR	ND	ND	ND	LR	591-08-2
Aldrin	X	X	X	X	X	309-00-2
2-Aminoanthraquinone	X	ND	ND	ND	X	117-79-3
Aminoazobenzene	X	ND	ND	ND	X	60-09-3
4-Aminobiphenyl	X	ND	ND	ND	X	92-67-1
3-Amino-9-ethylcarbazole	X	X	ND	ND	ND	132-32-1
Anilazine	X	ND	ND	ND	X	101-05-3
Aniline	X	X	ND	X	X	62-53-3
Ortho-anisidine	X	ND	ND	ND	X	90-04-0
Anthracene	X	X	X	X	X	120-12-7
Aramite HS	(43)	ND	ND	ND	X	140-57-8
Aroclor 1016	X	X	X	X	X	12674-11-2
Aroclor 1221	X	X	X	X	X	11104-28-2
Aroclor 1232	X	X	X	X	X	11141-16-5
Aroclor 1242	X	X	X	X	X	53469-21-9
Aroclor 1248	X	X	X	X	X	12672-29-6
Aroclor 1254	X	X	X	X	X	11097-69-1
Aroclor 1260	X	X	X	X	X	11096-82-5
Azinphos-methyl HS	(62)	ND	ND	ND	X	86-50-0
Barban	LR	ND	ND	ND	LR	101-27-9
Benzidine	CP	CP	CP	CP	CP	92-87-5
Benzoic Acid	X	X	ND	X	X	65-85-0
Benz(a)anthracene	X	X	X	X	X	56-55-3
Benzo(b)fluoranthene	X	X	X	X	X	205-99-2
Benzo(k)fluoranthene	X	X	X	X	X	207-08-9
Benzo(g,h,i)perylene	X	X	X	X	X	191-24-2
Benzo(a)pyrene	X	X	X	X	X	50-32-8
Para-benzoquinone	OE	ND	ND	ND	X	106-51-4
Benzyl Alcohol	X	X	ND	X	X	100-51-6
Alpha-BHC	X	X	X	X	X	319-84-6
Beta-BHC	X	X	X	X	X	319-85-7
Delta-BHC	X	X	X	X	X	319-86-8
Gamma-BHC	X	X	X	X		58-89-9
Lindane	X	X	X	X	X	58-89-9
Bis(2-chloroethoxy)methane	X	X	X	X	X	111-91-1
Bis(2-chloroethyl) Ether	X	X	X	X	X	111-44-4
Bis(2-chloroisopropyl) Ether	X	X	X	X	X	108-60-1
Bis(2-ethylhexyl) Phthalate	X	X	X	X	X	117-81-7
4-Bromophenyl Phenyl Ether	X	X	X	X	X	101-55-3
Bromoxynil	X	ND	ND	ND	X	1689-84-5
Butyl Benzyl Phthalate	X	X	X	X	X	85-68-7

ANALYTE:	3510*	3520	3540/3541	3550*	3580*	CAS #(a)
Captafol HS	(55)	ND	ND	ND	X	6/1/2425
Captan HS	(40)	ND	ND	ND	X	133-06-2
Carbaryl	X	ND	ND	ND	X	63-25-2
Carbofuran	X	ND	ND	ND	X	1563-66-2
Carbophenothion	X	ND	ND	ND	X	786-19-6
Chlordane	X	X	X	X	X	57-74-9
Chlorfenvinphos	X	ND	ND	ND	X	470-90-6
4-Chloroaniline	X	ND	ND	ND	X	106-47-8
Chlorobenzilate	X	ND	ND	ND	X	510-15-6
5-Chloro-2-methylaniline	X	ND	ND	ND	X	95-79-4
4-Chloro-3-methylphenol	X	X	X	X	X	59-50-7
hydrochloride	X	ND	ND	ND	X	6959-48-4
1-Chloronaphthalene	X	X	X	X	X	90-13-1
2-Chloronaphthalene	X	X	X	X	X	91-58-7
2-Chlorophenol	X	X	X	X	X	95-57-8
4-Chloro-1,2-phenylenendiamine	X	X	ND	ND	ND	95-83-0
4-Chloro-1,3-phenylenendiamine	X	X	ND	ND	ND	5131-60-2
4-Chlorophenyl Phenyl Ether	X	X	X	X	X	7005-72-3
Chrysene	X	X	X	X	X	218-01-9
Coumaphos	X	ND	ND	ND	X	56-72-4
Para-cresidine	X	ND	ND	ND	X	120-71-8
Crotoxyphos	X	ND	ND	ND	X	7700-17-6
2-Cyclohexyl-4,6-dinitrophenol	X	ND	ND	ND	LR	131-89-5
4,’'-DDD	X	X	X	X	X	72-54-8
4,’'-DDE	X	X	X	X	X	72-55-9
4,’'-DDT	X	X	X	X	X	50-29-3
Demeton-O HS	(68)	ND	ND	ND	X	298-03-3
Demeton-S	X	ND	ND	ND	X	126-75-0
Diallate (cis or trans)	X	ND	ND	ND	X	2303-16-4
2,4-Diaminotoluene DC,	OE(42) ND	ND	ND	ND	X	95-80-7
Dibenz(a,j)acridine	X	ND	ND	ND	X	224-42-0
Dibenz(a,h)anthracene	X	X	X	X	X	53-70-3
Dibenzofuran	X	X	ND	X	X	132-64-9
Dibenzo(a,e)pyrene	ND	ND	ND	ND	X	192-65-4
1,2-Dibromo-3-chloropropane	X	X	ND	ND	ND	96-12-8
Di-n-butyl Phthalate	X	X	X	X	X	84-74-2
Dichlone	OE	ND	ND	ND	X	117-80-6
1,2-Dichlorobenzene	X	X	X	X	X	95-50-1
1,3-Dichlorobenzene	X	X	X	X	X	541-73-1
1,4-Dichlorobenzene	X	X	X	X	X	106-46-7
3,3’'-Dichlorobenzidine	X	X	X	X	X	91-94-1
2,4-Dichlorophenol	X	X	X	X	X	120-83-2
2,6-Dichlorophenol	X	ND	ND	ND	X	87-65-0
Dichlorovos	X	ND	ND	ND	X	62-73-7
Dicrotophos	X	ND	ND	ND	X	141-66-2
Dieldrin	X	X	X	X	X	60-57-1

ANALYTE:	3510*	3520	3540/3541	3550*	3580*	CAS #(a)
Diethyl Phthalate	X	X	X	X	X	84-66-2
Diethylstilbestrol	AW,OS(67)	ND	ND	ND	X	56-53-1
Diethyl Sulfate	LR	ND	ND	ND	LR	64-67-5
Dihydrosaffrole	ND	ND	ND	ND	ND	56312-13-1
Dimethoate	HE,HS	ND	ND	ND	X	60-51-5
3,”-Dimethoxybenzidine	X	ND	ND	ND	LR	119-90-4
Dimethylaminoazobenzene	X	ND	ND	ND	X	60-11-7
7,12-Dimethylbenz(a)-anthracene	CP(45)	ND	ND	ND	CP	57-97-6
3,”-Dimethylbenzidine	X	ND	ND	ND	X	119-93-7
α,α-Dimethylphenethylamine	ND	ND	ND	ND	X	122-09-8
2,4-Dimethylphenol	X	X	X	X	X	105-67-9
Dimethyl Phthalate	X	X	X	X	X	131-11-3
1,2-Dinitrobenzene	X	ND	ND	ND	X	528-29-0
1,3-Dinitrobenzene	X	ND	ND	ND	X	99-65-0
1,4-Dinitrobenzene	HE(14)	ND	ND	ND	X	100-25-4
4,6-Dinitro-2-methylphenol	X	X	X	X	X	534-52-1
2,4-Dinitrophenol	X	X	X	X	X	51-28-5
2,4-Dinitrotoluene	X	X	X	X	X	121-14-2
2,6-Dinitrotoluene	X	X	X	X	X	606-20-2
Dinocap	CP,HS(28)	ND	ND	ND	CP	39300-45-3
Dinoseb	X	ND	ND	ND	X	88-85-7
Dioxathion	ND	ND	ND	ND	ND	78-34-2
Diphenylamine	X	X	X	X	X	122-39-4
5,5-Diphenylhydantoin	X	ND	ND	ND	X	57-41-0
1,2-Diphenylhydrazine	X	X	X	X	X	122-66-7
Di-n-octyl Phthalate	X	X	X	X	X	117-84-0
Disulfoton	X	ND	ND	ND	X	298-04-4
Endosulfan I	X	X	X	X	X	959-98-8
Endosulfan II	X	X	X	X	X	33212-65-9
Endosulfan Sulfate	X	X	X	X	X	1031-07-8
Endrin	X	X	X	X	X	72-20-8
Endrin Aldehyde	X	X	X	X	X	7421-93-4
Endrin Ketone	X	X	ND	X	X	53494-70-5
EPN	X	ND	ND	ND	X	2104-64-5
Ethion	X	ND	ND	ND	X	563-12-2
Ethyl Carbamate	DC(28)	ND	ND	ND	X	51-79-6
Ethyl Methanesulfonate	X	ND	ND	ND	X	62-50-0
Famphur	X	ND	ND	ND	X	52-85-7
Fensulfothion	X	ND	ND	ND	X	115-90-2
Fenthion	X	ND	ND	ND	X	55-38-9
Fluchloralin	X	ND	ND	ND	X	33245-39-5
Fluoranthene	X	X	X	X	X	206-44-0
Fluorene	X	X	X	X	X	86-73-7
2-Fluorobiphenyl (Surr)	X	X	X	X	X	321-60-8
2-Fluorophenol (Surr)	X	X	X	X	X	367-12-4
Heptachlor	X	X	X	X	X	76-44-8

ANALYTE:	3510*	3520	3540/3541	3550*	3580*	CAS #(a)
Heptachlor Epoxide	X	X	X	X	X	1024-57-3
Hexachlorobenzene	X	X	X	X	X	118-74-1
Hexachlorobutadiene	X	X	X	X	X	87-68-3
Hexachlorocyclopentadiene	X	X	X	X	X	77-47-4
Hexachloroethane	X	X	X	X	X	67-72-1
Hexachlorophene	AW,CP(62)	ND	ND	ND	CP	70-30-4
Hexachloropropene	X	ND	ND	ND	X	1888-71-7
Hexamethylphosphoramide	X	ND	ND	ND	X	680-31-9
Hydroquinone	ND	ND	ND	ND	X	123-31-9
Indeno(1,2,3-cd)pyrene	X	X	X	X	X	193-39-5
Isodrin	X	ND	ND	ND	X	465-73-6
Isophorone	X	X	X	X	X	78-59-1
Isosafrole	DC(46) ND	ND	ND	ND	X	120-58-1
Kepone	X	ND	ND	ND	X	143-50-0
Leptophos	X	ND	ND	ND	X	21609-90-5
Malathion	HS(5)	ND	ND	ND	X	121-75-5
Maleic Anhydride	HE	ND	ND	ND	X	108-31-6
Mestranol	X	ND	ND	ND	X	72-33-3
Methapyrilene	X	ND	ND	ND	X	91-80-5
Methoxychlor	X	ND	ND	ND	X	72-43-5
3-Methylcholanthrene	X	ND	ND	ND	X	56-49-5
4,"-Methylenebis (2-chloroaniline)	OE,OS(0)	ND	ND	ND	LR	101-14-4
4,"-Methylenebis-(N-n-dimethylaniline)	X	X	ND	ND	ND	101-61-1
Methyl methanesulfonate	X	ND	ND	ND	X	66-27-3
2-Methylnaphthalene	X	X	ND	X	X	91-57-6
Methyl Parathion	X	ND	ND	ND	X	298-00-0
2-Methylphenol	X	ND	ND	ND	X	95-48-7
3-Methylphenol	X	ND	ND	ND	X	108-39-4
4-Methylphenol	X	ND	ND	ND	X	106-44-5
2-Methylpyridine	X	X	ND	ND	ND	109-06-8
Mevinphos	X	ND	ND	ND	X	7786-34-7
Mexacarbate	HE,HS(68)	ND	ND	ND	X	315-18-4
Mirex	X	ND	ND	ND	X	2385-85-5
Monocrotophos	HE	ND	ND	ND	X	6923-22-4
Naled	X	ND	ND	ND	X	300-76-5
Naphthalene	X	X	X	X	X	91-20-3
1,4-Naphthoquinone	X	ND	ND	ND	X	130-15-4
1-Naphthylamine	OS(44)	ND	ND	ND	X	134-32-7
2-Naphthylamine	X	ND	ND	ND	X	91-59-8
Nicotine	DE(67)	ND	ND	ND	X	54-11-5
5-Nitroacenaphthene	X	ND	ND	ND	X	602-87-9
2-Nitroaniline	X	X	ND	X	X	88-74-4
3-Nitroaniline	X	X	ND	X	X	99-09-2
4-Nitroaniline	X	X	ND	X	X	100-01-6
5-Nitro-o-anisidine	X	ND	ND	ND	X	99-59-2

ANALYTE:	3510*	3520	3540/3541	3550*	3580*	CAS #(a)
Nitrobenzene	X	X	X	X	X	98-95-3
4-Nitrobiphenyl	X	ND	ND	ND	X	92-93-3
Nitrofen	X	ND	ND	ND	X	1836-75-5
2-Nitrophenol	X	X	X	X	X	88-75-5
4-Nitrophenol	X	X	X	X	X	100-02-7
5-Nitro-o-toluidine	X	ND	ND	ND	X	99-55-8
Nitroquinoline-1-oxide	X	ND	ND	ND	X	56-57-5
N-nitrosodi-n-butylamine	X	ND	ND	ND	X	924-16-3
N-nitrosodiethylamine	X	ND	ND	ND	X	55-18-5
N-nitrosodimethylamine	X	X	X	X	X	62-75-9
N-nitrosomethylethylamine	X	ND	ND	ND	X	10595-95-6
N-nitrosodiphenylamine	X	X	X	X	X	86-30-6
N-nitrosodi-n-propylamine	X	X	X	X	X	621-64-7
N-nitrosomorpholine	ND	ND	ND	ND	X	59-89-2
N-nitrosopiperidine	X	ND	ND	ND	X	100-75-4
N-nitrosopyrrolidine	X	ND	ND	ND	X	930-55-2
Octamethyl Pyrophosphoramide	LR	ND	ND	ND	LR	152-16-9
Parathion	X	ND	ND	ND	X	56-38-2
Pentachlorobenzene	X	ND	ND	ND	X	608-93-5
Pentachloronitrobenzene	X	ND	ND	ND	X	82-68-8
Pentachlorophenol	X	X	X	X	X	87-86-5
Phenacetin	X	ND	ND	ND	X	62-44-2
Phenanthrene	X	X	X	X	X	85-01-8
Phenobarbital	X	ND	ND	ND	X	50-06-6
Phenol	DC(28)	X	X	X	X	108-95-2
1,4-Phenylenediamine	X	ND	ND	ND	X	106-50-3
Phorate	X	ND	ND	ND	X	298-02-2
Phosalone	HS(65)	ND	ND	ND	X	2310-17-0
Phosmet	HS(15)	ND	ND	ND	X	732-11-6
Phosphamidon	HE(63)	ND	ND	ND	X	13171-21-6
Phthalic Anhydride	CP,HE(1)	ND	ND	ND	CP	85-44-9
2-Picoline	X	X	ND	ND	ND	109-06-8
Piperonyl Sulfoxide	X	ND	ND	ND	X	120-62-7
Pronamide	X	ND	ND	ND	X	23950-58-5
Pyrene	X	X	X	X	X	129-00-0
Pyridine	ND	ND	ND	ND	ND	110-86-1
Resorcinol	DC, OE(10)	ND	ND	ND	X	94-59-7
Safrole	X	ND	ND	ND	X	60-41-3
Sulfallate	X	ND	ND	ND	X	95-06-7
Terbufos	X	ND	ND	ND	X	13071-79-9
Terphenyl d(l4)(surr)	X	X	ND	X	X	1718-51-0
1,2,4,5-Tetrachlorobenzene	X	ND	ND	ND	X	95-94-3
2,3,4,6-Tetrachlorophenol	X	ND	ND	ND	X	58-90-2
Tetrachlorvinphos	X	ND	ND	ND	X	961-11-5
Tetraethyl Dithiopyrophosphate	X	X	ND	ND	ND	3689-24-5
Tetraethyl Pyrophosphate	X	ND	ND	ND	X	107-49-3

ANALYTE:	3510*	3520	3540/3541	3550*	3580*	CAS #(a)
Thionazine	X	ND	ND	ND	X	297-97-2
Thiophenol	X	ND	ND	ND	X	108-98-5
Benzenethiol	X	ND	ND	ND	X	108-98-5
Toluene Diisocyanate	HE(6)	ND	ND	ND	X	584-84-9
Ortho-toluidine	X	ND	ND	ND	X	95-53-4
Toxaphene	X	X	X	X	X	8001-35-2
1,2,4-Trichlorobenzene	X	X	X	X	X	120-82-1
2,4,5-Trichlorophenol	X	X	ND	X	X	95-95-4
2,4,6-Trichlorophenol	X	X	X	X	X	88-06-2
Trifluralin	X	ND	ND	ND	X	1582-09-8
2,4,5-Trimethylaniline	X	ND	ND	ND	X	137-17-7
Trimethyl Phosphate	HE(60)	ND	ND	ND	X	512-56-1
1,3,5-Trinitrobenzene	X	ND	ND	ND	X	99-35-4
Tris(2,3-dibromopropyl) phosphate	X	ND	ND	ND	LR	126-72-7
O,O,O-Triethyl Phosphorothioate	X	ND	ND	ND	X	126-68-1

KEY TO ANALYTE LIST ESC extraction technique Chemical Abstract Service Registry Number

(b) See Sec. 1.2 for other acceptable preparation methods.
(IS) This compound may be used as an internal standard.
(surr) This compound may be used as a surrogate.
(AW) Adsorption to walls of glassware during extraction and storage.
(CP) Non-reproducible chromatographic performance.
(DC) Unfavorable distribution coefficient (number in parenthesis is percent recovery).
(HE) Hydrolysis during extraction accelerated by acidic or basic conditions (number in parenthesis is percent recovery).
(HS) Hydrolysis during storage (number in parenthesis is percent stability).
(LR) Low response.
(ND) Not determined.
(OE) Oxidation during extraction accelerated by basic conditions (number in parenthesis is percent recovery).
(OS) Oxidation during storage (number in parenthesis is percent stability).
(X) Greater than 70 percent recovery by this technique.

Attachment IV: Characteristic Masses (m/z) for Extractable Organic Compounds

(Reprinted from SW-846 Method 8270C /Dec. 1996)

Compound	Primary Characteristic Ion	Secondary Characteristic Ion(s)
Pyridine	79	52,78,51
N-Nitrosodimethylamine	42	74,44
2-Picoline	93	66,92
Aniline	93	66,65
Phenol	94	65,66
Benzaldehyde	105	106,77,51
Bis(2-chloroethyl) ether	93	63,95
2-Chlorophenol	128	64,130
1,3-Dichlorobenzene	146	148,111
1,4-Dichlorobenzene-d4 (ISTD)	152	150,115
1,4-Dichlorobenzene	146	148,111
Benzyl alcohol	108	79,77
1,2-Dichlorobenzene	146	148,111
N-Nitrosomethylethylamine	88	42,43,56
Bis(2-chloroisopropyl) ether	45	77,121
Methyl methanesulfonate	80	79,65,95
N-Nitrosodi-n-propylamine	70	42,101,130
Hexachloroethane	117	201,199
Nitrobenzene	77	123,65
Isophorone	82	95,138
N-Nitrosodiethylamine	102	42,57,44,56
2-Nitrophenol	139	109,65
2,4-Dimethylphenol	122	107,121
Bis(2-chloroethoxy)methane	93	95,123
Benzoic acid	122	105,77
2,4-Dichlorophenol	162	164,98
Ethyl methanesulfonate	79	109,97,45,65
1,2,4-Trichlorobenzene	180	182,145
Naphthalene-d8 (ISTD)	136	68
Naphthalene	128	129,127
Hexachlorobutadiene	225	223,227
Caprolactam	113	55,56,42
4-Chloro-3-methylphenol	107	144,142
2-Methylnaphthalene	142	141
1-Methylnaphthalene	142	141
2-Methylphenol	107	108,77,79,90
Hexachloropropene	213	211,215,117,106,141
Hexachlorocyclopentadiene	237	235,272
N-Nitrosopyrrolidine	100	41,42,68,69
Acetophenone	105	71,51,120
4-Methylphenol	107	108,77,79,90
2,4,6-Trichlorophenol	196	198,200
2,4,5-Trichlorophenol	196	198,200
o-Toluidine	106	107,77,51,79

Compound	Primary Characteristic Ion	Secondary Characteristic Ion(s)
3-Methylphenol	107	108,77,79,90
2-Chloronaphthalene	162	127,164
N-Nitrosopiperidine	114	42,55,56,41
1-Chloronaphthalene	162	127,164
2-Nitroaniline	65	92,138
Dimethyl phthalate	163	194,164
Acenaphthylene	152	151,153
2,6-Dinitrotoluene	165	63,89
3-Nitroaniline	138	108,92
Acenaphthene-d10 (ISTD)	164	162,160
Acenaphthene	154	153,152
2,4-Dinitrophenol	184	63,154
2,6-Dinitrophenol	162	164,126,98,63
4-Chloroaniline	127	129,65,92
Isosafrole	162	131,104,77,51
Dibenzofuran	168	139
2,4-Dinitrotoluene	165	63,89
4-Nitrophenol	139	109,65
2-Naphthylamine	143	115,116
1,4-Naphthoquinone	158	104,102,76,50,130
Diethyl phthalate	149	177,150
Fluorene	166	165,167
N-Nitrosodi-n-butylamine	84	57,41,116,158
4-Chlorophenyl phenyl ether	204	206,141
Atrazine	200	215,58
4,6-Dinitro-2-methylphenol	198	51,105
N-Nitrosodiphenylamine	169	168,167
Safrole	162	104,77,103,135
Diphenylamine	169	168,167
1,2,4,5-Tetrachlorobenzene	216	214,179,108,143,218
1-Naphthylamine	143	115,89,63
4-Bromophenyl phenyl ether	248	250,141
2,4,5-Trichlorophenol	196	198,97,132,99
Hexachlorobenzene	284	142,249
Pentachlorophenol	266	264,268
5-Nitro-o-toluidine	152	77,79,106,94
Thionazine	107	96,97,143,79,68
4-Nitroaniline	138	65,108,92,80,39
Phenanthrene-d10 (ISTD)	188	94,80
Phenanthrene	178	179,176
Anthracene	178	176,179
Carbazole	167	166,168,139
1,3-Dinitrobenzene	168	76,50,75,92,122
Diallate (cis or trans)	86	234,43,70
Pentachlorobenzene	250	252,108,248,215,254
Pentachloronitrobenzene	237	142,214,249,295,265

Compound	Primary Characteristic Ion	Secondary Characteristic Ion(s)
4-Nitroquinoline-1-oxide	174	101,128,75,116
Di-n-butyl phthalate	149	150,104
2,3,4,6-Tetrachlorophenol	232	131,230,166,234,168
Demeton-O	88	89,60,61,115,171
Fluoranthene	202	101,203
1,3,5-Trinitrobenzene	75	74,213,120,91,63
Benzidine	184	92,185
Pyrene	202	200,203
Phorate	75	121,97,93,260
Demeton-S	88	60,81,89,114,115
Phenacetin	108	180,179,109,137,80
Dimethoate	87	93,125,143,229
4-Aminobiphenyl	169	168,170,115
Dimethylphenylamine	58	91,65,134,42
Pronamide	173	175,145,109,147
Dinoseb	211	163,147,117,240
Disulfoton	88	97,89,142,186
Butyl benzyl phthalate	149	91,206
Methyl parathion	109	125,263,79,93
Dimethylaminoazobenzene	225	120,77,105,148,42
Benz(a)anthracene	228	229,226
Chrysene-d12 (ISTD)	240	120,236
3,3'-Dichlorobenzidine	252	254,126
Chrysene	228	226,229
Kepone	272	274,237,178,143,270
Parathion	109	97,291,139,155
Bis(2-ethylhexyl) phthalate	149	167,279
3,3'-Dimethylbenzidine	212	106,196,180
Methapyrilene	97	50,191,71
Isodrin	193	66,195,263,265,147
Di-n-octyl phthalate	149	167,43
Aramite	185	191,319,334,197,321
Benzo(b)fluoranthene	252	253,125
Benzo(k)fluoranthene	252	253,125
Famphur	218	125,93,109,217
Benzo(a)pyrene	252	253,125
Perylene-d12 (ISTD)	264	260,265
7,12-Dimethylbenz(a)anthracene	256	241,239,120
2-Acetylaminofluorene	181	180,223,152
3-Methylcholanthrene	268	252,253,126,134,113
Dibenz(a,j)acridine	279	280,277,250
Indeno(1,2,3-cd)pyrene	276	138,227
Dibenz(a,h)anthracene	278	139,279
Benzo(g,h,i)perylene	276	138,277
Hexachlorophene	196	198,209,211,406,408

Compound	Primary Characteristic Ion	Secondary Characteristic Ion(s)
1,2-Diphenylhydrazine/Azobenzene	77	105,182
Mirex	272	274, 237,270
Kelthane (Dicofol)	251	139.111.253
Indene	115	116,117
Quinoline	129	128,130,102
Benzenethiol	110	109,66
Diphenyl Disulfide	218	109,65
Surrogates		
2-Fluorobiphenyl (surr)	172	171
2-Fluorophenol (surr)	112	64
Nitrobenzene-d5 (surr)	82	128,54
Phenol-d6 (surr)	99	42,71
Terphenyl-d14 (surr)	244	122,212
2,4,6-Tribromophenol (surr)	330	332,141
2-Methylnaphthalene-d10 (surr)	152	150, 122, 151
Fluoranthene-d10 (surr)	212	208, 313, 210
PAH by SIM		
Naphthalene	128	129
2-Methylnaphthalene	142	141
1-Methylnaphthalene	142	141
2-Chloronaphthalene	162	127
Acenaphthylene	152	153, 151
Acenaphthene	153	154, 152, 151
Dibenzofuran	168	139
Fluorene	166	165
Phenanthrene	178	179
Anthracene	178	179, 176
Fluoranthene	202	203, 200
Pyrene	202	203, 200
Benzo(a)anthracene	228	226
Chrysene	228	226, 229
Benzo(b)fluoranthene	252	253
Benzo(k)fluoranthene	252	253
Benzo(a)pyrene	252	253
Indeno(1,2,3-cd)pyrene	276	277, 138
Dibenz(a,h)anthracene	278	279, 139, 138
Benzo(g,h,i)perylene	276	138

Attachment V - QC Acceptance Criteria for Method 625

Compound	Test conc. (µg/L)	Limit for s (µg/L)	Range for x (µg/L)	Range p, p(s) (%)
Acenaphthene	100	27.6	60.1-132.3	47-145
Acenaphthylene	100	40.2	53.5-126.0	33-145
Aldrin	100	39	7.2-152.2	D-166
Anthracene	100	32	43.4-118.0	27-133
Benz(a)anthracene	100	27.6	41.8-133.0	33-143
Benzo(b)fluoranthene	100	38.8	42.0-140.4	24-159
Benzo(k)fluoranthene	100	32.3	25.2-145.7	11-162
Benzo(a)pyrene	100	39	31.7-148.0	17-163
Benzo(g,h,i)perylene	100	58.9	D-195.0	D-219
Benzyl butyl phthalate	100	23.4	D-139.9	D-152
beta-BHC	100	31.5	41.5-130.6	24-149
delta-BHC	100	21.6	D-100.0	D-110
Bis(2-chloroethyl) ether	100	55	42.9-126.0	12-158
Bis(2-chloroethoxy)methane	100	34.5	49.2-164.7	33-184
Bis(2-chloroisopropyl) ether	100	46.3	62.8-138.6	36-166
Bis(2-ethylhexyl) phthalate	100	41.1	28.9-136.8	8-158
4-Bromophenyl phenyl ether	100	23	64.9-114.4	53-127
2-Chloronaphthalene	100	13	64.5-113.5	60-118
4-Chlorophenyl phenyl ether	100	33.4	38.4-144.7	25-158
Chrysene	100	48.3	44.1-139.9	17-168
4,4'-DDD	100	31	D-134.5	D-145
4,4'-DDE	100	32	19.2-119.7	4-136
4,4'-DDT	100	61.6	D-170.6	D-203
Dibenzo(a,h)anthracene	100	70	D-199.7	D-227
Di-n-butyl phthalate	100	16.7	8.4-111.0	1-118
1,2-Dichlorobenzene	100	30.9	48.6-112.0	32-129
1,3-Dichlorobenzene	100	41.7	16.7-153.9	D-172
1,4-Dichlorobenzene	100	32.1	37.3-105.7	20-124
3,3'-Dichlorobenzidine	100	71.4	8.2-212.5	D-262
Dieldrin	100	30.7	44.3-119.3	29-136
Diethyl phthalate	100	26.5	D-100.0	D-114
Dimethyl phthalate	100	23.2	D-100.0	D-112
2,4-Dinitrotoluene	100	21.8	47.5-126.9	39-139
2,6-Dinitrotoluene	100	29.6	68.1-136.7	50-158
Di-n-octyl phthalate	100	31.4	18.6-131.8	4-146
Endosulfan sulfate	100	16.7	D-103.5	D-107
Endrin aldehyde	100	32.5	D-188.8	D-209
Fluoranthene	100	32.8	42.9-121.3	26-137
Fluorene	100	20.7	71.6-108.4	59-121
Heptachlor	100	37.2	D-172.2	D-192
Heptachlor epoxide	100	54.7	70.9-109.4	26.155
Hexachlorobenzene	100	24.9	7.8-141.5	D-152
Hexachlorobutadiene	100	26.3	37.8-102.2	24-116
Hexachloroethane	100	24.5	55.2-100.0	40-113
Indeno(1,2,3-cd)pyrene	100	44.6	D-150.9	D-171
Isophorone	100	63.3	46.6-180.2	21-196

Compound	Test conc. (µg/L)	Limit for s (µg/L)	Range for x (µg/L)	Range p, p(s) (%)
Naphthalene	100	30.1	35.6-119.6	21-133
Nitrobenzene	100	39.3	54.3-157.6	35-180
N-Nitrosodi-n-propylamine	100	55.4	13.6-197.9	D-230
Aroclor 1260	100	54.2	19.3-121.0	D-164
Phenanthrene	100	20.6	65.2-108.7	54-120
Pyrene	100	25.2	69.6-100.0	52-115
1,2,4-Trichlorobenzene	100	28.1	57.3-129.2	44-142
4-Chloro-3-methylphenol	100	37.2	40.8-127.9	22-147
2-Chlorophenol	100	28.7	36.2-120.4	23-134
2,4-Chlorophenol	100	26.4	52.5-121.7	39-135
2,4-Dimethylphenol	100	26.1	41.8-109.0	32-119
2,4-Dinitrophenol	100	49.8	D-172.9	D-191
2-Methyl-4,6-dinitrophenol	100	93.2	53.0-100.0	D-181
2-Nitrophenol	100	35.2	45.0-166.7	29-182
4-Nitrophenol	100	47.2	13.0-106.5	D-132
Pentachlorophenol	100	48.9	38.1-151.8	14-176
Phenol	100	22.6	16.6-100.0	5-112
2,4,6-Trichlorophenol	100	31.7	52.4-129.2	37-144

(s) = Standard deviation of four recovery measurements, in µg/L
(x) = Average recovery for four recovery measurements, in µg/L
(p, p(s)) = Measured percent recovery
(D) = Detected; result must be greater than zero
(a) = Criteria from 40 CFR Part 136 for Method 625, using a packed GC column. These criteria are based directly on the method performance data. Where necessary, the limits for recovery have been broadened to assure applicability of the limits to concentrations below those used to develop method performance data. These values are for guidance only. Appropriate derivation of acceptance criteria for capillary columns should result in much narrower ranges. See Method 8000 for information on developing and updating acceptance criteria for method performance.

Attachment VI - BNA Poor Performing Compounds

The following compounds are considered to be poor performing compounds.
Pyridine
Aniline
Benzoic Acid
n-Nitrosodimethylamine
Hexachlorocyclopentadiene
4-Chloroaniline
2-Nitroaniline
3-Nitroaniline
4-Nitroaniline
2,4-Dinitro-2-methylphenol
Pentachlorophenol
Carbazole
Benzidine
Atrazine
Acetophenone
Caprolactam
Benzaldehyde
1,2,4,5-Tetrachlorobenzene
Hexachlorophene

Attachment VII – Method 625.1 Criteria

Analyte	Range for Q (%)	Limit for s (%)	Range for $\bar{X}$ (%)	Range for P1, P2 (%)	Limit for RPD (%)
Acenaphthene*	70-130	29	60-132	47-145	48
Acenaphthylene*	60-130	45	54-126	33-145	74
Anthracene*	58-130	40	43-120	27-133	66
Benzidine*					
Benzo(a)anthracene*	42-133	32	42-133	33-143	53
Benzo(a)pyrene*	32-148	43	32-148	17-163	72
Benzo(b)fluoranthene*	42-140	43	42-140	24-159	71
Benzo(k)fluoranthene*	25-146	38	25-146	11-162	63
Benzo(ghi)perylene*	13-195	61	D-195	D-219	97
Benzyl butyl phthalate*	43-140	36	D-140	D-152	60
bis(2-Chloroethoxy)methane	52-164	32	49-165	33-184	54
bis(2-Ethylhexyl)phthalate*	43-137	50	29-137	8-158	82
bis(2-Chloroisopropyl) ether (2,2'-Oxybis[1-chloropropane])*	63-139	46	63-139	36-166	76
4-Bromophenyl phenyl ether*	70-130	26	65-120	53-127	43
2-Chloronaphthalene*	70-130	15	65-120	60-120	24
4-Chlorophenyl phenyl ether*	57-145	36	38-145	25-158	61
Chrysene*	44-140	53	44-140	17-168	87
Dibenz(a,h)anthracene*	13-200	75	D-200	D-227	126
Di-n-butylphthalate*	52-130	28	8-120	1-120	47
3,3'-Dichlorobenzidine*	18-213	65	8-213	D-262	108
Diethyl phthalate*	47-130	60	D-120	D-120	100
Dimethyl phthalate*	50-130	110	D-120	D-120	183
2,4-Dinitrotoluene*	53-130	25	48-127	39-139	42
2,6-Dinitrotoluene*	68-137	29	68-137	50-158	48
Di-n-octylphthalate*	21-132	42	19-132	4-146	69
Fluoranthene*	47-130	40	43-121	26-137	66
Fluorene*	70-130	23	70-120	59-121	38
Hexachlorobenzene*	38-142	33	8-142	D-152	55
Hexachlorobutadiene*	68-130	38	38-120	24-120	62
Hexachloroethane*	55-130	32	55-120	40-120	52
Indeno(1,2,3-cd)pyrene*	13-151	60	D-151	D-171	99
Isophorone*	52-180	56	47-180	21-196	93
Naphthalene*	70-130	39	36-120	21-133	65
Nitrobenzene*	54-158	37	54-158	35-180	62
N-Nitrosodi-n-propylamine*	59-170	52	14-198	D-230	
Phenanthrene*	67-130	24	65-120	54-120	39
Pyrene*	70-130	30	70-120	52-120	49
1,2,4-Trichlorobenzene*	61-130	30	57-130	44-142	50
4-Chloro-3-methylphenol	68-130	44	41-128	22-147	73
2-Chlorophenol	55-130	37	36-120	23-134	61
2,4-Dichlorophenol	64-130	30	53-122	39-155	50
2,4-Dimethylphenol	58-130	35	42-120	32-120	58
2,4-Dinitrophenol	39-173	79	D-173	D-191	132
2-Methyl-4,6-dinitrophenol	56-130	122	53-130	D-181	203
2-Nitrophenol	61-163	33	45-167	29-182	55

Analyte	Range for Q (%)	Limit for s (%)	Range for $\bar{X}$ (%)	Range for P1, P2 (%)	Limit for RPD (%)
4-Nitrophenol	35-130	79	13-129	D-132	131
Pentachlorophenol	42-152	52	38-152	14-176	86
Phenol	48-130	39	17-120	5-120	64
2,4,6-Trichlorophenol	69-130	35	52-129	37-144	58
4-Chloro-3-methylphenol					
2-Chlorophenol					
2,4-Dichlorophenol					
2,4-Dimethylphenol					
2,4-Dinitrophenol					
2-Methyl-4,6-dinitrophenol					
2-Nitrophenol					
4-Nitrophenol					
Acetophenone					
2-Acetylaminofluorene					
1-Acetyl-2-thiourea					
Alachlor					
Aldrin	7-152	39	7-152	D-166	81
Ametryn					
2-Aminoanthraquinone					
Aminoazobenzene					
4-Aminobiphenyl					
3-Amino-9-ethylcarbazole					
Anilazine					
Aniline					
o-Anisidine					
Aramite					
Atraton					
Atrazine					
Azinphos-methyl					
Barban					
Benzanthrone					
Benzenethiol					
Benzoic acid					
2,3-Benzofluorene					
p-Benzoquinone					
Benzyl alcohol					
alpha-BHC					
beta-BHC	42-131	37	42-131	24-149	61
gamma-BHC (Lindane)					
delta-BHC	D-130	77	D-120	D-120	129
Biphenyl					
Bromacil					
2-Bromochlorobenzene					
3-Bromochlorobenzene					
Bromoxynil					
Butachlor					
Butylate					

Analyte	Range for Q (%)	Limit for s (%)	Range for $\overline{X}$ (%)	Range for P1, P2 (%)	Limit for RPD (%)
n-C10 (n-decane)					
n-C12 (n-undecane)					
n-C14 (n-tetradecane)					
n-C16 (n-hexadecane)					
n-C18 (n-octadecane)					
n-C20 (n-eicosane)					
n-C22 (n-docosane)					
n-C24 (n-tetracosane)					
n-C26 (n-hexacosane)					
n-C28 (n-octacosane)					
n-C30 (n-triacontane)					
Captafol					
Captan					
Carbaryl					
Carbazole					
Carbofuran					
Carboxin					
Carbophenothion					
Chlordane 3,5					
bis(2-Chloroethyl) ether	52-130	65	43-126	12-158	108
Chloroneb					
4-Chloroaniline					
Chlorobenzilate					
Chlorfenvinphos					
4-Chloro-2-methylaniline					
3-(Chloromethyl)pyridine hydrochloride					
4-Chloro-2-nitroaniline					
Chlorpropham					
Chlorothalonil					
1-Chloronaphthalene					
3-Chloronitrobenzene					
4-Chloro-1,2-phenylenediamine					
4-Chloro-1,3-phenylenediamine					
2-Chlorobiphenyl					
Chlorpyrifos					
Coumaphos					
m + p-Cresol					
o-Cresol					
p-Cresidine					
Crotoxyphos					
2-Cyclohexyl-4,6-dinitro-phenol					
Cyanazine					
Cycloate					
p-Cymene					
Dacthal (DCPA)					
4,4’-DDD	D-135	56	D-135	D-145	93

Analyte	Range for Q (%)	Limit for s (%)	Range for $\bar{X}$ (%)	Range for P1, P2 (%)	Limit for RPD (%)
4,4'-DDE	19-130	46	19-120	4-136	77
4,4'-DDT	D-171	81	D-171	D-203	135
Demeton-O					
Demeton-S					
Diallate (cis or trans)					
2,4-Diaminotoluene					
Diazinon					
Dibenz(a,j)acridine					
Dibenzofuran					
Dibenzo(a,e)pyrene					
Dibenzothiophene					
1,2-Dibromo-3-chloropropane					
3,5-Dibromo-4-hydroxybenzonitrile					
2,6-Di-tert-butyl-p-benzoquinone					
Dichlone					
2,3-Dichloroaniline					
2,3-Dichlorobiphenyl					
2,6-Dichloro-4-nitroaniline					
2,3-Dichloronitrobenzene					
1,3-Dichloro-2-propanol					
2,6-Dichlorophenol					
Dichlorvos					
Dicrotophos					
Dieldrin 3	70-130	38	44-119	29-136	62
1,2:3,4-Diepoxybutane					
Di(2-ethylhexyl) adipate					
Diethylstilbestrol					
Diethyl sulfate					
Dilantin (5,5-Diphenylhydantoin)					
Dimethoate					
3,3′-Dimethoxybenzidine					
Dimethylaminoazobenzene					
7,12-Dimethylbenz(a)anthracene					
3,3′-Dimethylbenzidine					
N,N-Dimethylformamide					
3,6-Dimethylphenathrene					
alpha, alpha-Dimethylphenethylamine					
Dimethyl sulfone					
1,2-Dinitrobenzene					
1,3-Dinitrobenzene					
1,4-Dinitrobenzene					
Dinocap					
Dinoseb					
Diphenylamine					
Diphenyl ether					

Analyte	Range for Q (%)	Limit for s (%)	Range for $\overline{X}$ (%)	Range for P1, P2 (%)	Limit for RPD (%)
1,2-Diphenylhydrazine					
Diphenamid					
Diphenyldisulfide					
Disulfoton					
Disulfoton sulfoxide					
Disulfoton sulfone					
Endosulfan I					
Endosulfan II					
Endosulfan sulfate	D-130	42	D-120	D-120	70
Endrin					
Endrin aldehyde	D-189	45	D-189	D-209	75
Endrin ketone					
EPN					
EPTC					
Ethion					
Ethoprop					
Ethyl carbamate					
Ethyl methanesulfonate					
Ethylenethiourea					
Etridiazole					
Ethynylestradiol-3-methyl ether					
Famphur					
Fenamiphos					
Fenarimol					
Fensulfothion					
Fenthion					
Fluchloralin					
Fluridone					
Heptachlor	D-172	44	D-172	D-192	74
Heptachlor epoxide	70-130	61	71-120	26-155	101
2,2′,3,3′,4,4′,6-Heptachlorobiphenyl					
2,2′,4,4′,5′,6-Hexachlorobiphenyl					
Hexachlorocyclopentadiene					
Hexachlorophene					
Hexachloropropene					
Hexamethylphosphoramide					
Hexanoic acid					
Hexazinone					
Hydroquinone					
Isodrin					
2-Isopropylnaphthalene					
Isosafrole					
Kepone					
Leptophos					
Longifolene					
Malachite green					

Analyte	Range for Q (%)	Limit for s (%)	Range for $\bar{X}$ (%)	Range for P1, P2 (%)	Limit for RPD (%)
Malathion					
Maleic anhydride					
Merphos					
Mestranol					
Methapyrilene					
Methoxychlor					
2-Methylbenzothioazole					
3-Methylcholanthrene					
4,4′-Methylenebis(2-chloroaniline)					
4,4′-Methylenebis(N,N-dimethylaniline)					
4,5-Methylenephenanthrene					
1-Methylfluorene					
Methyl methanesulfonate					
2-Methylnaphthalene					
Methylparaoxon					
Methyl parathion					
1-Methylphenanthrene					
2-(Methylthio)benzothiazole					
Metolachlor					
Metribuzin					
Mevinphos					
Mexacarbate					
MGK 264					
Mirex					
Molinate					
Monocrotophos					
Naled					
Napropamide					
1,4-Naphthoquinone					
1-Naphthylamine					
2-Naphthylamine					
1,5-Naphthalenediamine					
Nicotine					
5-Nitroacenaphthene					
2-Nitroaniline					
3-Nitroaniline.					
4-Nitroaniline.					
5-Nitro-o-anisidine					
4-Nitrobiphenyl					
Nitrofen					
5-Nitro-o-toluidine					
Nitroquinoline-1-oxide					
N-Nitrosodi-n-butylamine					
N-Nitrosodiethylamine					
N-Nitrosodimethylamine					
N-Nitrosodiphenylamine					

Analyte	Range for Q (%)	Limit for s (%)	Range for $\bar{X}$ (%)	Range for P1, P2 (%)	Limit for RPD (%)
N-Nitrosomethylethylamine					
N-Nitrosomethylphenylamine					
N-Nitrosomorpholine					
N-Nitrosopiperidine					
N-Nitrosopyrrolidine					
trans-Nonachlor					
Norflurazon					
2,2′,3,3′,4,5′,6,6′-Octachlorobiphenyl					
Octamethyl pyrophosphoramide					
4,4’-Oxydianiline					
Parathion					
PCB–1016					
PCB–1221					
PCB–1232					
PCB–1242					
PCB–1248					
PCB–1254					
PCB–1260	19-130	77	19-130	D-164	128
PCB–1268					
Pebulate					
Pentachlorobenzene					
Pentachloronitrobenzene					
2,2′,3,4′,6-Pentachlorobiphenyl					
Pentachloroethane					
Pentamethylbenzene					
Perylene					
Phenacetin					
cis-Permethrin					
trans-Permethrin					
Phenobarbital					
Phenothiazene					
1,4-Phenylenediamine					
1-Phenylnaphthalene					
2-Phenylnaphthalene					
Phorate					
Phosalone					
Phosmet					
Phosphamidon					
Phthalic anhydride					
alpha-Picoline (2-Methylpyridine)					
Piperonyl sulfoxide					
Prometon					
Prometryn					
Pronamide					
Propachlor					
Propazine					

Analyte	Range for Q (%)	Limit for s (%)	Range for $\bar{X}$ (%)	Range for P1, P2 (%)	Limit for RPD (%)
Propylthiouracil					
Pyridine					
Resorcinol (1,3-Benzenediol)					
Safrole					
Simazine					
Simetryn					
Squalene					
Stirofos					
Strychnine					
Styrene 9					
Sulfallate					
Tebuthiuron					
Terbacil..					
Terbufos					
Terbutryn					
alpha-Terpineol					
1,2,4,5-Tetrachlorobenzene					
2,2′,4,4′-Tetrachlorobiphenyl					
2,3,7,8-Tetrachlorodibenzo-p-dioxin					
2,3,4,6-Tetrachlorophenol					
Tetrachlorvinphos					
Tetraethyl dithiopyrophosphate					
Tetraethyl pyrophosphate					
Thianaphthene (2,3-Benzothiophene)					
Thioacetamide					
Thionazin					
Thiophenol (Benzenethiol)					
Thioxanthone					
Toluene-1,3-diisocyanate					
Toluene-2,4-diisocyanate					
o-Toluidine					
Toxaphene 3,5					
Triadimefon					
1,2,3-Trichlorobenzene					
2,4,5-Trichlorobiphenyl					
2,3,6-Trichlorophenol					
2,4,5-Trichlorophenol					
Tricyclazole					
Trifluralin					
1,2,3-Trimethoxybenzene					
2,4,5-Trimethylaniline					
Trimethyl phosphate					
Triphenylene					
Tripropyleneglycolmethyl ether					
1,3,5-Trinitrobenzene					

Analyte	Range for Q (%)	Limit for s (%)	Range for $\bar{X}$ (%)	Range for P1, P2 (%)	Limit for RPD (%)
Tris(2,3-dibromopropyl) phosphate					
Tri-p-tolyl phosphate					
O,O,O-Triethyl phosphorothioate.					
Trithiane					
Vernolate					

Many of the analytes in this table do not have QC acceptance criteria. If calibration is to be verified and other QC tests are to be performed for these analytes, acceptance criteria must be developed and applied. EPA has provided guidance for development of QC acceptance criteria (see 40 CFR 136.6(b)(2)(i) and *Protocol for EPA Approval of New Methods for Organic and Inorganic Analytes in Wastewater and Drinking Water* (EPA–821–B–98–003) March 1999). Alternatively, analytes that do not have acceptance criteria may be based on laboratory control charts, or 60 to 140% may be used.

* At a minimum, these compounds must be spiked into the MS/MSD analyses when direction cannot be obtained from the data user.

Attachment VIII – Method 625.1 Suggested Internal Standards and Surrogates

Compound	Range for Surrogate Recovery	
	Calibration Verification	Recovery from Samples
Base/Neutral Fraction		
Acenaphthalene-d_8	66-152	33-168
Acenaphthene-d_{10}	71-141	30-180
Aniline-d5		
Anthracene-d_{10}	58-171	53-142
Benzo(a)anthracene-d_{12}	28-357	22-329
Benzo(a)pyrene-d_{12}	32-194	32-194
4-Chloroaniline-d_4	1-145	1-145
bis(2-Chloroethyl)ether-d_8	52-194	25-222
Chrysene-d_{12}	23-290	23-290
Decafluorobiphenyl		
4,4'-Dibromobiphenyl		
4,4'-Dibromooctafluorobiphenyl		
1,4-Dichlorobenzene-d_4	65-153	11-245
2,2'-Difluorobiphenyl		
Dimethyl phthalate-d_6	47-211	1-500
Fluoranthene-d_{10}	61-164	38-172
4-Fluoroaniline		
1-Fluoronaphthalene		
2-Fluoronaphthalene		
2-Methylnaphthalene-d_{10}	50-150	50-150
Naphthalene-d_8	71-141	22-192
Nitrobenzene-d_5	46-219	15-314
2,3,4,5,6-Pentafluorobiphenyl		
Perylene-d_{12}		
Phenanthrene-d_{10}	67-149	34-168
Pyrene-d_{10}	48-210	28-196
Pyridine-d_5		
Acid Fraction		
2-Chlorophenol-d_4	55-180	33-180
2,4-Dichlorophenol-d_3	64-157	34-182
4,6-Dinitro-2-methylphenol-d_2	56-177	22-307
2-Fluorophenol		
4-Methylphenol-d_8	25-111	25-111
2-Nitrophenol-d_4	61-163	37-163
4-Nitrophenol-d_4	35-287	6-500
Pentafluorophenol		
2-Perfluoromethylphenol		
Phenol-d_5	48-208	8-424

Many of the surrogates in this table do not have QC acceptance criteria. If calibration is to be verified and other QC tests are to be performed for these surrogates, acceptance criteria must be developed and applied. EPA has provided guidance for development of QC acceptance criteria (see 40 CFR 136.6(b)(2)(i) and *Protocol for EPA Approval of New Methods for Organic and Inorganic Analytes in Wastewater and Drinking Water* (EPA–821–B–98–003) March 1999). Alternatively, surrogates that do not have acceptance criteria may be based on laboratory control charts, or 60 to 140% may be used.

Attachment IX – DoD Requirements

1.0 Equipment/Instrument Maintenance

Instrument maintenance must be performed routinely to optimize instrument performance and improve chromatography. Commonly performed maintenance includes baking columns, changing injection port liners, changing pump oil, etc. A new calibration curve must be analyzed following any major maintenance performed on the analytical system.

2.0 Computer Hardware and Software

Software name and version: HP Chemstation G1701CA Version C.00.00 or equivalent

3.0 Troubleshooting

Table 1. GCMS Troubleshooting Guide

Problem	Cause	Treatment
Peaks broaden and tail	Poor column installation causing dead volume in the injector	Reinstall column in injector. Check seal at ferrule. Check insertion depth. Ensure a good column cut.
	Solvent flashing in hot injector	Reduce injection speed on hot injectors and if possible reduce injector temperature
	Injector not being purged properly after splitless injection	For splitless injection, the vent flow should be 70 ml/min, and the injector should be switched to the split mode 0.5_1.5 min after injection.
Tailing sample peaks for active components	Active sites in the injector insert or liner	Change or clean the injector insert
	Active sites or degraded phase in column	Remove the front 15 cm of the column and reinstall. If retention times are changing or cutting the column does not help, replace the column.
	Injector not hot enough for higher boiling compounds	Increase the injector temperature and lower the injection speed. Check that the graphite ferrule is free of cracks and the septum support is tight.
Low response and tailing of high boiling point compounds	Injector is not hot enough to vaporize high boilers	Increase injector temperature
	Interface/ion source not getting to adequate temperature	Change the manifold heater
Leading sample peaks	Column overload due to excess amount of component injected	Dilute the sample or do split injection
	Degradation of stationary phase	Change the column
	Carrier gas velocity too low	Increase carrier gas flow rate
Poor chromatographic resolution	Column temperature or program not optimized	Modify method by changing temperature ramp segment slopes
	Carrier gas flow rate not optimized	Decrease carrier gas linear velocity

Table 1. GCMS Troubleshooting Guide

Problem	Cause	Treatment
	Stationary phase has degraded	Replace the column
Peak splitting, especially low boilers	Sample is flashing in the injector simulating two injections	Lower injector temperature
Retention times shift in chromatogram	Unstable carrier gas flow controller/regulator	Check pneumatics for leaks. Replace flow controller/ regulator if necessary.
	Column contamination or degradation	Condition or replace column
	Leaks at septum or column to injector connection	Replace septum regularly and check that the septum nut and the capillary column nut are tight
Cannot reach operating vacuum	Analyzer contaminated by diffusion pump oil	Shut down and clean mass spec
	Major air leak around column fitting into interface	Replace column ferrule and reseat compression fitting
No calibration gas peaks	Cal gas valve not open	Open cal gas valve
	Calibration gas solenoid valve stuck open. All calibration gas evaporated.	Have solenoid replaced. Put fresh PFBTA in the cal gas vial.
Analysis sensitivity has decreased	Background has increased	Check column bleed, septum bleed, pump oil, and ion source contamination
	Detector needs replacement	Replace detector
	Defective syringe	Try a new or proven syringe
	"Blown" septum or other massive leaks at the inlet or with carrier gas flow. Poor peak shapes usually result from bad leaks.	Find and fix leaks and adjust gas flow.
	Purge flow or split ratio too high	Adjust gas flow rates

4.0 Other Requirements

4.1 All hardcopy laboratory notebooks must be reviewed by the Supervisor, or their designee, on a monthly basis.

4.2 If not self-explanatory (e.g., a typo or transposed number), corrections to technical and quality records shall also include a justification for the change.

4.3 A storage blank must be stored with all volatile organic samples, regardless of suspected concentration levels.

4.4 A person performing a manual integration must sign and date each manually integrated chromatogram and record the rationale for performing manual integration. Electronic signatures are acceptable.

4.5 The results of calibration and verification of support equipment must be within the specifications required of the application for which this equipment is used or the equipment must be removed from service until repaired. Calibration and verification records, including those of established correction factors, must be maintained. In the absence of method-specific requirements, the minimum requirements are as follows:

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Balance calibration check [Using two standard weights that bracket the expected mass]	Daily prior to use	Top-loading balance: ±2% or ±0.02g, whichever is greater Analytical balance: ±0.1% or ±0.5 mg, whichever is greater
Verification of standard mass [Using weights traceable to the International System of Units (SI) through a NMI	Every 5 years	Certificate of Calibration from ISO/IEC 17025 accredited calibration laboratory
Monitoring of refrigerator/freezer temperatures	Daily (i.e. 7 days per week) [use MIN/MAX thermometers or data loggers equipped with notification of out of control event capabilities if personnel not available to record daily]	Refrigerators: 0˚C to 6˚C Freezers: ≤-10˚C
Thermometer verification check [Using a thermometer traceable to the SI through an NMI] [Performed at two temperatures that bracket the target temperature(s). Assume linearity between the two bracketing temperatures.] [If only a single temperature is used, at the temperature of use]	Liquid in glass: Before first use and annually Electronic: Before first use and quarterly	Apply correction factors or replace thermometer
Volumetric labware	Class B: By lot before first use Class A and B: Upon evidence of deterioration	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on 10 replicate measurements)
Non-volumetric labware [Applicable only when used for measuring initial sample volume and final extract/ digestates volume]	By lot before first use or upon evidence of deterioration	Bias: Mean within ±3% of nominal volume Precision: RSD ≤3% of nominal volume (based on 10 replicate measurements)
Mechanical volumetric pipette	Quarterly	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on minimum of 3 replicate measurements) [Note: for variable volume pipettes, the nominal volume is the volume of use]
Glass microliter syringe	Upon receipt and upon evidence of deterioration	General Certificate of Bias & Precision upon receipt Replace if deterioration is evident

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Drying oven temperature check	Daily prior to and after use	Within ±5% of set temperature
Water purification system	Daily prior to use	See method blank criteria given in Section 4.20 of this addendum

4.6 The expiration date of the prepared standard shall not exceed the expiration date of the primary standard. All containers must bear a preparation date.

4.7 To avoid preparing non-representative samples, the laboratory shall not “target” within a relatively small mass range (e.g., 1.00 ± 0.01g) because such targeting will produce non-representative subsamples if the sample has high heterogeneity. The laboratory shall not manipulate the sample material so the sample aliquot weighs exactly 1.00g ± 0.01g, as an example.

4.8 In the absence of project-specific requirements, the minimum standard data qualifiers to be used are:

U	Analyte was not detected and is reported as less than the LOD or as defined by the customer. The LOD has been adjusted for any dilution or concentration of the sample.
J	The reported result is an estimated value (e.g., matrix interference was observed or the analyte was detected at a concentration outside the quantitation range).
B	Blank contamination. The recorded result is associated with a contaminated blank.
N	Non-target analyte. The analyte is a tentatively identified compound using mass spectrometry or any non-customer requested compounds that are tentatively identified.
Q	One or more quality control criteria failed (e.g., LCS recovery, surrogate spike recovery, or CCV recovery).

Additional data qualifiers may be used, or different letters or symbols to denote the qualifiers listed above, as long as they are appropriately defined and their use is consistent with project-specific requirements (e.g., QSM 5.0, the contract, and project-planning documents).

4.9 If the time of the sample collection is not provided, assume the most conservative time of day. For the purpose of batch processing, the start and stop dates and times of the batch preparation shall be recorded.

4.10 Each preparation method listed on the scope of accreditation must have quarterly LOD/LOQ verifications. However, not all possible combinations of preparation and cleanup techniques are required to have LOD/LOQ verifications. If LOD/LOQ verifications are not performed on all combinations, the laboratory must base the LOD/LOQ verifications on the worst case basis (preparation method with all applicable cleanup steps).

4.11 After each MDL determination, the laboratory must establish the LOD by spiking a quality system matrix at a concentration of at least 2 times but no greater than four times the

MDL. This spike concentration establishes the LOD and the concentration at which the LOD shall be verified. It is specific to each suite of analyte, matrix, and method (including sample preparation). The following requirements apply to the initial LOD establishment and to the LOD verifications:

- The apparent signal to noise (S/N) ratio at the LOD must be at least three and the results must meet all method requirements for analyte identification (e.g., ion abundance, second column confirmation, or pattern recognition). For data systems that do not provide a measure of noise, the signal produced by the verification sample must produce a result that is at least three standard deviations greater than the mean method blank concentration. This is initially estimated based on a minimum of four method blank analyses and later established with a minimum of 20 method blank results.
- If the LOD verification fails, then the laboratory must repeat the MDL determination and LOD verification or perform and pass two consecutive LOD verifications at a higher spike concentration and set the LOD at the higher concentration.
- The laboratory shall maintain documentation for all MDL determinations and LOD verifications.
- The DL and LOD must be reported for all analyte-matrix-methods suites, unless it is not applicable to the test or specifically excluded by project requirements.

4.12 The LOD shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOD verifications on a one per batch basis. All verification data will be in compliance, reported, and available for review.

4.13 For DoD, at a minimum, the LOQ shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOQ verifications on a one per batch basis.

4.14 All initial instrument calibrations must be verified with a standard obtained from a second manufacturer prior to analyzing any samples. The use of a standard from a second lot obtained from the same manufacturer (independently prepared from different source materials) is acceptable for use as a second source standard. The concentration of the second source standard shall be at or near the midpoint of the calibration range. The acceptance criteria for the initial calibration verification must be at least as stringent as those for the continuing calibration verification.

4.15 Exclusion of calibration points without documented scientifically valid technical justification is not permitted.

4.16 The concentration of the CCV standard shall be greater than the low calibration standard and less than or equal to the midpoint of the calibration range.

4.17 All CCVs analyzed must be evaluated and reported. If a CCV fails, reanalysis or corrective actions must be taken.

- If a CCV fails, the laboratory can immediately analyze two additional consecutive CCVs (immediately is defined as starting a consecutive pair within one hour; no samples can be run between the failed CCV and the two additional CCVs). This approach allows for spurious failures of analytes to be reported without reanalysis of samples. Any corrective actions that change the dynamics of the system (e.g., clip column, clean injection port, run blanks) requires that all samples since the last acceptable CCV be reanalyzed.

- Both of these CCVs must meet acceptance criteria in order for the samples to be reported without reanalysis.
- If either of these two CCVs fail or if the laboratory cannot immediately analyze two CCVs, the associated samples cannot be reported and must be reanalyzed.
- Corrective action(s) and recalibration must occur if the above scenario fails. All affected samples since the last acceptable CCV must be reanalyzed.
- Flagging of data for a failed CCV is only appropriate when the affected samples cannot be reanalyzed. The laboratory must notify the client prior to reporting data associated with a failed CCV.

4.18 The results of all MS/MSDs must be evaluated using the same acceptance criteria used for the DoD LCS limits (see Addendum Tables 3 through 6) or project limits, if specified. If the specific analyte(s) are not available in the Addendum Tables 3 through 6, the laboratory shall use their LCS in-house limits (see the LIMS) as a means of evaluating MS/MSDs. The MS and MSD must be spiked with all reported analytes.

4.19 Surrogate spike results shall be compared with DoD LCS limits (see Addendum Tables 3 through 6) or acceptance criteria specified by the client. If these criteria are not available, the laboratory shall compare the results with its in-house statistically established LCS criteria (see the LIMS).

4.20 The method blank shall be considered to be contaminated if:

- The concentration of any target analyte (chemical of concern) in the blank exceeds 1/2 the LOQ and is greater than 1/10th the amount measured in any associated sample, or 1/0th the regulatory limit, whichever is greater;
- The concentration of any common laboratory contaminant in the blank exceeds the LOQ;
- If a method blank is contaminated as described above, then the laboratory shall reprocess affected samples in a subsequent preparation batch, except when sample results are below the LOD. If insufficient sample volume remains for reprocessing, the results shall be reported with appropriate data qualifiers.

4.21 Sporadic Marginal Exceedances are not allowed for target analytes (chemicals of concern as identified by a project) without project-specific approval. Target analytes are considered those few analytes that are critical for the success of a project (such as risk drivers) where sporadic marginal exceedances cannot be allowed. Laboratories should consult with clients whenever long lists of analytes are requested for analysis to determine if marginal exceedances will not be allowed.

4.22 DoD considers the same analyte exceeding the LCS control limit two (2) out of three (3) consecutive LCS to be indicative of non-random behavior, which requires corrective action and reanalysis of the LCS.

Table 3. LCS Control Limits – Method 8270 Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
92-52-4	1,1-Biphenyl	1645	78.5	13	40	117
95-94-3	1,2,4,5-Tetrachlorobenzene	1810	77.8	13.7	37	119
120-82-1	1,2,4-Trichlorobenzene	3577	75.7	13.9	34	118
95-50-1	1,2-Dichlorobenzene	3352	74.6	14	33	117
528-29-0	1,2-Dinitrobenzene [1,2-DNB]	203	79.4	11.9	44	115
122-66-7	1,2-Diphenylhydrazine [Azobenzene]	2039	83	13.9	41	125
99-35-4	1,3,5-Trinitrobenzene [1,3,5-TNB]	154	89.2	10.7	57	121
541-73-1	1,3-Dichlorobenzene	3288	72.6	14.1	30	115
99-65-0	1,3-Dinitrobenzene [1,3-DNB]	598	84.6	14	43	127
106-46-7	1,4-Dichlorobenzene	3793	73.1	13.9	31	115
100-25-4	1,4-Dinitrobenzene	248	84.4	15.7	37	132
130-15-4	1,4-Naphthoquinone	150	81.2	8.8	55	108
90-13-1	1-Chloronaphthalene	119	81.1	11.1	48	115
90-12-0	1-Methylnaphthalene	3004	79.2	13.2	40	119
58-90-2	2,3,4,6-Tetrachlorophenol	1724	84.7	13.6	44	125
935-95-5	2,3,5,6-Tetrachlorophenol	227	75.9	11.9	40	112
608-27-5	2,3-Dichloroaniline	108	82.4	13	44	121
95-95-4	2,4,5-Trichlorophenol	4014	82.6	13.7	41	124
118-79-6	2,4,6-Tribromophenol	2930	85.7	15.4	39	132
88-06-2	2,4,6-Trichlorophenol	4183	82.1	14.5	39	126
120-83-2	2,4-Dichlorophenol	3794	80.9	13.7	40	122
105-67-9	2,4-Dimethylphenol	3886	78.4	16.2	30	127
121-14-2	2,4-Dinitrotoluene	4075	86.8	12.9	48	126
87-65-0	2,6-Dichlorophenol	1364	79.2	12.6	41	117
606-20-2	2,6-Dinitrotoluene	3706	85	13	46	124
53-96-3	2-Acetylaminofluorene	175	94	13.3	54	134
91-58-7	2-Chloronaphthalene	3569	77.5	12.1	41	114
95-57-8	2-Chlorophenol	3977	77.3	14.5	34	121
321-60-8	2-Fluorobiphenyl	3191	79.5	11.8	44	115
367-12-4	2-Fluorophenol	3008	75.2	13.3	35	115
91-57-6	2-Methylnaphthalene	5059	80.1	14	38	122
95-48-7	2-Methylphenol (o-Cresol)	4016	77	14.9	32	122
88-74-4	2-Nitroaniline	3639	85.4	13.8	44	127
119-75-5	2-Nitrodiphenylamine	279	88.1	11.6	53	123
88-75-5	2-Nitrophenol	3804	79.6	14.5	36	123
109-06-8	2-Picoline [2-Methylpyridine]	181	64.5	12.7	27	103
91-94-1	3,3'-Dichlorobenzidine	3521	71.3	16.5	22	121
56-49-5	3-Methylcholanthrene	188	95.1	13	56	134
99-09-2	3-Nitroaniline	3454	75.9	14.3	33	119
65794-96-9	3/4-Methylphenol [m/p-Cresol]	2900	76.5	14.1	34	119
534-52-1	4,6-Dinitro-2-methylphenol	3739	80.7	17.2	29	132
101-55-3	4-Bromophenyl phenyl ether	3708	85.1	13	46	124
59-50-7	4-Chloro-3-methylphenol	3880	83.3	12.9	45	122

Table 3. LCS Control Limits – Method 8270 Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
106-47-8	4-Chloroaniline [p-Chloroanlinie]	3435	61.3	14.9	17	106
7005-72-3	4-Chlorophenyl phenyl ether	3673	83	12.7	45	121
106-44-5	4-Methylphenol [p-Cresol]	1555	84.1	14.1	42	126
100-02-7	4-Nitrophenol	3976	80.6	17	30	132
99-55-8	5-Nitro-o-toluidine [2-Amino-4-nitrotoluene]	187	69.8	15.8	23	117
57-97-6	7,12-Dimethylbenz(a)-anthracene	338	96.2	15.3	50	142
83-32-9	Acenaphthene	5300	81.3	13.7	40	123
208-96-8	Acenaphthylene	5194	81.8	16.8	32	132
98-86-2	Acetophenone	2101	73.9	13.6	33	115
120-12-7	Anthracene	5250	85.2	12.7	47	123
1912-24-9	Atrazine	1428	87.1	13.4	47	127
103-33-3	Azobenzene	378	82.1	14.2	39	125
56-55-3	Benz(a)anthracene	5385	87.4	12.9	49	126
50-32-8	Benzo(a)pyrene	5500	86.9	13.9	45	129
205-99-2	Benzo(b)fluoranthene	5323	88.3	14.5	45	132
191-24-2	Benzo(g,h,i)perylene	5263	88.5	15.1	43	134
207-08-9	Benzo(k)fluoranthene	5386	89.6	14.2	47	132
100-51-6	Benzyl alcohol	2895	75.7	15.6	29	122
111-91-1	bis(2-Chloroethoxy)methane	3705	78.4	14.2	36	121
111-44-4	Bis(2-chloroethyl) ether	3711	75.4	14.9	31	120
39638-32-9	bis(2-Chloroisopropyl) ether	769	82	16.3	33	131
117-81-7	Bis(2-ethylhexyl) phthalate	4018	91.9	13.7	51	133
103-23-1	bis(2-Ethylhexyl)adipate	156	90.8	10.1	61	121
85-68-7	Butyl benzyl phthalate	3956	90.3	14	48	132
105-60-2	Caprolactam	1203	81.3	11.9	46	117
86-74-8	Carbazole	3095	86.3	12	50	123
510-15-6	Chlorobenzilate	172	99.7	16.9	49	150
218-01-9	Chrysene	5395	87.1	12.2	50	124
84-74-2	Di-n-butyl phthalate	4041	89.4	12.8	51	128
117-84-0	Di-n-octyl phthalate	3985	92.4	16	45	140
2303-16-4	Diallate [cis or trans]	173	93.7	12.7	56	132
53-70-3	Dibenzo(a,h)anthracene	5393	89.5	14.7	45	134
132-64-9	Dibenzofuran	3749	81.5	12.7	44	120
84-66-2	Diethyl phthalate	4012	87.2	12.3	50	124
60-51-5	Dimethoate	137	68	13.3	28	108
131-11-3	Dimethyl phthalate	4023	85.9	12.6	48	124
60-11-7	Dimethylaminoazobenzene	177	98.7	11.6	64	134
88-85-7	Dinoseb	123	67.3	17.1	16	119
101-84-8	Diphenyl ether	114	95.6	6	78	114
122-39-4	Diphenylamine	854	79.5	10.6	48	111
62-50-0	Ethyl methanesulfonate	174	85.1	16.9	34	136
206-44-0	Fluoranthene	5340	88.3	12.9	50	127
86-73-7	Fluorene	5150	84.2	13.8	43	125

Table 3. LCS Control Limits – Method 8270 Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
118-74-1	Hexachlorobenzene	4138	83.5	13	45	122
87-68-3	Hexachlorobutadiene	4003	77.3	15.3	32	123
67-72-1	Hexachloroethane	4049	72.2	14.9	28	117
1888-71-7	Hexachloropropene	259	81.9	16.7	32	132
95-13-6	Indene	188	85.3	8.9	59	112
193-39-5	Indeno(1,2,3-cd)pyrene	5367	89.3	14.7	45	133
465-73-6	isodrin	167	93.8	12.8	56	132
78-59-1	Isophorone	3787	75.9	15.2	30	122
120-58-1	Isosafrole	174	89.5	15.4	43	136
66-27-3	Methyl methanesulfonate	150	77.9	13.1	38	117
100-75-4	N-Nitorosopiperidine	232	89.4	9.8	60	119
924-16-3	N-Nitrosodi-n-butylamine	236	91.7	10.8	59	124
621-64-7	N-Nitrosodi-n-propylamine	3857	78.2	13.9	36	120
55-18-5	N-nitrosodiethylamine	421	82.1	13.8	41	124
62-75-9	N-Nitrosodimethylamine	3170	71.6	16.2	23	120
86-30-6	N-Nitrosodiphenylamine	2968	82.7	14.8	38	127
10595-95-6	n-Nitrosomethylethylamine	265	78.7	14.9	34	123
59-89-2	n-Nitrosomorpholine	172	91.3	13.8	50	133
930-55-2	n-Nitrosopyrrolidine	326	85.5	13.6	45	126
91-20-3	Naphthalene	5342	78.8	14.7	35	123
98-95-3	Nitrobenzene	4103	77.8	14.7	34	122
4165-60-0	Nitrobenzene-d5	3226	79.3	14.2	37	122
56-57-5	Nitroquinoline-1-oxide	177	91.3	24.5	18	165
126-68-1	O,O,O-Triethyl phosphorothioate	138	91.6	10.8	59	124
593-45-3	Octadecane	113	87.4	14.5	44	131
608-93-5	Pentachlorobenzene	346	89.7	11.8	54	125
76-01-7	Pentachloroethane	131	70.4	10.6	39	102
87-86-5	Pentachlorophenol	4161	78.7	18	25	133
82-68-8	Pentchloronitrobenzene	579	86.1	16	38	134
62-44-2	Phenacetin	185	95	12.5	57	133
85-01-8	Phenanthrene	5259	85.4	12	50	121
108-95-2	Phenol	4029	77.3	14.4	34	121
4165-62-2	Phenol-d5	1016	77.4	14.9	33	122
23950-58-5	Pronamide	179	93	12.4	56	130
129-00-0	Pyrene	5518	87.2	13.3	47	127
91-22-5	Quinoline	219	90	11.9	54	126
94-59-7	Safrole	176	87.8	13.6	47	129
1718-51-0	Terphenyl-d14	3111	90.5	12.3	54	127
3689-24-5	Tetraethyl dithiopyrophosphate [Sulfotep]	136	94.4	14	52	137
297-97-2	Thionazine	139	94.6	10.7	62	127

Table 4. LCS Control Limits – Method 8270 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
92-52-4	1,1-Biphenyl	2247	82.1	11.1	49	115
95-94-3	1,2,4,5-Tetrachlorobenzene	2326	77.9	14.5	35	121
120-82-1	1,2,4-Trichlorobenzene	4716	72.6	14.5	29	116
95-50-1	1,2-Dichlorobenzene	4442	71.4	13.3	32	111
528-29-0	1,2-Dinitrobenzene [1,2-DNB]	112	83.9	8.3	59	109
122-66-7	1,2-Diphenylhydrazine [Azobenzene]	2244	85.4	12.2	49	122
99-35-4	1,3,5-Trinitrobenzene [1,3,5-TNB]	241	89.1	16	41	137
541-73-1	1,3-Dichlorobenzene	4375	68.6	13.6	28	110
99-65-0	1,3-Dinitrobenzene [1,3-DNB]	601	88.2	13.1	49	128
106-46-7	1,4-Dichlorobenzene	5433	70.4	13.9	29	112
90-13-1	1-Chloronaphthalene	211	84.5	8.8	58	111
90-12-0	1-Methylnaphthalene	3742	80	13.1	41	119
134-32-7	1-Naphthylamine	258	73.7	16.6	24	124
58-90-2	2,3,4,6-Tetrachlorophenol	2293	89	13	50	128
935-95-5	2,3,5,6-Tetrachlorophenol	266	85.6	11.7	50	121
608-27-5	2,3-Dichloroaniline	150	99.2	9.8	70	129
95-95-4	2,4,5-Trichlorophenol	5707	88.1	11.8	53	123
118-79-6	2,4,6-Tribromophenol	2059	91.5	16	43	140
88-06-2	2,4,6-Trichlorophenol	6136	87.2	12.4	50	125
120-83-2	2,4-Dichlorophenol	5330	84	12.2	47	121
105-67-9	2,4-Dimethylphenol	5298	77.5	15.6	31	124
51-28-5	2,4-Dinitrophenol	5127	82.9	20	23	143
121-14-2	2,4-Dinitrotoluene	6032	92.3	11.8	57	128
87-65-0	2,6-Dichlorophenol	1583	84	11.4	50	118
606-20-2	2,6-Dinitrotoluene	5107	90.7	11.2	57	124
53-96-3	2-Acetylaminofluorene	228	98.9	12.9	60	138
91-58-7	2-Chloronaphthalene	5084	78	12.8	40	116
95-57-8	2-Chlorophenol	5571	77.5	13.2	38	117
93951-73-6	2-Chlorophenol-d4	119	79.9	8.7	54	106
321-60-8	2-Fluorobiphenyl	2263	81.2	12.4	44	119
367-12-4	2-Fluorophenol	2022	68.8	16.6	19	119
91-57-6	2-Methylnaphthalene	6330	80.7	13.6	40	121
95-48-7	2-Methylphenol (o-Cresol)	5800	73	14.5	30	117
88-74-4	2-Nitroaniline	4855	90.8	12.1	55	127
119-75-5	2-Nitrodiphenylamine	272	97.3	11.3	64	131
88-75-5	2-Nitrophenol	5097	84.6	12.7	47	123
109-06-8	2-Picoline [2-Methylpyridine]	195	71.6	12.6	34	109
91-94-1	3,3'-Dichlorobenzidine	4815	77.9	16.9	27	129
56-49-5	3-Methylcholanthrene	237	94	12.8	56	133
99-09-2	3-Nitroaniline	4808	84.4	14.5	41	128
65794-96-9	3/4-Methylphenol [m/p-Cresol]	3472	69.7	13.6	29	110
534-52-1	4,6-Dinitro-2-methylphenol	5097	90.1	15.5	44	137
101-55-3	4-Bromophenyl phenyl ether	5074	89.1	11.5	55	124

Table 4. LCS Control Limits – Method 8270 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
59-50-7	4-Chloro-3-methylphenol	5338	85.5	11.3	52	119
106-47-8	4-Chloroaniline [p-Chloroanlinie]	4687	75.3	14	33	117
7005-72-3	4-Chlorophenyl phenyl ether	5071	86.7	11.3	53	121
106-44-5	4-Methylphenol [p-Cresol]	2798	72.5	15.8	25	120
99-55-8	5-Nitro-o-toluidine [2-amino-4-nitrotoluene]	260	82.1	14.6	38	126
57-97-6	7,12-Dimethylbenz(a)-anthracene	373	97.1	11.9	61	133
83-32-9	Acenaphthene	6952	84.5	12.3	47	122
208-96-8	Acenaphthylene	6662	85.3	14.7	41	130
98-86-2	Acetophenone	2877	82.1	12	46	118
120-12-7	Anthracene	6792	89.6	11	57	123
140-57-8	Aramite	100	82.8	16.3	34	132
1912-24-9	Atrazine	2328	92.8	16.4	44	142
103-33-3	Azobenzene	578	88.5	9.3	61	116
56-55-3	Benz(a)anthracene	6867	91.6	11.1	58	125
50-32-8	Benzo(a)pyrene	7045	90.8	12.4	54	128
205-99-2	Benzo(b)fluoranthene	6767	92	12.9	53	131
191-24-2	Benzo(g,h,i)perylene	6624	92	13.9	50	134
207-08-9	Benzo(k)fluoranthene	6803	93.2	12.1	57	129
100-51-6	Benzyl alcohol	3349	71.2	13.5	31	112
111-91-1	bis(2-Chloroethoxy)methane	5094	83.9	11.9	48	120
111-44-4	Bis(2-chloroethyl) ether	5139	80.8	12.6	43	118
39638-32-9	bis(2-Chloroisopropyl) ether	1140	83.4	15.4	37	130
117-81-7	Bis(2-ethylhexyl) phthalate	5288	95.2	13.3	55	135
85-68-7	Butyl benzyl phthalate	5173	93.3	13.5	53	134
86-74-8	Carbazole	4187	91.1	10.4	60	122
510-15-6	Chlorobenzilate	226	104.3	15.4	58	150
218-01-9	Chrysene	6779	91.3	10.7	59	123
124-18-5	Decane	126	66.9	12.8	29	105
84-74-2	Di-n-butyl phthalate	5329	93	11.4	59	127
117-84-0	Di-n-octyl phthalate	5222	95.5	15	51	140
2303-16-4	Diallate [cis or trans]	249	95.3	9.6	67	124
226-36-8	Dibenz(a,h)acridine	136	104.4	9.7	75	134
53-70-3	Dibenzo(a,h)anthracene	6840	92.7	13.8	51	134
132-64-9	Dibenzofuran	4963	85.3	10.8	53	118
84-66-2	Diethyl phthalate	5207	90.1	11.5	56	125
131-11-3	Dimethyl phthalate	4977	86	13.7	45	127
60-11-7	Dimethylaminoazobenzene	238	97.1	11.6	62	132
88-85-7	Dinoseb	144	93.4	10.8	61	126
101-84-8	Diphenyl ether	142	91.7	7.8	68	115
122-39-4	Diphenylamine	754	83	9.2	55	111
298-04-4	Disulfoton	122	92.5	12.5	55	130
62-50-0	Ethyl methanesulfonate	215	90.1	9.4	62	118
206-44-0	Fluoranthene	6826	92.6	11.9	57	128

Table 4. LCS Control Limits – Method 8270 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
86-73-7	Fluorene	6786	88.1	12	52	124
118-74-1	Hexachlorobenzene	6263	88.7	12.1	53	125
87-68-3	Hexachlorobutadiene	5878	73.1	16.9	22	124
39638-32-9	bis(2-Chloroisopropyl) ether	1140	83.4	15.4	37	130
117-81-7	Bis(2-ethylhexyl) phthalate	5288	95.2	13.3	55	135
85-68-7	Butyl benzyl phthalate	5173	93.3	13.5	53	134
86-74-8	Carbazole	4187	91.1	10.4	60	122
510-15-6	Chlorobenzilate	226	104.3	15.4	58	150
218-01-9	Chrysene	6779	91.3	10.7	59	123
124-18-5	Decane	126	66.9	12.8	29	105
84-74-2	Di-n-butyl phthalate	5329	93	11.4	59	127
117-84-0	Di-n-octyl phthalate	5222	95.5	15	51	140
2303-16-4	Diallate [cis or trans]	249	95.3	9.6	67	124
226-36-8	Dibenz(a,h)acridine	136	104.4	9.7	75	134
53-70-3	Dibenzo(a,h)anthracene	6840	92.7	13.8	51	134
132-64-9	Dibenzofuran	4963	85.3	10.8	53	118
84-66-2	Diethyl phthalate	5207	90.1	11.5	56	125
131-11-3	Dimethyl phthalate	4977	86	13.7	45	127
60-11-7	Dimethylaminoazobenzene	238	97.1	11.6	62	132
88-85-7	Dinoseb	144	93.4	10.8	61	126
101-84-8	Diphenyl ether	142	91.7	7.8	68	115
122-39-4	Diphenylamine	754	83	9.2	55	111
298-04-4	Disulfoton	122	92.5	12.5	55	130
62-50-0	Ethyl methanesulfonate	215	90.1	9.4	62	118
206-44-0	Fluoranthene	6826	92.6	11.9	57	128
86-73-7	Fluorene	6786	88.1	12	52	124
118-74-1	Hexachlorobenzene	6263	88.7	12.1	53	125
87-68-3	Hexachlorobutadiene	5878	73.1	16.9	22	124
67-72-1	Hexachloroethane	5904	68	15.7	21	115
95-13-6	Indene	253	93.8	13.7	53	135
193-39-5	Indeno(1,2,3-cd)pyrene	6880	92.6	13.6	52	134
465-73-6	isodrin	212	97.6	10	68	128
78-59-1	Isophorone	5190	83.3	13.7	42	124
120-58-1	Isosafrole	230	91.1	11.8	56	126
66-27-3	Methyl methanesulfonate	237	70.1	12.3	33	107
298-00-0	Methyl parathion	121	101.6	19	45	159
100-75-4	N-Nitorosopiperidine	299	88.6	10.8	56	121
924-16-3	N-Nitrosodi-n-butylamine	322	90.4	10.3	60	121
621-64-7	N-Nitrosodi-n-propylamine	5145	84	11.7	49	119
55-18-5	N-nitrosodiethylamine	488	81.8	12.9	43	121
86-30-6	N-Nitrosodiphenylamine	3743	86.8	11.9	51	123
10595-95-6	n-Nitrosomethylethylamine	311	78.7	12.7	41	117
59-89-2	n-Nitrosomorpholine	214	86.2	10.3	55	117
930-55-2	n-Nitrosopyrrolidine	716	80.8	10.8	48	113
91-20-3	Naphthalene	6953	80	13.5	40	121
98-95-3	Nitrobenzene	5955	83	12.8	45	121

Table 4. LCS Control Limits – Method 8270 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
4165-60-0	Nitrobenzene-d5	2223	82.1	12.6	44	120
126-68-1	O,O,O-Triethyl phosphorothioate	212	92.6	8.8	66	119
95-53-4	o-Toluidine	296	69.9	13.2	30	110
593-45-3	Octadecane	151	89	13.1	50	128
56-38-2	Parathion	152	102.6	12.3	66	140
608-93-5	Pentachlorobenzene	401	91.1	10.7	59	123
76-01-7	Pentachloroethane	139	60.9	10.4	30	92
87-86-5	Pentachlorophenol	6083	86.4	17.1	35	138
82-68-8	Pentchloronitrobenzene	618	94.5	13.4	54	135
62-44-2	Phenacetin	241	97.9	8.9	71	124
85-01-8	Phenanthrene	6822	89.6	10.2	59	120
298-02-2	Phorate	126	88.6	16.8	38	139
23950-58-5	Pronamide	249	97	10.5	65	129
129-00-0	Pyrene	7013	91.1	11.5	57	126
91-22-5	Quinoline	249	100.1	10.5	69	132
94-59-7	Safrole	233	90	9.7	61	119
1718-51-0	Terphenyl-d14	1893	91.7	13.9	50	134
3689-24-5	Tetraethyl dithiopyrophosphate [Sulfotep]	200	96.7	11.9	61	133
297-97-2	Thionazine	196	102	10.1	72	132

Table 5. LCS Control Limits – Method 8270 SIM Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
90-12-0	1-Methylnaphthalene	2267	76.6	11.3	43	111
95-95-4	2,4,5-Trichlorophenol	169	79.9	14.9	35	125
91-58-7	2-Chloronaphthalene	615	76.7	10.5	45	108
321-60-8	2-Fluorobiphenyl	1961	80.6	11.6	46	115
91-57-6	2-Methylnaphthalene	2535	76.8	12.5	39	114
83-32-9	Acenaphthene	2813	77.7	11.2	44	111
208-96-8	Acenaphthylene	2761	77.1	12.8	39	116
120-12-7	Anthracene	2812	82.1	10.7	50	114
56-55-3	Benz(a)anthracene	2827	88	11.4	54	122
50-32-8	Benzo(a)pyrene	2789	87.3	12.5	50	125
205-99-2	Benzo(b)fluoranthene	2790	90.3	12.6	53	128
191-24-2	Benzo(g,h,i)perylene	2739	87.8	13	49	127
207-08-9	Benzo(k)fluoranthene	2761	89.3	11.2	56	123
111-44-4	Bis(2-chloroethyl) ether	192	65.4	15.8	18	113
117-81-7	Bis(2-ethylhexyl) phthalate	181	108.9	13.9	67	150
85-68-7	Butyl benzyl phthalate	144	103.5	10.6	72	135
86-74-8	Carbazole	183	79.3	14.6	36	123
218-01-9	Chrysene	2812	87.5	10.2	57	118
84-74-2	Di-n-butyl phthalate	150	106.5	12.9	68	145
117-84-0	Di-n-octyl phthalate	144	105.5	16.8	55	156
53-70-3	Dibenzo(a,h)anthracene	2778	89.2	13.2	50	129
132-64-9	Dibenzofuran	282	71.9	12.2	35	108
84-66-2	Diethyl phthalate	147	99.3	10.9	67	132
131-11-3	Dimethyl phthalate	149	99.3	9.3	71	127
206-44-0	Fluoranthene	2782	87.3	10.7	55	119
86-73-7	Fluorene	2795	80.6	11.2	47	114
118-74-1	Hexachlorobenzene	201	81.9	14.2	39	125
193-39-5	Indeno(1,2,3-cd)pyrene	2812	89.6	13.5	49	130
62-75-9	N-Nitrosodimethylamine	117	90.7	10.9	58	124
91-20-3	Naphthalene	2823	74.7	12.2	38	111
4165-60-0	Nitrobenzene-d5	531	84.7	13.6	44	125
87-86-5	Pentachlorophenol	259	82.4	15.5	36	129
85-01-8	Phenanthrene	2792	80.8	10.6	49	113
129-00-0	Pyrene	2792	85.8	10.2	55	117
1718-51-0	Terphenyl-d14	1864	95.3	12.6	58	133

Table 6. LCS Control Limits – Method 8270 SIM Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
92-52-4	1,1-Biphenyl	106	77.3	7.3	56	99
90-12-0	1-Methylnaphthalene	2566	77.9	12.5	41	115
95-95-4	2,4,5-Trichlorophenol	488	84.1	13.4	44	124
118-79-6	2,4,6-Tribromophenol	164	83.7	12.7	46	122
606-20-2	2,6-Dinitrotoluene	118	67.2	15.8	20	115
91-58-7	2-Chloronaphthalene	717	72.4	12.7	34	111
321-60-8	2-Fluorobiphenyl	747	79.2	8.8	53	106
91-57-6	2-Methylnaphthalene	2984	76.5	12.6	39	114
83-32-9	Acenaphthene	3241	80.9	11.1	48	114
208-96-8	Acenaphthylene	3234	77.8	14.4	35	121
120-12-7	Anthracene	3224	85.8	11	53	119
56-55-3	Benz(a)anthracene	3277	89.3	10.1	59	120
50-32-8	Benzo(a)pyrene	3284	86.4	11.2	53	120
205-99-2	Benzo(b)fluoranthene	3248	89.7	12.3	53	126
191-24-2	Benzo(g,h,i)perylene	3178	86	14.1	44	128
207-08-9	Benzo(k)fluoranthene	3167	89.3	11.9	54	125
111-44-4	Bis(2-chloroethyl) ether	775	77.8	12.6	40	116
117-81-7	Bis(2-ethylhexyl) phthalate	275	114.1	19.6	55	173
85-68-7	Butyl benzyl phthalate	159	90.7	17.3	39	143
86-74-8	Carbazole	631	84	13.1	45	123
218-01-9	Chrysene	3215	88.3	10.4	57	120
84-74-2	Di-n-butyl phthalate	153	102.5	14.2	60	145
117-84-0	Di-n-octyl phthalate	157	103.3	19	46	160
53-70-3	Dibenzo(a,h)anthracene	3233	87.2	14.5	44	131
132-64-9	Dibenzofuran	864	77.5	14.1	35	120
84-66-2	Diethyl phthalate	142	94.5	13.5	54	135
206-44-0	Fluoranthene	3242	89.1	10.4	58	120
86-73-7	Fluorene	3232	84.1	11.3	50	118
118-74-1	Hexachlorobenzene	947	84.8	13	46	124
87-68-3	Hexachlorobutadiene	187	84.5	14.7	40	129
193-39-5	Indeno(1,2,3-cd)pyrene	3244	88.7	13.7	48	130
62-75-9	N-Nitrosodimethylamine	162	62.5	10	33	92
91-20-3	Naphthalene	3277	78.8	11.9	43	114
4165-60-0	Nitrobenzene-d5	444	83.1	9.2	55	111
87-86-5	Pentachlorophenol	808	88.4	17.6	36	141
85-01-8	Phenanthrene	3240	83.6	10.3	53	115
129-00-0	Pyrene	3252	87.1	11.3	53	121
1718-51-0	Terphenyl-d14	642	95.1	12.4	58	132

Table 7. Quality Control Requirements – Organic Analysis by Gas Chromatography/Mass Spectrometry

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Tune Check	Prior to ICAL and prior to each 12-hour period of sample analysis.	Specific ion abundance criteria of DFTPP from method.	Retune instrument and verify.	Flagging is not appropriate.	No samples shall be analyzed without a valid tune.
Performance Check	At the beginning of each 12-hour period, prior to analysis of samples.	Degradation ≤ 20% for DDT. Benzidine and pentachlorophenol shall be present at their normal responses, and shall not exceed a tailing factor of 2.	Correct problem, then repeat performance checks.	Flagging is not appropriate.	No samples shall be analyzed until performance check is within criteria. The DDT breakdown and Benzidine/Pentachlorophenol tailing factors are considered overall system checks to evaluate injector port inertness and column performance and are required regardless of the reported analyte list.
Initial calibration (ICAL) for all analytes (including surrogates)	At instrument set-up, prior to sample analysis	Each analyte must meet one of the three options below: **Option 1:** RSD for each analyte ≤ 15%; **Option 2:** linear least squares regression for each analyte: r2 ≥ 0.99; **Option 3**: non-linear least squares regression (quadratic) for each analyte: r2 ≥ 0.99.	Correct problem then repeat ICAL.	Flagging is not appropriate.	Minimum 5 levels for linear and 6 levels for quadratic. No samples shall be analyzed until ICAL has passed. If the specific version of a method requires additional evaluation (e.g., RFs or low calibration standard analysis and recovery criteria) these additional requirements must also be met.

Table 7. Quality Control Requirements – Organic Analysis by Gas Chromatography/Mass Spectrometry

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Retention Time window position establishment	Once per ICAL and at the beginning of the analytical sequence.	Position shall be set using the midpoint standard of the ICAL curve when ICAL s performed. On days when ICAL is not performed, the initial CCV is used.	NA.	NA.	Required for each analyte and surrogate.
Evaluation of Relative Retention Times(RRT)	With each sample.	RRT of each reported analyte within ± 0.06 RRT units.	Correct problem, then rerun ICAL.	NA	RRTs may be updated based on the daily CCV. RRTs shall be compared with the most recently updated RRTs.
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis	All reported analytes within ± 20% of true value.	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.
Continuing Calibration Verification (CCV)	Daily before sample analysis; after every 12 hours of analysis time; and at the end of the analytical batch run.	All reported analytes and surrogates within ± 20% of true value. All reported analytes and surrogates within ± 50% for end of analytical batch CCV.	Recalibrate, and reanalyze all affected samples since the last acceptable CCV; or Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails, take corrective action(s) and re-calibrate; then reanalyze all affected samples since the	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed. If the specific version of a method requires additional evaluation (e.g., average RFs) these additional requirements must also be met.

Table 7. Quality Control Requirements – Organic Analysis by Gas Chromatography/Mass Spectrometry

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Internal standards (IS)	Every field sample, standard and QC sample.	Retention time within ± 10 seconds from retention time of the midpoint standard in the ICAL; EICP area within - 50% to +100% of ICAL midpoint standard.	Inspect mass spectrometer and GC for malfunctions and correct problem. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	If corrective action fails in field samples, data must be qualified and explained in the case narrative. Apply Q-flag to analytes associated with the non-compliant IS. Flagging is not appropriate for failed standards.	
Method Blank (MB)	One per preparatory batch.	No analytes detected > ½ LOQ or > 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater. Common contaminants must not be detected > LOQ.	Correct problem. If required, reprep and reanalyze MB and all samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid method blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Table 7. Quality Control Requirements – Organic Analysis by Gas Chromatography/Mass Spectrometry

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Laboratory Control Sample (LCS)	One per preparatory batch.	A laboratory must use the limits in Tables 3 through 6 for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits (see the LIMS) if project limits are not specified.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Must contain all surrogates and all analytes to be reported. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Matrix Spike (MS)	One per preparatory batch.	A laboratory must use the limits in Tables 3 through 6 for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits (see the LIMS) if project limits are not specified.	Examine the project specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	Must contain all surrogates and all analytes to be reported. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference, i.e., matrix effect or analytical error.
Matrix Spike Duplicate (MSD) or Matrix Duplicate (MD)	One per preparatory batch.	A laboratory must use the limits in Tables 3 through 6 for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits (see the LIMS) if project limits are not specified. MSD or MD: RPD of all analytes ≤ 20% (between MS and MSD or sample and MD).	Examine the project specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	MSD: Must contain all surrogates and all analytes to be reported. The data shall be evaluated to determine the source of difference.

Table 7. Quality Control Requirements – Organic Analysis by Gas Chromatography/Mass Spectrometry

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Surrogate Spike	All field and QC samples.	QC acceptance criteria specified by the project, if available; otherwise use limits in Tables 3 through 6 or in-house LCS limits (see the LIMS) if analyte(s) are not listed.	Correct problem, then reprep and reanalyze all failed samples for all surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference with surrogate is present, reanalysis may not be necessary.	Apply Q-flag to all associated analytes if acceptance criteria are not met and explain in the case narrative.	Alternative surrogates are recommended when there is obvious chromatographic interference.

Table 8. Quality Control Requirements – Organic Semi-Volatile Analysis by GC/MS in SIM Mode

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Tune Check	Prior to ICAL and prior to each 12-hour period of sample analysis.	Specific ion abundance criteria of DFTPP from method 8270. Tune check can be acquired as a full scan.	Retune instrument and verify.	Flagging is not appropriate.	No samples shall be analyzed without a valid tune. In addition to the full scan tune check, optimization for the analytes of interest is recommended.
Deuterated Monitoring Compounds (DMCs) (surrogates)	All field and QC samples.	PAH analysis: DMCs required for polyaromatic hydrocarbon (PAH) target analytes: fluoranthene-d10 and 2-methylnaphthalene-d10. Minimum RRF for PAH DMCs: 0.40. All DMCs: Requires 50-150% recovery until in-house limits can be established.	Correct problem, and then reprep and reanalyze all samples with failing DMCs if sufficient sample material is available. If obvious chromatographic interference is present, reanalysis may not be necessary, but the client must be notified prior to reporting data and the failures must be discussed in the Case Narrative.	Apply Q-flag to all associated samples and analytes if acceptance criteria are not met and explain in the Case Narrative.	For non-PAH target analytes, other DMCs with similar chemistry must be assigned. Laboratories may use the same extract for full scan and SIM analysis if the SIM-specific DMCs are added prior to extraction.

Table 8. Quality Control Requirements – Organic Semi-Volatile Analysis by GC/MS in SIM Mode

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Performance Checks	At the beginning of each 12-hour period, prior to analysis of samples.	Degradation ≤ 20% for DDT.	Correct problem, then repeat performance checks.	Flagging is not appropriate.	No samples shall be analyzed until the performance checks are within criteria. DDT breakdown and tailing factors are considered overall measures of port inertness and column performance and are required checks for SIM operation. DDT breakdown and tailing factor checks can be acquired as a full scan.
Initial Calibration (ICAL) for all analytes	At instrument set-up, prior to sample analysis.	Each analyte must meet one of the following options: RSD for each analyte ≤ 20% [If pentachlorophenol is a target analyte, an RSD of ≤ 40% allowed] Or Linear least squares regression for each analyte: r2 ≥ 0.99.	Correct problem then repeat ICAL.	Flagging is not appropriate.	Minimum 5 levels required for ICAL with one calibration point at the same concentration as the daily CCV. No samples shall be analyzed until ICAL has passed.

Table 8. Quality Control Requirements – Organic Semi-Volatile Analysis by GC/MS in SIM Mode

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Retention Time window position establishment	Once per ICAL and at the beginning of the analytical sequence.	Position shall be set using the midpoint standard of the ICAL curve when ICAL is performed. On days when ICAL is not performed, the initial CCV is used.	NA.	NA.	Calculated for each analyte.
Evaluation of Relative Retention Times (RRT)	With each sample.	RRT of each reported analyte within ± 0.06 RRT units of the mean RRT of the calibration standards. RRTs may be updated based on the daily CCV.	Correct problem, then rerun ICAL.	NA.	RRTs shall be compared with the most recently updated RRTs. Characteristic ions must maximize in the same scan or within one scan of each other. After any maintenance is performed which could affect retention times, RRTs may be updated based on the daily CCV.
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis.	All reported analytes within ± 20% of true value. If pentachlorophenol is a target analyte, a %D from the true value of ±50% is allowed.	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.

Table 8. Quality Control Requirements – Organic Semi-Volatile Analysis by GC/MS in SIM Mode

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Continuing Calibration Verification (CCV)	Daily before sample analysis; after every 12 hours of analysis time; and at the end of the analytical batch run.	Concentration the same as the mid-point calibration standard (or lower). All reported analytes within ± 20% of true value. If pentachlorophenol is a target analyte, a %D from true value of ± 50% is allowed. All reported analytes within ±50% for end of analytical batch within ± 50% for end of analytical batch CCV.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) until a passing CCV is attained, and then reanalyze all associated samples since last acceptable CCV. Alternatively, perform an ICAL (including appropriate instrument QC) if necessary; then reanalyze all associated samples since the last acceptable CCV	If reanalysis cannot be performed, data must be qualified and explained in the Case Narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since last acceptable calibration verification.	Results may not be reported without valid CCVs. Flagging is only appropriate in cases where the samples cannot be reanalyzed. If the specific version of a method requires additional evaluation (e.g., average RFs), these additional requirements must also be met.

Table 8. Quality Control Requirements – Organic Semi-Volatile Analysis by GC/MS in SIM Mode

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Internal Standards (IS)	Every field sample, Standards, blanks, and QC sample.	Retention time within ± 10 seconds from retention time of the midpoint standard in the ICAL; EICP area within-50% to +100% of ICAL midpoint standard. On days when ICAL is not performed, the initial CCV is used.	Inspect mass spectrometer and GC for malfunctions and correct problem. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	If corrective action fails in field samples, data must be qualified and explained in the Case Narrative. Apply Q-flag to analytes associated with the non-compliant IS. Flagging is not appropriate for failed standards.	Internal Standard is spiked no greater than0.40 ng/µL concentration. According to the EPA Contract Laboratory Program Statement of Work (CLP SOW), this is the concentration of internal standard specified for SIM analysis. The SOW indicates calibration standards range from 0.10 to 1.0 ng/µL, so 0.40 ng/µL is mid-range. 1, 4-dichlorobenzene-d4 is ignored for SIM
Method Blank (MB)	One per preparation batch, prior to analysis of any field samples.	No analytes detected > ½ LOQ or > 1/10th the amount measured in any sample or 1/10th the regulatory limit, whichever is greater.	Conduct investigation to determine the source of the contamination and take appropriate corrective actions. Correct problem. If required, reprep and reanalyze MB and all QC samples and field samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the Case Narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated analytical batch.	Laboratories may use the same extract for full scan and SIM analysis provided the applicable DMCs and IS are spiked at the appropriate concentrations. Results may not be reported without a valid Method Blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Table 8. Quality Control Requirements – Organic Semi-Volatile Analysis by GC/MS in SIM Mode

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Laboratory Control Sample (LCS)	One per preparation batch.	A laboratory must use Table 3 through Table 6 Limits (8270 SIM) for batch control if project specific limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Correct problem, and then reanalyze the LCS and all samples in the associated analytical batch for failed analytes if sufficient sample material is available.	If reanalysis cannot be performed, data must be qualified and explained in the Case Narrative. Apply Q-flag to specific analyte(s) in all samples in the associated analytical batch.	Must contain all analytes to be reported. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Matrix Spike (MS)	One per preparation batch.	A laboratory must use the QSM Appendix C Limits (8270 SIM) for batch control if project specific limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply the J-flag if acceptance criteria are not met and explain in the Case Narrative.	Must contain all analytes to be reported spiked at concentrations appropriate for SIM analysis. For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference (i.e., matrix effect or analytical error).

Table 8. Quality Control Requirements – Organic Semi-Volatile Analysis by GC/MS in SIM Mode

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Matrix Spike Duplicate (MSD) or Matrix Duplicate (MD)	One per preparation batch.	A laboratory must use the QSM Appendix C Limits (8270 SIM) for batch control if project specific limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified. MSD or MD: RPD of all analytes ≤ 40% (between MS and MSD or sample and MD).	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply the J-flag if acceptance criteria are not met and explain in the Case Narrative.	The MSD must contain all analytes to be reported spiked at concentrations appropriate for SIM analysis. All data must be evaluated to determine the source of difference. For Sample/MD: RPD criteria only apply to analytes whose concentration in the sample is greater than or equal to the LOQ.
Characteristic ions for MS confirmation	Minimum 3 ions.	The relative intensities of the characteristic ions of target analytes agree within 30% of the relative intensities in the reference spectrum and the relative intensities must be > 0. Confirmation requires S/N ratio of ≥ 3 for each quant and confirmation ion.	No data can be reported without MS confirmation.	NA.	Need 3 structurally significant ions that are logical fragments – not isotopic clusters. Internal standard and DMC can use fewer than 3 ions.

Document Information

Document Number: ENV-SOP-MTJL-0185 **Revision:** 06

Document Title: "Total Organic Carbon (TOC) & Total Inorganic Carbon (TIC) Using Shimadzu 5000A (EPA Methods 415.1 & 9060A, SM 5310B) … Groundwater and Wastewater Only"

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Notes

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All Dates and Times are listed in: Central Time Zone

Signature Manifest

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All dates and times are in Central Time Zone.

ENV-SOP-MTJL-0185

QM Approval

Name/Signature	Title	Date	Meaning/Reason
Elizabeth Turner (007857)	Manager - Quality Program	18 May 2021, 08:47:34 AM	Approved

Management Approval

Name/Signature	Title	Date	Meaning/Reason
James Burns (006456)	Manager - EHS	18 May 2021, 09:39:13 AM	Approved
Heidi Ferrell (006481)	Manager - Operations	18 May 2021, 10:44:13 AM	Approved
Keith Blanchard (004545)	Manager	19 May 2021, 09:05:29 AM	Approved

STANDARD OPERATING PROCEDURE
TITLE: Total Organic Carbon (TOC) & Total Inorganic Carbon (TIC)(EPA Methods 415.1, 9060A, and SM 5310 B)
ISSUER: Pace National – Mt. Juliet, Tennessee

1.0 SCOPE AND APPLICATION

1.1 This procedure is used to determine Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC) and Total Inorganic Carbon (TIC) in aqueous samples.

1.2 The typical Reporting Limit (RL) is 1.0 mg/L. See LIMS for active limits.

1.3 An MDL study must be completed at least annually or more frequently if major instrumentation changes occur. Method Detection Limits (MDLs) are performed based on ENV-SOP-MTJL-0016. Updated MDL records are filed and stored in a central location within the department.

1.2.1 Limit of Detection (LOD) and Limit of Quantitation (LOQ) studies are completed at the frequency required by the TNI standard per the procedure identified in the ENV-SOP-MTJL-0016, *Method Detection Limits (MDL), Limits of Detection (LOD) and Limits of Quantitation (LOQ).* Should the procedure be utilized for DOD support; then the frequency of these studies must meet the requirements of the current DOD QSM.

2.0 METHOD SUMMARY AND DEFINITIONS

2.1 For TOC/DOC, acidified samples are purged to remove the Inorganic Carbon. This may also remove some volatile organics. The carbon component of the sample undergoes oxidation, thermally or chemically, to form Carbon Dioxide, which is measured by a Near-Dispersive Infrared detector (NDIR).

2.2 See the current Quality Assurance Manual for other definitions associated with terms found in this document.

3.0 HEALTH AND SAFETY

3.1 The toxicity or carcinogenicity of each chemical or sample being diluted in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

3.2 The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets (SDS) for all hazardous chemicals are available to all personnel. Employees must abide by the environmental, health, and safety (EHS) policies and procedures specified in this SOP and in the Pace National Chemical Hygiene / Safety Manual.

3.3 Personal protective equipment (PPE) such as safety glasses and/or side shields, gloves, a laboratory coat, and shoes that are not cloth, canvas, and/or perforated must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure. When handling glass, needles, knives, or any material with a potential sharp edge, employees must use cut-resistant gloves.

3.4 Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids, bases, or oxidizers in a fume hood whenever possible with the appropriate PPE designed for handing these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions.

3.5 Spill kits are located in each laboratory department. Employees are to familiarize themselves with the location and contents of each spill kit in their area.

3.6 Universal precautions should be observed when performing any tests or procedures. Hard surfaces, instrument surfaces may be contaminated and should be handled according to good laboratory practices.

3.7 Contact your supervisor or local EHS coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure. Any accidents involving personnel or sample supplies are to be reported immediately to either the Manager and/or to the Safety Officer.

4.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

4.1 All samples must have been collected using a sampling plan that addresses the considerations of this procedure.

4.2 Samples should be collected in glass, polyethylene or Fluoropolymer with minimal headspace. Following sampling, all samples should be cooled to ≤6°C (not frozen) from transport to receipt and storage in the laboratory.

4.2.1 Samples for the analysis of TOC should be preserved to a pH<2 with Hydrochloric acid, Sulfuric acid or Phosphoric acid.

4.2.2 Samples for the analysis of TIC should not be chemically preserved.

4.2.3 Samples for the analysis of DC should not be preserved prior to filtration. Filter with 0.45µm filter. Preserve with acid, if applicable.

4.3 Volume required – 250mL per sample.

4.4 Chemically preserved samples must be analyzed within 28 days of sample collection.

5.0 INTERFERENCES

5.1 High levels of Chloride ions may present special problems for analysis. The major factors affecting successful analysis are maintaining effective sample/oxidant ratios, allowing sufficient analysis time, and reducing the corrosive effects of the Chlorine produced.

The Chlorine produced in the oxidation of brine or Hydrochloric Acid sample may cause corrosion of the molecular sieve trap and may affect the ability of the molecular sieve substrate to efficiently trap and release CO_2.

The negative results of high Chloride levels can be partially offset by use of sample volumes of less than 100µL and dilution. Analysis of concentrated Hydrochloric Acid (36-38%) is not advised. Concentrated acid should be diluted to 1:1. The instruments may contain Halogen scrubbers to minimize interference from Chloride.

5.2 The purge step that is performed to remove inorganic carbon may result in the loss of volatile organic carbon. For this reason, the results reported for this analysis are considered Non-Purgeable Organic Carbon (NPOC). Per method, EPA calls this TOC.

6.0 EQUIPMENT AND SUPPLIES

6.1 Shimadzu Total Organic Carbon Analyzer Model TOC-V or L or equivalent

6.2 Shimadzu Autosampler ASI-V or equivalent

6.3 Shimadzu regular sensitivity vials – part #630-00342-41 or equivalent

6.4 Trace Elemental Instruments Xpert TOC with autosampler

6.5 Syringe filters, Whatman GD/XP, 0.45m pore, VWR 6873-2504 25mm or equivalent

6.6 Disposable syringes, 10mL or equivalent

6.7 Gases, various – Nitrogen, Argon, Oxygen and/or Air

6.8 Volumetric Glassware, Flasks, pipets, graduated cylinders, Class A, various sizes

7.0 REAGENTS AND STANDARDS

7.1 All reagents and standards must be recorded in the appropriate preparation log and assigned a unique number. See ENV-SOP-MTJL-0041, *Standard Logger – Tree Operation*. Additional information regarding reagent preparation can be found in the Standards Logger (Tree) digital archive system. All spiking solutions and surrogate standard solutions should be replaced at least every six (6) months or sooner if a problem is detected unless otherwise noted.

7.2 Laboratory Reagent Water, less than ½ RL or MDL, as needed.

7.3 25% Phosphoric Acid – Dilute 29.3mL of Ultra Pure (85.4%) Phosphoric Acid (VWR™ JT6908-4 or equivalent) to 100mL with reagent water.

7.4 1000mg/L TOC Primary Source Stock Standard – Add about 800mL of laboratory reagent water to a Class A 1L volumetric flask. Dissolve 2.128g of previously dried and desiccated Potassium Hydrogen Phthalate (EM Science PX1476-3 or equivalent). Dilute to mark with laboratory reagent water and mix thoroughly. Preserve to pH<2 with concentrated HCl or H2SO4. Do not add excess acid. Commercially certified standards are acceptable. Use ISO 34 vendor, if available.

7.5 TOC Primary Intermediate Source (100 mg/L) – Prepare using 25.0 ml of 1000 mg/L stock to 250 ml reagent water in a class A volumetric flask. Prepare calibrations standards as follows using volumetric glassware and laboratory reagent water. A blank is included as a point in the calibration curve, but the regression equation for the calibration curve is not forced through zero. Preserve each to pH<2. Do not add excess acid.

Calibration Curve Concentrations
100mg/L – direct injection of TOC
50mg/L – dilute 50mL of 100mg/L TOC to 100 ml with reagent water
25mg/L – dilute 25mL of 100mg/L TOC to 100mL with reagent water
5.0mg/L –dilute 5mL of 100mg/L TOC to 100mL with reagent water
1.0mg/L (RL) –dilute 1mL of 100mg/L TOC to 100mL with reagent water
0.5mg/L-dilute 0.5mL of 100mg/L TOC stock to 100mL with reagent water
0mg/L – Laboratory reagent water

NOTE: Analyze in ascending order

7.6 1000mg/L TOC Secondary Source Stock (SSCV/SSCCV) – Stock solution purchased from a vendor different than the primary, NSI product number IS-026-500 or equivalent. This should be a Guide34 or ISO 17034 accredited standard, if available. Used to verify initial calibration.

7.7 50mg/L TOC Secondary Source (SSCV/SSCCV) working standard – Using volumetric glassware and laboratory reagent water, dilute 50mL of the TOC Secondary Source stock standard to 1000mL. Preserve with acid.

7.8 50mg/L TOC Primary Source working standard (CCV) – Using volumetric glassware and laboratory reagent water, dilute 50mL of the TOC Primary Source stock standard to 1000mL. Preserve with acid.

7.9 1mg/L Report Limit Verification (RLV) standard – Using volumetric glassware and laboratory reagent water, dilute 1mL of the TOC Primary Source stock solution to 1000mL. Preserve with acid. Readback of calibration standard is acceptable.

7.10 1000mg/L Total Inorganic Carbon (TIC) Primary Source Stock Standard – Add about 800mL of reagent water to a Class A 1L volumetric flask. Dissolve 4.4122g anhydrous Sodium Carbonate (VWR™ BDH0284 or equivalent) and 3.497g anhydrous Sodium Bicarbonate (VWR™ BDH0280 or equivalent). Dilute to mark with reagent water and mix well. Do **not** preserve (i.e., acidify).

7.11 1000mg/L TIC (SSCV/SSCCV) Secondary Source Stock Solution. Using standards from a different source or lot number, prepare instructions in 7.7.

7.12 50mg/L TIC (SSCV/SSCCV) Secondary Source Working Standard – Using Class A volumetric glassware and laboratory reagent water, dilute 5.0mL of the TIC Secondary Source Stock Standard to 100mL.

7.13 50mg/L TIC (CCV) – Using Class A volumetric glassware and laboratory reagent water, dilute 5.0mL of the TIC Primary Source Standard stock solution to 200mL.

7.14 1mg/L TIC RLV standard – Using Class A volumetric glassware and laboratory reagent water, dilute 0.1mL of the IC Primary Source Stock Standard to 100mL. Readback of calibration standard is acceptable.

7.15 50mg/L TIC Check Standard – Using Class A volumetric glassware and reagent water, dilute 50mL of 1000mg/L TIC Primary Stock to 1000mL. Preserve to pH 2 with acid prior to analysis. It is acceptable to spike a known volume of CCV daily to verify on-going TIC removal.

8.0 PROCEDURE

8.1 Generally, no sample preparation is required unless filtration or dilution is necessary. Any solid or precipitate in the sample bottle should be removed by filtration using a Whatman 25mm GDX, Nylon or PES 0.45um disposable syringe filter. If this occurs, it must be documented in PrepData by the analyst and reported as TOC (lab filtered). Any sample with a TOC concentration exceeding the upper calibration standard must be diluted to obtain a value within the calibration range. If filtered, a Method Blank and LCS must also be filtered and meet acceptance criteria.

8.2 Calibration (if calibration is not required proceed to step 8.3).

8.2.1 Open a new sample table.

8.2.2 Name the file mmddyy_CAL.

8.2.3 Refer to the instrument manual or work instructions for specific instructions. The instrument will make a minimum of four injections of each standard. If an injection response appears to be an outlier (standard deviation >4 units), the software will exclude that response and prompt the instrument to make another injection. Results of at least two consecutive injections must be reproducible within +/- 10% for samples analyzed by SM 5310B. The average of the four valid injections will be reported for 9060. The range of the analyses will not be reported due to the limitations of LIMS.

8.2.4 When all the calibrants have been analyzed, review the calibration curve. Review the curve to determine acceptability (i.e., r >=0.995 or r2 >=0.990). If the acceptance criteria are not met, new standards must be prepared, and the instrument must be recalibrated. A new calibration curve must be analyzed every six months, sooner if major changes are made to the instrumentation or methodology.

8.2.5 Following successful calibration and prior to sample analysis, a SSCV i.e. second-source standard must be analyzed.

8.3 Sample Analysis

8.3.1 Open a new sample table. Name the file mmddyy.

8.3.2 Refer to instrument manual or work instructions to insert sample ID’s.

8.3.3 Make sure all containers are properly filled

8.3.4 Begin typing in the names of your samples in the following order. It is important that the quality control samples are typed in exactly as shown, so that they will be recognized by the capture software.

ICV
RL (1.0 mg/L) if needed
ICSTD, not used for TIC
LCS
Method Blank
Eight samples with one MS/MSD
CCV
CCB
Ten samples
CCV
CCB

NOTE: The ICSTD check is used to verify that the TOC method removes Inorganic Carbon during the purge step. The resulting concentration must be <RDL. It is acceptable to add IC to CCV to verify TIC removal for TOC analysis.

STATE NOTE: For Wisconsin and West Virginia samples, the resulting concentration must be <MDL.

NOTE If running Drinking Water samples, use MS and Duplicate per ten (10) samples.

8.3.5 Pour into autosampler vials and place in designated autosampler positions. Filter any samples that contain solid material and report the analyte as “dissolved” and note “lab filtered”, This must also be documented by analyst in PrepData. . If a sample is diluted, type the dilution factor into the appropriate cell in the sample table.

8.3.6 Click on the “Start” button.

8.3.7 The instrument will make a minimum of four injections of each sample. If the software detects that one of the injection results is an outlier (standard deviation > 4 units), it will exclude that result and make another injection. All sample results must be comprised of four useable injections to be valid. The average of the four valid injections will be reported.

8.3.8 Monitor the run as it proceeds and add any re-analyses required due to failed QC (See Section 10) or dilutions needed.

8.3.9 When the run is complete, print as a PDF via background printer.

8.3.10 Export as a data file with the sample data ID (mmddyy). The data is now ready for review and reporting using the capture software.

8.4 Dissolved Organic Carbon (DOC)

8.4.1 Dissolved Carbon is determined by filtering an unpreserved sample within 48 hours of collection then preserving to pH<2 with acid and minimal headspace. Do not use excessive acid. If Inorganic Carbon is needed, do not acidify.

8.4.2 Filter sample with 0.45µm filter using standard filtration techniques. A filtered LCS and filtered Method Blank is required if performed by the laboratory.

9.0 DATA ANALYSIS AND CALCULATIONS

9.1 The instrument software plots the sample response on the appropriate calibration curve. Sample concentration is calculated using the following formula:

Sample Concentration (mg/L) = (Sample Concentration from Calibration Curve) x (Dilution Factor)

9.2 See the current Quality Assurance Manual for other equations associated with common calculations.

10.0 QUALITY CONTROL AND METHOD PERFORMANCE

10.1 All analysts must meet the qualifications specified in ENV-SOP-MTJL-0015, *Technical Training and Personnel Qualifications* before approval to perform this method. Analysts must complete an initial demonstration of proficiency before being approved to perform this method. Continuing proficiency must be demonstrated using proficiency testing, laboratory control sample analysis and/or MDL studies. Method performance is assessed per analyst. Updated method performance records are filed and stored in a central location within the department.

10.2 Use the designated run log to record batch order and standards/reagents used during analysis. See ENV-SOP-MTJL-0014, *Data Handling and Reporting.*

10.3 Batches are defined as sets of 1 – 20 samples. Batch analysis must include the following: 1 Method Blank, 1 Initial Calibration Verification (i.e., second-source_, 1 Laboratory Control Sample (LCS), 1 Matrix Spike/ Matrix Spike Duplicate (MS/MSD) 1 Inorganic Carbon Check Standard (ICSTD) for TOC 1 Continuing Calibration Verification (CCV) following every 10 samples and at the end of the run, 1 Continuing Calibration Blank (CCB) following every CCV and 1 Reporting Limit (RL) Standard. All batch information must be maintained in the preparation documentation assigned to the department. For Drinking Water samples, run in batches of ten (10) is recommended. Each set will have MS and Duplicate.

10.4 Calibration Curve – Run as needed. The correlation coefficient (r) must be >/= 0.995, r2 >/= 0.99. There can be no outliers. The instrument must be recalibrated every six (6) months or sooner if major changes are made to instrumentation or methodology.

10.5 SSCV – A SSCV must be analyzed after successful calibration. It must be prepared from a secondary source. The %R must be 90-110.

10.6 ICV – An ICV may be analyzed at the beginning of every workgroup. It may be prepared from either Source. The %R must be 90-110.

10.7 Method Blank - One method blank must be analyzed with every batch of twenty samples. The blank concentration must be < ½ RL or <MDL, as applicable.

10.8 LCS – A LCS must be analyzed per batch. The %R must be 90-110.

10.9 MS/MSD – A matrix spike/matric spike duplicate must be analyzed with each batch. The %R must be 80-120, and the RPD must be <20.

10.10 Duplicate - One sample duplicate must be analyzed for every 10 samples for Drinking Water samples. The RPD must be <20.

10.11 RL Check - One RL check must be analyzed with every batch of twenty samples. The recovery of the RL must be within ±40% of true value.

STATE NOTE: For samples originating in South Carolina, the recovery of the RL check must be ±10% of the true value.

10.12 CCV – A CCV must be analyzed after every ten samples and at end of run. It is prepared from the Primary Source. %R must be 90-110.

10.13 CCB – A CCB must be analyzed after every 10 samples and at the end of the workgroup. The concentration must be <½ RL or MDL, as applicable.

10.14 Any sample analyte responses that are beyond the linear range of the calibration curve must be diluted and re-analyzed.

11.0 DATA VALIDATION AND CORRECTIVE ACTION

11.1 All data must undergo a primary review by the analyst. The analyst must check the performance of the initial calibration, mid-point check standard and continuing calibrations to ensure that they meet the criteria of the method. The analyst should review any sample that has quantifiable compounds and make sure that they have been confirmed. The analyst must also verify that reported results are derived from quantitation between the MDL and the highest standard of the initial calibration curve. All calculations must be checked (any dilutions, %solids, etc.). Data must be checked for the presence or absence of appropriate flags. Comments should be noted when data is flagged.

11.2 All data must undergo a second analyst review. The analyst checking the data must check the performance of the initial calibration, mid-point check standard and continuing calibrations to ensure that they meet the criteria of the method.

11.2.1 The analyst should look at any sample that has quantifiable compounds and check the integration.

11.2.2 Blanks must be clean of all interfering peaks.

11.2.3 Quality control criteria.

11.2.4 Data must be checked for the presence or absence of appropriate flags. Comments should be noted when data is flagged.

11.3 Calibration Curve – If the calibration curve fails, check instrument. Rerun calibration curve. If it still fails, re-prep and re-analyze calibration standards.

11.4 SSCV – If the control fails and analysis of second consecutive verification fails, take corrective action.

11.5 ICV/CCV – If the ICV or CCV fails and analysis of a second consecutive (immediate) calibration verification fails to produce results within acceptance criteria, corrective actions shall be performed. The laboratory shall demonstrate acceptable performance after the final round of corrective action with two consecutive calibration verifications, or a new initial instrument calibration shall be performed.

11.6 Method Blank - If the method blank, fails rerun once. If it fails again, the reason for the failure must be found and corrected. A passing method blank must be analyzed before any samples can be analyzed. If needed, verify filtered Blank analyzed.

General guidelines for qualifying sample results with regard to method blank quality are as follows:

- If the method blank concentration is less than the MDL and sample results are greater than the RL, then no qualification is required.
- No qualification is necessary when an analyte is detected in the method blank but not in the associated samples.
- If the concentration in a sample is more than ten times the concentration in the method blank, then no qualification is required.
- If the method blank concentration is greater than the MDL but less than the RL and sample results are greater than the MDL, then qualify associated sample results to indicate that analyte was detected in the method blank.
- If the method blank concentration is greater than the RL, further corrective action and qualification is required. An analyst should consult their supervisor for further instruction.

11.7 LCS – If the LCS or SSCCV fails, rerun once. If the failure is repeated, identify and correct the reason for the failure and rerun affected samples. If needed, verify LCS was filtered.

11.8 MS/MSD – If the recovery is <80%, the MS, MSD, and related sample shall be qualified with a J6. If >150%, the MS or MS/MSD and the related sample shall be qualified with a J5. If the RPD is >20%, the MS, MSD, and related sample shall be qualified with a J3.

11.9 Duplicate - If the RPD is >20, the results may be reported with a J3 qualifier. If the RPD is beyond acceptance limits and the sample concentration is <5X the RL, then the value can be flagged with a “P1” qualifier indicating that the RPD calculation is not applicable at that concentration.

11.10 RL - If the RL fails, rerun once. If the failure is repeated, identify and correct the reason for the failure. Instrument maintenance or re-calibration may be required.

11.11 CCB – If the CCB fails, rerun once. If the failure is repeated, identify and correct the reason for the failure. All samples between the failing CCB and the last compliant CCB must be re-analyzed.

11.12 Data that does not meet acceptable QC criteria may be acceptable for use in certain circumstances. For example, if a calibration verification standard is above the acceptable QC criteria and all samples being bracketed are below the reporting limit, the data is acceptable based on a high calibration bias with undetectable levels in the field samples. Any positive samples require re-analysis.

12.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

12.1 The EPA requires that laboratory waste management practices be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner. See ENV-SOP-MTJL-0051, *Waste Management Plan.*

12.2 See ENV-SOP-MTJL-0046, *Environmental Sustainability & Pollution Prevention*.

13.0 METHOD MODIFICATIONS/CLARIFICATIONS

13.1 None.

14.0 REFERENCES

14.1 *Total Organic Carbon*, SW-846 Method 9060A, Revision 1, November 2004.

14.2 *Organic Carbon, Total (Combustion or Oxidation)*, EPA Method 415.1, Editorial Revision 1974, Approved for NPDES.

14.3 *Total Organic Carbon, High-Temperature Combustion Method*, Standard Methods 5310B, 22nd Edition or on-line version.

14.4 Shimadzu TOC-5000A Instrument Manual.

14.5 TE Instruments User and Maintenance Manual.

Attachment I: Revision History

Current Version (Pace National):

Date	Description of Revisions
5/18/2021	Annual review and revision plus response to South Carolina DHEC request. Revised header as well as Sections 1.1, 1.2, 2.1, 4.2.3, 4.4, 5.1, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13, 7.14, 7.15, 8.1, 8.2, 8.2.4, 8.3, 8.3.4, 8.3.5, 8.3.8, 8.4 and all subsections, 10.2, 10.6, 10.9, 10.10, 10.11, 11.2.3, 11.6, 11.7, 13.1, and 14.3. Re-formatted Attachment II. Deleted Sections 8.5 through 8.33, 10.12, 13.2, and 14.5.

Superseded Versions (ESC Lab Sciences SOP #340356A):
:

Version	Date	Description of Revisions
0	12/00	Origination
1	1/29/02	
2	4/23/03	
3	6/26/04	
4	11/3/04	
5	09/18/08	Technical and Quality Review and update.
6	8/21/09	Annual Technical and Quality Review and update. Revised sections 7.1, 10.0, 11.0, 12.1, 14.1; Added sections 9.2 – 9.3; Updated to EPA 9060A.
7	7/12/11	Annual Technical and Quality Review and update. Revised sections 7.5, 8.2.6, 8.3.9, 9.2 through 9.5, 10.4, 11.1 through 11.2, and 12.1; Added sections 2.10 through 2.15, 10.4, and 11.13
8	11/10/11	Annual Technical and Quality Review and update. Revised sections 4.2; Added Section 5.3 and Attachment II
9	9/10/12	Annual Technical and Quality Review and update. Revised sections 1.3, 2.6, 2.7, 7.5 through 7.7, 8.2.5, 8.3.9, 8.3.12, 8.3.13, 11.7 and 11.11; Added sections 1.4.1, 2.16, 2.17, 5.4, 6.4, 6.5, 7.8 through 7.15, 8.4 through 8.6, 13.1 through 13.2, and 14.4 through 14.5.
10	9/17/14	Annual Technical and Quality Review and update. Revised title and sections 1.1, 4.2, 4.3, 7.1, 7.5, 7.6, 7.10, 7.12, 8.2.5, 8.3.12, 8.5.12 and 11.13.1; Added sections 7.17, 14.6 and 14.7.
11	9/8/2015	Header and signature block formatting. Technical and quality review and update. Revised Sections 8.3.10, 10.3, 10.9, 11.8, and 12.2.
12	10/27/2016	Technical and quality review and update. Header and signature block re-formatting. Revised Sections 1.4.1, 2.2, 6.1, 6.2, 7.1, 7.7, 8.3.9, 8.5.9, 9.2, 10.2, 10.7, 10.8, 10.12, 10.13, 11.3, 11.4, 11.5, 11.7, 11.11, 14.1, 14.2, 14.3, 14.4, 14.6, and Attachment II Section 4.1. Deleted Sections 2.2 through 2.17, 9.2 through 9.5, 10.12, 11.4, 11.10, 11.13.1, 11.13.2, and 14.7.
13	7/14/2018	Technical and quality review and update. Replaced logo and watermark. Revised Sections 1.4, 1.4.1, 3.1, 7.9 through 7.15, 10.3, and 12.1. Deleted Sections 7.16 and 7.17.

Version	Date	Description of Revisions
ENV-SOP-MTJL-0185	12/13/2018	Technical and quality review and update. Deleted header, footer and signature bar. Revised sections 1.4, 1.4.1, 4.2, 4.2.1, 4.2.2, 5.2, 5.3, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13, 7.14, 7.15, 8.2.2, 8.3.2, 8.4.2, 8.4.3, 8.5.2, 10.1, 10.2, 10.3, 10.4, 10.5, 10.8, 11.1, 11.2, 11.2.4, 11.6, 11.7, 11.8, 12.1, 12.2, 14.3, 14.4 and 14.6. Deleted sections 4.5, 8.3.3, 8.3.6, 8.5.3, 8.5.6, 11.2.2 and renumbered as necessary. Revised Attachments I and II.

STANDARD OPERATING PROCEDURE
TITLE: Total Organic Carbon (TOC) & Total Inorganic Carbon (TIC)(EPA Methods 415.1, 9060A, and SM 5310 B)
ISSUER: Pace National – Mt. Juliet, Tennessee

Superseded Versions (Pace National):

Date	Description of Revisions
2/14/2019	Technical and quality review and update. Revised sections 1.2, 2.1, 4.2, 7.5, 7.11, 8.1, 8.2.2, 8.2.6, 8.3.2, 8.3.7, 8.3.8, 8.3.10, 8.3.11, 8.4.2, 8.4.6, 8.5.2, 8.5.7, 8.5.8, 8.5.10, 8.5.11, 8.6.1, 8.6.6, 10.5, 11.2.3 and 12.1. Added state note in section 8.3.7. Added sections 4.2.3, 6.6, 8.6.2, 8.6.3. Deleted sections 8.2.3, 8.4.3, 8.6.2, 8.6.3, 8.6.4 and renumbered as necessary. Revised Attachment I.
3/26/2019	Revised Section 10.11 to increase the RL Check's acceptance criteria from ±20% to ±40%.
5/31/2020	Technical review and update. Updated header and footer. Revised all subsections of 3.0. Deleted Sections 1.1, 1.3, 5.2, 6.4, 6.6, 7.11, 7.12, 8.2.2, 8.2.3, 8.3.2, 8.3.3, 8.3.4, 8.3.5, 8.3.6, 8.4.2, 8.5.2, 8.5.3, 8.5.4, 8.5.5, 8.5.6, 8.6.3, 10.6 and 14.4 and renumbered as necessary. Revised Sections 1.2, 2.1, 3.2, 4.1, 4.2, 4.2.1, 4.2.2, 4.2.3, 5.1, 5.3, 6.5, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.13, 7.14, 7.15, 8.1, 8.2.4, 8.2.5, 8.3.1, 8.3.7, 8.3.8, 8.3.9, 8.3.10, 8.3.11, 8.3.12, 8.4, 8.4.1, 8.4.4, 8.4.5, 8.5, 8.5.1, 8.5.7, 8.5.8, 8.5.9, 8.5.10, 8.5.11, 8.5.12, 8.5.13, 8.6, 8.6.1, 8.6.2, 10.3, 10.4, 10.5, 10.7, 10.8, 10.9, 10.10, 10.12, 11.6, 11.8 and 14.3. Added Sections 3.4, 6.4, 6.6, 6.7, 6.8, 7.14, 8.2.2, 8.2.3, 8.2.6, 8.3.2, 8.3.3, 8.4.2, 8.4.6, 8.5.2, 10.5, 10.12, 10.13, 11.4 and 14.7 and renumbered as necessary.

Attachment II: Recommended Preventative Maintenance Program – Shimadzu TOC-V CPH

Weekly

Regenerate TC Catalyst with 1N HCl (8.33mL diluted to 100mL). Place 1N HCl in S8 (Acid) Autosampler position. Select “Regeneration of TC Catalyst” from the Maintenance screen under the Instrument tab. Press Start. This needs to be performed at least once a week or when sensitivity or repeatability has dropped.

Bi-monthly

Wash or replace TC catalyst whenever sensitivity or repeatability drops or every two months with heavy usage. Replace glass wool. The platinum screen may be reused.

- Cool furnace to room temperature.
- Disconnect the mounting plate with sliding TC sample injection block from the fixed plate. Remove TC combustion tube. Loosen the pedestal and loosen the nut on the elbow.
- Clean the platinum nets and the inside wall of the combustion tube with 4N HCl (33.3mL diluted to 100mL). Rinse with deionized water and dry.
- Wash catalyst in tap water to remove accumulated or sticking salt. Neutralize alkali with 2.5N HCl (20.8mL diluted to 100mL). Dry catalyst at 700oC. If reproducibility cannot be restored, replace the platinum catalyst.
- Pack combustion tube with a platinum screen and approximately 5mm of loosely packed glass wool.
- Add platinum beads to a level of 110mm above the platinum screen.
- Insert the combustion tube into the center hole of the furnace with the tube leg down.
- Connect leg tube projecting from the TC furnace bottom with the elbow connector. Protect inside and outside surfaces of the combustion tube from grease, oils, and organics.
- Apply a thin film of high vacuum silicone grease to the outer surface of the combustion tube, which is to be in contact with the o-ring.
- Insert the upper tube end to the bottom hole of the sliding TC sample injection block.
- Screw the mounting plate with the sliding injection block to the fixed plate, ensuring that the slider and the slider-driving gear are engaged. Do not apply vertical force to the slider.
- Adjust the height of the pedestal to make the adjustable screw upper end connect with and support the lower end of the elbow connector.

Every three months

Replace the water in the humidifier.

Every six months

Replace CO2 absorber (scrubber).

Replace halogen scrubber, sooner if it becomes discolored.

As Needed

Check for system leaks. Remove the waste lid. Pinch L (long) tubing. Bubbles should appear in the waste. Replace the lid.

Replace the syringe pump plunger tip when the bubbles around the tip cannot be removed or if liquid leaks from the lower part of the barrel. Lower the syringe pump in the “Maintenance Mechanical Check” mode. Remove the syringe by unscrewing the base of the plunger and the tip of the syringe. Replace the old tip by pulling with force. Put the new tip on a flat surface with the hole side facing up. Insert the plunger end perpendicularly from above. Replace the syringe. Perform the “Zero Point Detection of Sample Syringe Pump’ from the Maintenance screen.

Perform the “Zero Point Detection of Sample Syringe Pump” from the Maintenance screen whenever the sample syringe has been removed or changed. Be sure that deionized water is in the S1 position.

Regenerate IC solution with 1N HCL. Place 1N HCL in S8 (Acid) autosampler position. Select “Regeneration of IC Solution” from the maintenance screen under the instrument tab. Press start.

Replace sampling and injection needle. Remove tubing and slider.

Replace needle and run capillary wire through needle. Ensure needle does not go below the slider. Test by rubbing needle over metal. Replace slider and tubing. Replace white and black o-rings periodically or as gas occur.

Document Information

Document Number: ENV-SOP-MTJL-0100	**Revision:** 05
Document Title: Volatile Organic Compounds by GC/MS (EPA 8260B, 8260C, 624, 624.1 and SM 6200B)	
Department(s): VOA	

Date Information

Effective Date: 21 May 2021

Notes

Document Notes:

All Dates and Times are listed in: Central Time Zone

Signature Manifest

Document Number: ENV-SOP-MTJL-0100 **Revision:** 05

Title: Volatile Organic Compounds by GC/MS (EPA 8260B, 8260C, 624, 624.1 and SM 6200B)

All dates and times are in Central Time Zone.

ENV-SOP-MTJL-0100

QM Approval

Name/Signature	Title	Date	Meaning/Reason
Elizabeth Turner (007857)	Manager - Quality Program	20 May 2021, 01:02:51 PM	Approved

Management Approval

Name/Signature	Title	Date	Meaning/Reason
Kayla Coble (006639)	Supervisor	20 May 2021, 10:28:18 AM	Approved
James Burns (006456)	Manager - EHS	20 May 2021, 10:50:06 AM	Approved
Christopher Johnson (006487)	Manager - Operations	20 May 2021, 11:05:38 AM	Approved

STANDARD OPERATING PROCEDURE
TITLE: Volatile Organic Compounds by GC/MS
(EPA 8260B, 8260C, 8260D, 624, 624.1, and SM6200 B)
ISSUER: Pace National – Mt. Juliet, Tennessee

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) describes the laboratory procedure for the determination of volatile organic compounds by EPA methods 8260B, 8260C, 8260D, 624.1, Standard Method 6200B, GRO, or similar volatile GC/MS analyses. This procedure is applicable to nearly all kinds of samples, regardless of water content, including ground water, aqueous sludge, caustic liquors, acid liquors, waste solvents, oily wastes, mousses, tars, fibrous wastes, polymeric emulsions, filter cakes, spent carbons, spent catalysts, soils and sediments. The compounds that can be determined using this SOP are listed in Appendix C, which contains a list of the typical primary and secondary ions used in determining these compounds.

1.1 Target Analyte List and Limits of Quantitation (LOQ).

The target analytes and the normal LOQ that can be achieved with this procedure are provided in Table 1, Appendix A.

LOQ are established in accordance with Pace policy and SOPs for method validation and for the determination of detection limits (DL) and quantitation limits (LOQ). DL and LOQ are routinely verified and updated when needed. The current LOQ for each target analyte that can be determined by this SOP as of the effective date of this SOP is provided in Table 1, Appendix A.

The reporting limit (RL) is the value to which analytes are reported as detected or not detected in the final report. When the RL is less than the lower limit of quantitation (LLOQ), all detects and non-detects at the RL are qualitative. The LLOQ is the lowest point of the calibration curve used for each target analyte.

DL, LOQ, and RL are always adjusted to account for actual amounts used and for dilution.

1.2 Specific instructions for employees of the Pace Analytical National Center for Testing & Innovation (Pace National) Sacramento, California laboratory are included in this document as “SAC Notes”.

STATE NOTE: For samples analyzed in conjunction with the Ohio Voluntary Action Program (VAP) please utilize ENV-SOP-MTJL-0099.

CLIENT NOTE: For clients, whose environment laboratory quality program is administered by Environmental Standards Inc. (ESI), see controlled document QUA-30 VOA. \\FAP\NovDiskH\QAQC\Controlled Docs

2.0 SUMMARY OF METHOD

2.1 Volatile organic compounds (VOCs) are determined from a 5mL sample withdrawn from a sealed 40mL vial. For water samples analyzed for low levels of analytes using Method 5030 (ENV-SOP-MTJL-0131), the entire vial is placed into the instrument autosampler. The autosampler purges 5mL of sample and adds 1µL of surrogate standards and internal standards. An inert gas is bubbled through a sparger needle inserted into the sample. The purged volatile components then travel via a transfer line to a sorbent trap. When purging is complete, the trap is rapidly heated. The trap is backflushed with a helium carrier gas, to transport the desorbed sample components into a gas chromatographic (GC) column. The GC column separates and carries the components to a mass spectrometer (MS) or a specific detector, depending on the determinative method selected.

METHOD NOTE: For Method 624.1, different sample sizes in the range of 5–25mL are allowed in order to meet differing sensitivity requirements. Calibration and QC samples must have the same volume as field samples.

2.2 For other samples, Method 5035 (ENV-SOP-MTJL-0129), volatile organic compounds are determined from a 5g sample combined with 5mL reagent water.

3.0 INTERFERENCES

3.1 Major sources of contamination are volatile materials in the laboratory and impurities in the inert purging gas and in the sorbent trap. The use of non-polytetrafluoroethylene (PTFE) thread sealants, plastic tubing, or flow controllers with rubber components must be avoided since such materials out-gas organic compounds which will be concentrated in the trap during the purge operation.

3.2 Analyses of reagent blanks provide information about the presence of contaminants. When potential interfering peaks are noted in blanks, the analyst should change the purge gas source and regenerate the molecular sieve purge gas filter. Subtracting blank values from sample results is not permitted.

3.3 Interfering contamination may occur when a sample containing low concentrations of volatile organic compounds is analyzed immediately after a sample containing high concentrations of volatile organic compounds. After analysis of a sample containing high concentrations, one or more instrument blanks may be analyzed to check for cross contamination. Alternatively, when analysis of a blank is not possible prior to the next sample, such as when an unattended autosampler is employed, the analyst should review the results for at least the next sample after the high-concentration sample. If analytes in the high-concentration sample are not present in the subsequent field sample, then the lack of carryover has been demonstrated.

3.4 This interference may be prevented by rinsing the purging apparatus and sample syringes with portions of organic-free reagent water between samples.

3.5 For samples containing large amounts of water-soluble materials, suspended solids, high boiling compounds, or high concentrations of compounds being determined, it may be necessary to wash the purging device with a soap solution, rinse it with organic-free reagent water, and then dry the purging device in an oven at 105°C.

3.6 In extreme situations, the whole purge and trap device may require dismantling and cleaning.

3.7 Screening of the samples prior to purge and trap GC/MS analysis is highly recommended to prevent contamination of the system. This is especially true for soil and waste samples. Screening may be accomplished by using a portable PID or equivalent.

3.8 Choice of quantitative ions and qualifier ions: Some compounds may co-elute, so the selection of quantitation ions and qualifier ions must be made carefully so these ions are specific to each of the compounds that co-elute. Qualifier ions that are most commonly used are listed in Appendix C and are recommended from the published 8260 methods.

3.9 Special precautions must be taken to avoid contamination when analyzing for methylene chloride. The analytical and sample storage area must be isolated from all atmospheric sources of methylene chloride. Otherwise, random background levels will result. Since methylene chloride will permeate through PTFE tubing, all gas chromatography carrier gas lines and purge gas plumbing must be constructed from stainless steel or copper tubing. Laboratory clothing worn by the analyst must be clean since clothing previously exposed to methylene chloride fumes during liquid/liquid extraction procedures can contribute to sample contamination.

3.10 Samples can be contaminated by diffusion of volatile organics (particularly methylene chloride and fluorocarbons) through the septum seal into the sample during shipment and storage. A trip blank prepared from organic-free reagent water and carried through the sampling and handling protocol can serve as a check on such contamination. A storage blank must be analyzed every two weeks to check for cross contamination of samples while samples are stored in the volatiles laboratory walk-in cooler. The storage blanks are purchased from a vendor and must matrix match the contents of the cold room or refrigerator and is placed in the cooler for a period of two weeks. Every two weeks, the applicable storage blanks are analyzed to verify that no contamination of client samples has taken place due to contamination in the storage unit.

3.11 This procedure can be used to quantitate most volatile organic compounds that have boiling points below 200°C and that are insoluble or slightly soluble in water. Volatile water-soluble compounds can be included in this analytical technique. However, for the more soluble compounds, quantitation limits are approximately 50 times higher due to poor purging efficiency. Such compounds include low-molecular-weight halogenated hydrocarbons, aromatics, ketones, nitriles, acetates, acrylates, ethers, and sulfides.

3.12 Soil samples that contain carbonate minerals (either from natural sources or applied as an amendment) may effervesce upon contact with the acidic preservative solution in the low concentration sample vial. If a large amount of effervescent gas is generated, the sample may lose a significant amount of volatile analytes. If a sample effervesces, an unpreserved sample will be collected to eliminate volatiles loss whenever possible. The holding time for unpreserved VOC samples is seven days, rather than 14 days.

3.13 An analyst may re-analyze any sample if instrumentation or human error is suspected. This includes all QC samples, which can only be re-analyzed twice. If failure continues, instrument maintenance must be performed and/or the instrument must be re-calibrated.

4.0 DEFINITIONS

Refer to the Laboratory Quality Manual for a glossary of common lab terms and definitions.

4.1 Lower Limit of Quantitation (LLOQ) – For analyses performed according to the requirements of Method 8000D, the lowest concentration at which the laboratory has demonstrated target analytes can be reliably measured and reported with a certain degree of confidence, which must be greater than or equal to the lowest point in the calibration curve.

5.0 HEALTH AND SAFETY

5.1 The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

5.2 The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets (SDS) for all hazardous chemicals are available to all personnel. Employees must abide by the environmental, health, and safety (EHS) policies and procedures specified in this SOP and in the Pace National Chemical Hygiene / Safety Manual.

5.3 Personal protective equipment (PPE) such as safety glasses and/or side shields, gloves, a laboratory coat, and shoes that are not cloth, canvas, and/or perforated must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure. When handling glass, needles, knives, or any material with a potential sharp edge, employees must use cut-resistant gloves.

5.4 Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids, bases, or oxidizers in a fume hood whenever possible with the appropriate PPE designed for handing these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

5.5 Spill kits are located in each laboratory department. Employees are to familiarize themselves with the location and contents of each spill kit in their area.

5.6 Universal precautions should be observed when performing any tests or procedures. Hard surfaces, instrument surfaces may be contaminated and should be handled according to good laboratory practices.

5.7 Contact your supervisor or local EHS coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure. Any accidents involving personnel or sample supplies are to be reported immediately to either the Manager and/or to the Safety Officer.

6.0 SAMPLE COLLECTION, PRESERVATION, HOLDING TIME, AND STORAGE

Samples should be collected in accordance with a sampling plan and procedures appropriate to achieve the regulatory, scientific, and data quality objectives for the project.

The laboratory performs samples collection for samples to be analyzed by this SOP in accordance with laboratory SOPs ENV-SOP-MTJL-0067, *Wastewater Sampling*, ENV-SOP-MTJL-0068, *Groundwater Sampling,* and ENV-SOP-MTJL-0313, *Field Sampling*. Refer to these SOPs for these instructions.

The laboratory will provide containers for the collection of samples upon client request for analytical services. Bottle kits are prepared in accordance with laboratory SOP ENV-SOP-MTJL-0064, *Sample Shipping*. For this test method, immediately after sample collection, samples should be checked for pH and Chlorine and field treated. The bottle kits provided by the laboratory should include field test kits and treatment reagent.

Requirements for container type, preservation, and field quality control (QC) for the common list of test methods offered by Pace are included in the laboratory’s quality manual.

General Requirements

Matrix	Routine Container	Minimum Sample Amount[1]	Preservation	Holding Time
Water	40mL vials (in duplicate)	Two 40 mL vials headspace free,3 vials preferred	pH<2 HCl; ≤6°C; Ascorbic acid or Na2S2O3 if Cl present	14 Days (Method 624: 7 days for aromatics if unpreserved)
Soil	4oz. w/zero headspace; 3 5g samples; 5g or 25g collected in an Encore or equivalent sampling device	5 g	pH<2 NaHSo4; Methanol	14 Days

[1] *Minimum amount needed for each discrete analysis.*

Field / Matrix QC

Trip Blank	Equipment Blank	MS/MSD	Field Duplicate
1/cooler	Per Sampling & Analysis Plan	1 pair at 5% Frequency	Per Sampling & Analysis Plan

Thermal preservation is checked and recorded on receipt in the laboratory in accordance with laboratory SOP ENV-SOP-MTJL-0060, *Sample Receiving*. Chemical preservation is checked and recorded at time of receipt or prior to sample preparation.

After receipt, samples are stored at 6°C until sample preparation. Prepared samples (extracts, digestates, distillates, other) are stored at 6°C until sample analysis.

After analysis, unless otherwise specified in the analytical services contract, samples are retained for 30 days from date of final report and then disposed of in accordance with Federal, State, and Local regulations.

6.1 Volatile analysis for water and methanol preserved soil samples must be completed within 14 days from the time of sample collection. Water samples that are not chemically preserved must be analyzed within seven (7) days. It is also a Pace National requirement that water samples with 2-Chloroethyl vinyl ether (2-CEVE), as a compound of interest, be collected unpreserved and analyzed within 7 days of collection. It has been shown that the acid preservative reacts with the 2-CEVE, which could result in false negative reporting of 2-CEVE in samples. Unpreserved soil samples must be analyzed within 48 hours from the time of collection, added to preservative or otherwise frozen at ≤-7°C. High-level soil samples collected in Encore^{TM} or equivalent type sampling devices must be placed in vials of methanol according to Method 5035 (ENV-SOP-MTJL-0129).

STATE NOTE: The State of South Carolina requires that all soil samples must be collected and analyzed using Method 5035. Samples must be preserved within 48 hours from the time of collection, if collected in Encore^{TM} type sampling devices. The holding time for soil samples preserved with methanol or sodium bisulfate is 14 days from the time of collection. Non-Preserved South Carolina VOCs require 7-day holding time.

6.2 Aqueous samples must be collected in at least duplicate in 40mL vials with minimal or no headspace to minimize the loss of highly volatile analytes. Sample kits can be configured to request additional vials per client request. Typically, the pH is adjusted to <2 with HCl, but the preservation requirements may vary by EPA program and may be specified in a regulation or project planning document that requires compliance monitoring for a given contaminant. An example of this is some samples from Missouri or Kansas may be preserved with tri-sodium phosphate and will have a resulting pH>12.

6.3 Soil samples may be collected by one of the following: 1) A 4oz. soil jar filled with soil with zero headspace, 2) Two 5g samples preserved in the field with 5mL $NaHS0_4$ to a pH<2 and one 5g sample preserved in the field with methanol (for high level analysis or data generated on Agilent^{TM} 5977A or 5977B instruments [with an extractor ion or high efficiency source] may be reported to low-level MDL/RL values due to the enhanced sensitivity associated with these instruments) or 3) A 5g or 25g sample collected in an Encore or equivalent type sampling device and frozen in the laboratory within 48 hours from the time of collection.

For all soil samples, a 4oz. soil jar should also be collected to determine percent solids and for screening purposes. All samples and extracts must be shipped and stored at <6°C.

STATE NOTE: Soil and Water samples received from the states of Missouri or Kansas may be preserved with tri-sodium phosphate and will have a resulting pH>12.

STATE NOTE: For Alaska samples, when using a water miscible solvent (e.g., methanol) to extract soil volatile organic compounds (VOC), the adjustment of solvent volume for soil moisture content must be performed. Significant soil moisture can add to a pronounced dilution when performing methanol extractions. The potential under reporting of volatile concentrations is more pronounced as the percent moisture content increases. See section 10.2.3 for the calculation.

6.4 Method 624.1 Considerations

6.4.1 If acrolein is to be determined, analyze the sample within three (3) days. To extend the holding time to 14 days, acidify a separate sample to pH 4–5 with HCl.

6.4.2 Experimental evidence indicates that some aromatic compounds, notably benzene, toluene, and ethyl benzene are susceptible to rapid biological degradation under certain environmental conditions. Refrigeration alone may not be adequate to preserve these compounds in wastewaters for more than seven days. To extend the holding time for aromatic compounds to 14 days, acidify the sample to approximately pH 2.

6.4.3 If halocarbons are to be determined, use an acidified sample.

6.4.4 Ethers are prone to hydrolysis at pH 2 when a heated purge is used. Aqueous samples should not be acid preserved if ethers are of interest or if the alcohols, they would form upon hydrolysis are of interest and the ethers are anticipated to present.

6.4.5 2-Chloroethyl vinyl ether is subject to hydrolysis at low pH; therefore, determine 2-Chloroethyl vinyl ether from the un-acidified sample.

7.0 EQUIPMENT AND SUPPLIES

The operation, cleaning, and scheduled maintenance procedures, as prescribed by the equipment manufacturer, are followed as provided in the Operator's Manuals. Documentation of maintenance or system modifications is recorded in a maintenance logbook which accompanies each analytical system.

7.1 Equipment

7.1.1 Instrumentation: All instrumentation meets or exceeds EPA method requirements. There are a total of 46 instruments; GCs include models 5890, 6890, 7890a, 7890b, 8890b, Intuvo or equivalent and MSs include 5973, 5975, 5977a, 5977b, HES (High efficiency source) or equivalent. Specific information for each instrument is included in the associated maintenance logbook.

Sample introduction system: Archon Autosampler, EST Centurion, OI 4760, Encon P & T, EST Evolution, OI 4660 or equivalent

7.1.2 Analytical Balance, capable of weighing to 0.01g, or equivalent

7.2 Supplies

7.2.1 Glassware: volumetric glassware equipped with penny head ground glass stopper. The volumetric flasks are cleaned by rinsing with methanol and laboratory reagent water. The volumetric flasks can be dried in a low temperature oven at less than 120°C and are never cleaned with a brush or strong alkali solution.

7.2.2 The carrier gas used for volatiles analysis is Helium-5.0 grade.

7.2.3 Syringes used for preparing the calibration curve and preparing samples and sample dilutions are Hamilton brand (or equivalent). Syringe sizes used are 0.50µL, 10µL, 25µL, 50µL, 100µL, 250µL, 500µL, 1mL, and 5mL.

7.2.4 Glass Sample (VOA) and Standard Vials

7.2.4.1 40mL VOA vials with a Teflon™/silicone septa and polypropylene open-top cap.

7.2.4.2 8mL vials with Teflon™/silicone/Teflon™ septa and polypropylene open-top cap. (Used to store unused standards)

7.2.4.3 2mL amber vial with Teflon™/silicone/Teflon™ septa (used to store unused standards)

7.2.5 Miscellaneous

7.2.5.1 Stainless Steel Spatula or wooden tongue depressor

7.2.5.2 Teflon™-coated stir bars, 8mm x 16mm

7.2.5.3 Glass beads –VWR™ #EM1.04015.0500, or equivalent

7.2.6 Oven: Fisher IsoTemp Forced-Air Oven with capabilities of 100°C, or equivalent

8.0 REAGENTS AND STANDARDS

All reagents and standards must be recorded in the appropriate preparation log and assigned a unique number. See ENV-SOP-MTJL-0041, *Standards Logger – Tree Operation*. Additional information regarding reagent preparation can be found in the Standards Logger (Tree) digital archive system. All spiking solutions and surrogate standard solutions should be replaced at least every six months or sooner if a problem is detected unless otherwise noted. Working standards for most compounds should be replaced after four weeks unless the integrity of the standard is suspected to of being compromised prior to that time. Working standards for gases should be replaced after one week unless the acceptability of the standard can be documented.

8.1 Reagents

8.1.1 Nanopure water or equivalent: Nanopure water is used in all blanks to ensure it contains less than the method detection limit (MDL) of all compounds of interest. If volatile compounds are detected in the blank above MDL all samples associated with this blank must be flagged (see Section 11.3.1.1).

NOTE: For all DoD samples the laboratory water is used in all blanks to assure that it contains less than 1/2 LOQ of all compounds of interest. The blank must be assessed to ensure that the water does not show any detection of any VOC compounds. If volatile compounds are detected in the blank above 1/2 LOQ, then those samples must be flagged.

8.1.2 Methanol, CH_3OH – purge-and-trap grade, demonstrated to be free of analytes. Store apart from other solvents.

8.1.3 Sodium Bisulfate, Na2S2O3 - QEC Level 3 Certified, or equivalent

8.2 Standards

8.2.1 STOCK SOLUTIONS – Primary and Secondary Sources

- Stock calibration solutions must be purchased as <u>certified</u> solutions.
- Certificates must be kept on file.
- All Stock standards must be stored $\leq$ 6 ° C or as recommended by the standard manufacturer.
- All non-gas stock standards must be replaced after six months, or sooner, if check standards indicate a problem.
- Both gas and liquid standards must be monitored closely by comparison to the initial calibration curve and by comparison to a second source ICV, or Secondary Source Verification Standard (SSCV).
- Gas intermediate/secondary standards must be replaced weekly, or sooner, if comparison to check standards indicates a problem.
- Non-gas intermediate/secondary standards must be replaced after six months, or sooner, if comparison to check standards indicates a problem.

8.2.1.1 Primary Source - Primary source standards are used to prepare the initial 5-point calibration curve (additional levels may be used as needed), the continuing calibration verification (CCV) standard, LCS and matrix spikes. The CCV is analyzed to verify the initial calibration and is prepared using the primary source standard used to produce the calibration curve. See Section 9.2.3.2.4 through 9.2.3.2.8 for the instrument preparation of the calibration standards. When primary standards are consumed, new standards must meet the same QC criteria as the consumed standards. Stock standards must be stored below -10 ° C and have a six-month holding time once opened. The expiration date of the diluted standards must not exceed the expiration date of the stock standards from which they are prepared. Once diluted, the standard must be replaced weekly. The standard list of target LCS compounds are those compounds listed in Appendix I. The LCS must be prepared in the appropriate matrix (organic-free reagent water or purified solid) depending upon the matrix within the analytical batch; and contain all of the method target analytes. A subset of the method target analytes could be used based on the project specific requirements.

STATE NOTE: South Carolina DHEC and the USACE require that all target analytes are present and evaluated in the LCS

Calibration Mix

The calibration mix is prepared in methanol in a 25mL volumetric flask by adding:

Manufacturer	Product	Cat. #	Amount added (mL)	Final Conc. (ppm)
Phenomenex	Revised 8260 Calibration Mix	AL0-130502	1	100
Phenomenex	Custom Ketones Mix	AL0-130115	1	500
Phenomenex	Acrolein	AL0-130159	1	500
Phenomenex	Custom 8260 Additions Mix	AL0-180004	1.25	100
Phenomenex	Vinyl Acetate	AL0-130117	1	500
Phenomenex	2-Chloroethyl vinyl ether	AL0-130116	1	500
Phenomenex	Ethanol Standard	AL0-130551	0.5	5000
AccuStandard	Vinyl Bromide	S-2688A	1.25	100
Agilent	Custom Standard (1,3,5-TCB)	CUS-0002027	1.25	100

8.2.1.1.1 The calibration standard mix is prepared by making a 1:1 ratio of the gas standard (Agilent, ULTRAgold^{TM} Custom Standard CUS-27747 or equivalent at 100µg/mL) and the calibration mix standard.

8.2.1.1.1.1 For soil autosamplers (5mL), a dilution of 10x is required for the ICV mix. The solution is stored in 3mL aliquots in zero headspace vials. The storage temperature is below $\leq$6° C.

AP9/Oxygenates Calibration Mix

The AP9/Oxygenate ICV solution is prepared in methanol in a 25mL volumetric flask by adding:

Manufacturer	Product	Cat. #	Amount added (mL)	Final Conc. (ppm)
NSI	Ethyl Acetate	681	0.125	50
NSI	Custom AP9 Standard	Q-6603-O	3.125	50
Absolute	Isopropanol	70941	0.625	25
NSI	Tert-Butyl formate	321	0.625	50

8.2.1.2 Secondary Source - Secondary source standards must be used to prepare the secondary source verification standard (SSCV) or initial calibration verification (ICV). These standards are purchased from a different vendor or the primary vendor can supply different lot numbers, if a separate vendor is not available. The standard is at a concentration near the mid-level calibration standard. Stock standards must be stored at or below $\leq$6°C and have a six-month holding time once opened, except the ICV gases which have 1 week holding time. Once diluted, the standard must be replaced weekly.

SSCV

Prepare the SSCV mix in methanol in a 10mL volumetric flask as follows. A separate source or separate lot number is used for standard verification. The standard list of target LCS compounds are those compounds listed in Appendix I.

Manufacturer	Product	Cat. #	Amount added (mL)	Final Conc. (ppm)
NSI	8260 Custom Mix 2	Q-6354-O	0.4	500
Restek	Acrolein	30645	1	500
SPEX CertiPrep	AZ fuel additive 4 comps.	VO-ESCTN-9	0.8	100
Agilent	Custom Standard	CUS-30388	0.4	Varies
Agilent	Custom Standard (ethanol)	CUS-30649	0.2	5000
Restek	1,3,5-Trichlorobenzene	31081	1	100
SPEX CertiPrep	Vinyl Bromide	S-4049	1	100

8.2.1.2.1 The working second source (SSCV) or Initial Calibration Verification (ICV) is prepared by making a 1:1 ratio of the gas standard (Phenova, VOA Gas Calibration Mix AL0-130108 or equivalent at 200µg/mL) and the second source standard.

8.2.1.2.2 For soil autosamplers (5mL), a dilution of 10x is required. The solution is stored in 3mL aliquots in zero headspace vials. The storage temperature is at or below -10° C.

AP9/Oxygenates SSCV

The AP9/Oxygenates SSCV is prepared in methanol in a 10mL volumetric flask by adding:

Manufacturer	Product	Cat. #	Amount added (mL)	Final Conc. (ppm)
NSI	Custom AP9 Standard	Q-6603-O	1.25	50
NSI	Ethyl Acetate	681	.05	50
Absolute	Isopropanol	70941	0.25	25
NSI	Tert-Butyl formate	321	0.25	50

8.3 Surrogate standard stock solutions must be purchased as certified solutions. Certificates must be kept on file. Stock standards must be stored at or below ≤6°C and have a six-month holding time, once opened. Surrogate spiking solutions are purchased from Phenova, Part# AL0-130491, or equivalent, at 20,000ug/mL, which contains both internal standards and surrogate compounds. This solution is then diluted by 100X to obtain a 200ug/mL working solution.

8.3.1 The following are Pace National designated volatiles' analysis surrogates:

- Toluene-d8
- 4-Bromofluorobenzene

- 1,2-Dichloroethane-d4

8.4 Internal standard stock solutions must be purchased as certified solutions. Certificates must be kept on file. Stock standards must be stored at or below <u><</u>6° C and have a six-month holding time, once opened. [Internal standard and surrogate standard – Phenova, Part# AL0-130491, or equivalent]

8.4.1 The following are Pace National designated volatiles' analysis internal standards:

- 1,4-Dichlorobenzene-d4
- Fluorobenzene
- Chlorobenzene-d5

SAC NOTE: Internal Standard/Surrogate Mix – o2si 8260 Internal Surrogate Solution Catalog No.: 121722-08-20PAK. This mix is diluted 250x to produce a 50 µg/mL internal standard and surrogate mix. During analysis, 5µL of this solution is added to 5mL of sample, resulting in a concentration of 50 µg/L. The internal standards and surrogates are the same as listed in 8.3.1 and 8.4.1 with the addition of Tert-butyl Alcohol-d10 as an internal standard.

8.5 4-Bromofluorobenzene (BFB) standard - The BFB in the custom internal standard mix is used to verify mass spectrometer tuning. Since internal standards and surrogates are added to all samples and standards, BFB is included as part of our initial calibration and calibration verification standards. Certificates of analysis must be kept on file. Stock standards must be stored at or below $\leq$6°C and have a six-month holding time, once opened.

8.6 Matrix spike (MS) standard - Stock standards must be stored at or below $\leq$6°C and have a six-month holding time, once opened. Once diluted, the standard must be replaced weekly.

8.6.1 The matrix spike standard is prepared from the stock standard in Section 8.2.1.

8.6.2 The spike should be at a mid-level of the calibration range. Some contracts may require a site-specific concentration.

8.6.3 Standard spiking practice requires the use of ALL TARGET ANALYTES as specified in Appendix I and must be evaluated against the current control limits presented in the LIMS.

All compounds in the spike solution must be evaluated for acceptable recovery. In the absence of established control limits, default recovery limits are 70 - 130%.

9.0 PROCEDURE

Analysis Summary: Volatile compounds are introduced into the gas chromatograph by purge and trap, via the Archon autosampler, as described on Section 2. Soils require method 5035 for sample preparation, See ENV-SOP-MTJL-0129.

9.1 Equipment Preparation

Chromatographic conditions: All changes in analytical conditions are listed in the Maintenance Log.

9.1.1 Support Equipment

All support equipment used must be calibrated or verified prior to use according to SOP ENV-SOP-MTJL-0039, *General Analytical Balance Operation and Verification in the Laboratory* current revision or replacement.

Screening the sample prior to purge-and-trap analysis provides guidance on whether sample dilution is necessary and prevents contamination of the purge-and-trap system by screening of 5mL of sample using an HNU or equivalent portable PID. See ENV-SOP-MTJL-0102, Volatile Organic Compounds Screening using the RAE Systems Photoionization Gas Detector Model MiniRAE 3000.

9.1.2 Instrument

9.1.2.1 Routine Instrument Operating Conditions

9.1.2.1.1 Typical conditions for each instrument and column are listed below:

Inlet	off
Detector	200°C
Oven Equib. Time:	0.50 minutes
Oven Max	240°C
Init Temp	45°C hold 1.0 minute
Ramp	20°C/min to 240 hold 1.0 minute

9.1.2.1.2 Typical conditions for each autosampler are listed below:

Heating sample	1 minute at 40oC
Purge	11 minutes at 40oC
Desorb	1 minutes at 250oC
Bake	2 minutes at 260oC

9.1.2.1.3 Typical conditions for each MS detector are listed below:

Electron energy – 70 volts (nominal)
Mass range – 35 to 300 amu
Scan time – 1.2 sec/scan
Manifold vacuum – 3 x 10-6 torr

9.1.2.1.4 TUNING - Each GC/MS system must be hardware-tuned (1µL < 50ng) with BFB to meet the criteria listed below. The mass-spectrometer must meet acceptable BFB sensitivity criteria before analysis can begin. The instrument must be tuned every 12 hours for 624.1, 8260B, 8260C, and 6200B. BFB tuning for method 8260D is prior to each calibration.

BFB Key Ions and Ion Abundance Criteria for 8260B, 8260C, 8260D, 624.1	
Mass	**Ion Abundance Criteria**
95	50 - 200% of mass 174
96	5 - 9% of mass 95
173	< 2% of mass 174
174	50 - 200% of mass 95
175	5 - 9% of mass 174
176	95 - 105% of mass 174
177	5 - 10% of mass 176

BFB Key Ions and Ion Abundance Criteria for 6200	
Mass	**Ion Abundance Criteria**
50	15.0-40.0% of mass 95
75	30.0-60.0% of mass 95
95	base peak, 100% relative abundance
96	5.0-9.0% of mass 95
173	< 2.0% of mass 174
174	> 50.0% of mass 95
175	5.0-9.0% of mass 174
176	> 95.0%, but less than 101% of mass 174
177	5.0-9.0% of mass 176

EPA 624.1 NOTE: The 12-hour tune clock begins after analysis of the BFB, the LCS, and the BLANK and ends 12 hours later. BFB, the LCS, and BLANK are outside of the 12-hour tune clock. The MS and MSD are treated as samples are analyzed within the 12-hour clock.

9.2 Initial calibration

9.2.1 Calibration Design

Calibration Levels for single analytes

Soil Samples - Soil samples are analyzed with a heated purge in the soil chamber of the Archon, or equivalent autosampler. The calibration curve is generated by injecting the following volumes of Calibration Mix (See Section 8.2.1.1) into 5mL of reagent water. Surrogate standard is prepared by diluting the surrogate by1:10 using (NSI lab solutions, 8260 Surrogate Mix Q-4392 or equivalent at1000µg/mL).

8260 Calibration Curve - GC/MS Soil (into 5mL water)

Intermediate solution volume (µL)	Concentration of standard (ppb)	Surrogate Added (µL)	Concentration of Surrogate (ppb)
0.025	0.25	0	n/a
0.05	0.5 (LOD Point)	0	n/a
0.1	1	1	1
0.2	2	2	2
0.5	5	3	3
2.5	25	4	4
7.5	75	5	5
10	100	6	6
20	200	7	7

8260 Calibration Curve - GC/MS Soil (into 50mL water) for use with Agilent 5977A or 5977B Only

Intermediate solution volume (µL)	Concentration of standard (ppb)	Surrogate Added (µL)	Concentration of Surrogate (ppb)
0.02	0.02 (LOD Point)	0	n/a
0.04	0.04	0	n/a
0.1	0.1	0	n/a
0.2	0.2	0	n/a
0.5	0.5	0	n/a
1	1	1	1
2	2	2	2
5	5	3	3
25	25	4	4
75	75	5	5
100	100	6	6

AP9/Oxygenates Calibration Curve - GC/MS Soil (into 5mL of water)

Intermediate solution volume (µL)	Concentration of standard (ppb)
0.5	0.5
1	1.0
5	5
10	10
15	15
20	20

AP9/Oxygenates Calibration Curve - GC/MS Soil (into 50mL of water)	
Intermediate solution volume (µL)	Concentration of standard (ppb)
5	0.5
10	1.0
50	5
100	10
150	15
200	20

Note 1: When analyzing soil samples by the low-concentration method (Section 9.4), the calibration standards must be heated to 40°C ± 1°C prior to purging.

Note 2: Injections should be performed from the lowest to the highest standards with a cleanup injected after the highest standard and followed by the secondary source standard to verify the initial calibration curve.

Water Samples - Water samples are run with a heated purge using the Archon, or equivalent autosampler. The calibration curve is generated by injecting the following volumes of Calibration Mix (See Section 8.2.1.1) into 50mL of water. Surrogate standard is added to the curve points, (Phenova, Custom IS-SURR Mix AL0-130574 or equivalent at1000µg/mL).

8260 Calibration Curve - GC/MS Water (into 50mL water)			
Intermediate solution volume (µL)	Concentration of standard (ppb)	Surrogate Added (µL)	Concentration of Surrogate (ppb)
0.02	0.02	0	n/a
0.04	0.04	0	n/a
0.1	0.1	0	n/a
0.2	0.2	0	n/a
0.5	0.5 (LOD Point)	0	n/a
1	1	1	1
2	2	2	2
5	5	3	3
25	25	4	4
75	75	5	5
100	100	6	6
200	200	7	7

AP9/Oxygenates Calibration Curve - GC/MS Water (into 50mL of water)	
Intermediate solution volume (µL)	Concentration of standard (ppb)
5	0.5
10	1.0
50	5
10	10
150	15
200	20

SAC NOTE: See Controlled Document DAV-03 VOA ICAL Reference for calibration table.

9.2.2 Calibration Sequence

Curve – General Criteria

- A minimum of 5-point calibration is performed using the primary standards listed in Section 8.2.1.1. Additional levels may be included to better meet project or client requirements. Regardless of the specific number, the calibration levels analyzed should correspond to a range of concentrations expected to be found in samples, without exceeding the working range of the GC/MS system.
- A calibration point must be analyzed at or below the reporting limit. The concentration of the lowest calibration standard analyzed should be at least 3-5 times the MDL. The instrument response must be distinguishable from the instrument background noise. The signal to noise ratio is the magnitude of the signal strength detected by the mass spectrometer relative to the magnitude of the background noise of the instrument. Instrument conditions must be optimized before the analysis of a calibration curve to minimize background effects.

STATE NOTE: The reporting level standard must be refit after calibration is complete. This standard is required by the state of North Carolina and is used to verify the low end of the calibration curve.

STATE NOTE: When analyzing samples from Minnesota, the reporting limit must be verified with each calibration or at least monthly. Verification can be performed by re-quantitation of the low calibration standards using the newly updated calibration curve or by analyzing a separate reporting level standard following calibration curve update. This standard must recover ±40% of the expected concentration. If the criterion is not met, a higher-level standard may be re-quantitated or analyzed; however, the reporting limit must be amended to reflect the increased concentration of the standard utilized. Analytes known to be poor performers are dealt with on a case-by-case basis.

- The highest standard must not exceed the linear range of the detector. The concentration of the highest standard must produce a response, which does not cause the MS detector to become saturated. The highest concentration used in the calibration curve must allow the analyte to meet the calibration requirements outlined in Sections 9.2.3.

- When using Method 5035, ENV-SOP-MTJL-0129, the calibration curve must be prepared in the same solutions used to preserve the field samples.

- **EPA 8260C NOTE:** The method of linear regression analysis has the potential for a significant bias to the lower portion of a calibration curve, while the relative percent difference and quadratic methods of calibration do not have this potential bias. When calculating the calibration curves using the linear regression model, a minimum quantitation check on the viability of the lowest calibration point should be performed by re-fitting the response from the low concentration calibration standard back into the curve. It is not necessary to reanalyze a low concentration standard; rather the data system can recalculate the concentrations as if it were an unknown sample. The recalculated concentration of the low calibration point should be within ±30% of the standard's true concentration.

- **EPA 8260D NOTE:** The method of linear regression analysis has the potential for a significant bias to the lower portion of a calibration curve, while the relative percent difference and quadratic methods of calibration do not have this potential bias. A minimum quantitation check on the viability of all calibration points should be performed by re-fitting the response from each calibration standard back into the curve. The recalculated concentration of the reporting level point should be within ±50% of the standard's true concentration. All other recalculated concentration calibration points should be within ±30% of the standard’s true concentration. If a failure occurs in the low point and it is equivalent to the LLOQ, the analyte should be reported as estimated near that concentration or the LLOQ should be reestablished at a higher concentration.

  STATE NOTE: South Carolina does not allow the use of quadratic regression for compounds that have previously demonstrated linearity.

- The method reference spectra must be updated from the mid-point of each calibration.

9.2.3 ICAL Evaluation

9.2.3.1 Curve Fit

9.2.3.1.1 Linear Regression - Criteria

When any compound does not meet the calibration criteria for RF, the most appropriate curve fitting model is used. If linear regression is used, it must be noted on the data (preferably on the CCV RF report), next to the affected compound. It must also meet correlation coefficient (r) criteria of 0.995 or better. SM

6200 requires a linear regression correlation coefficient of >0.994.

Linear regression is achieved by plotting the instrument response versus the concentration of the standards. The resulting regression line must not be forced through the origin and the origin must not be included as a calibration point.

STATE NOTE: For all Wisconsin sample analyses, analysts must evaluate the %RSD of calibrations to ensure that they do not have unacceptable curvature. The %RSD limit criteria, as found in the specific methods listed above, applies to calibrations using average RF calibrations. For linear and quadratic curve fits, a limit of 40% RSD is used for normal target analytes and 50% RSD is utilized for known poor performing compounds.

The most appropriate curve fitting model from among the following choices must be utilized (given in the order of preference): Average Response Factor

- Linear – No Weighting
- Linear – 1/x Weighting
- Linear – 1/x^2 Weighting
- Quadratic

STATE NOTE: South Carolina does not allow the use of quadratic regression for compounds that have previously demonstrated linearity.

9.2.3.1.2 Calibration Corrective Action

When the RSD exceeds 15% or linear regression criteria could not be met, plot and inspect the calibration data for abnormal chromatographic responses. The inspection may indicate analytical problems, including errors in standard preparation, the presence of active sites in the chromatographic system, analytes that exhibit poor chromatographic behavior, etc.

If calibration criteria are not met, then one of the following options must be applied to the GC/MS initial calibration:

9.2.3.2 Relative Standard Error (RSE)

A measure of relative error must be documented for each calibration. For analytes using an Average curve fit, the %RSD is the relative error, and no further evaluation is required. For analytes using a linear or quadradic curve fit, the relative error must be evaluated for the calibration low and mid-points using one of the procedures below.

9.2.3.2.1 %Relative Error (%RE)

If using this method of determining relative error, the %RE of the calibration mid-point must be between 70-130%. For the calibration low point, %RE must be between 50-150%. The %RE is evaluated busing on the response/resultant concentration in the applicable initial calibration standards.

9.2.3.2.2 %Relative Standard Error (%RSE)

If using this method of determining relative error, the acceptance limits for %RSE are numerically identical to the %RSD criteria. The %RSE is evaluated by creating a copy of the applicable calibration standard files and then quantitating the copied files against the new calibration.

Note: Calibration standard files must be copied and re-named for use in this evaluation. DO NOT over-write the initial calibration files.

Adjust the instrument and/or perform instrument maintenance and re-analyze the calibration standards until the RSD of the calibration meets criteria.

9.2.3.2.3 Narrow the calibration range until the response is linear. If the low standard is below the estimated quantitation limit (i.e., for the poor purgers in a commercially available prepared standard mix), then this standard may be dropped. Re-calculate the RSD without the low standard to determine if the RSD meets the QC limit. If the lowest standard is dropped, the reporting limit could require a change. Check with the supervisor to determine if a point can be removed and not affect reporting limits requirements.

Compounds that are very soluble in water generally are poor purgers. The ketones, vinyl acetate, acrolein, and acrylonitrilie fall into this category.

9.2.3.2.4 EPA 8260B: Response Factors (RF's) & Calibration Check Compounds (CCC's) - Soil/Water

Using the RFs for the initial calibration curve from Section 8.2.2, calculate and record the percent relative standard deviation (%RSD) for all compounds. Calculate the percent RSD as in Section 10.2.5. Linearity can be assumed if the RSD criteria is met, thus allowing quantitation calculations to be performed using RF.

CCC Criteria - The %RSD for each individual CCC must be less than 30%. The CCCs are:

1,1-Dichloroethene	Toluene
Chloroform	Ethylbenzene
1,2-Dichloropropane	Vinyl chloride

Target Analytes and other Non-CCC's - The RSD must meet the following criteria

<15% RSD for all 8260B Target Analytes
<20% RSD for all 8260C/D Target Analytes
<35% RSD for all 624.1 Target Analytes
<20% RSD for all KSGRO Samples
<15% RSD for n-Hexane
<20% RSD for 6200 Analytes
<15% appendix 9 Analytes
<10% RSD for all 601/602 Target Analytes

Compounds not meeting the RSD requirement may be considered for linear regression as stated in 8.2.7.3

9.2.3.2.5 EPA 8260C: Response Factors (RF's)

9.2.3.2.5.1 Calibration Curve Criteria - Calculate the mean response factor and the relative standard deviation (RSD) of the response factors for each target analyte using the following equations. The RSD should be less than or equal to 20% for each target analyte. It is also recommended that a minimum response factor for the most common target analytes as noted in Appendix G, be demonstrated for each individual calibration level as a means to ensure that these compounds are behaving as expected. In addition, meeting the minimum response factor criteria for the lowest calibration standard is critical in establishing and demonstrating the desired sensitivity. Due to the large number of compounds that may be analyzed by this method, some compounds will fail to meet these criteria. For these occasions, it is acknowledged that the failing compounds may not be critical to the specific project and therefore they may be used as qualified data or estimated values for screening purposes.

9.2.3.2.6 When the RSD exceeds 20% or linear regression criteria could not be met, plot and inspect the calibration data for abnormal chromatographic responses. The inspection may indicate analytical problems, including errors in standard preparation, the presence of active sites in the chromatographic system, analytes that exhibit poor chromatographic behavior, etc.

NOTE: To maximize batches calibration RSDs are held to the strictest method reported, the RSD used for all methods is 15%.

9.2.3.2.7 EPA 8260D: Response Factors (RF's)

9.2.3.2.7.1 Calibration Curve Criteria – Calculate the mean RF and the relative standard deviation (RSD) of the RFs for each target analyte. The RSD should be <20% for each target analyte. Appendix H contains minimum RFs that may be used as guidance in determining whether the system is behaving properly and as a check to see if calibration standards are prepared correctly. It is neither expected nor required that all analytes meet these minimum RFs in the guidance table, however target analytes must not have an RF <0.01. Due to the large number of compounds that may be analyzed by this method, some compounds will fail to meet these criteria. For these occasions, it is acknowledged that the failing compounds may not be critical to the specific project and therefore they may be used as qualified data or estimated values for screening purposes.

9.2.3.2.7.2 When the RSD exceeds 20% or linear regression criteria could not be met, plot and inspect the calibration data for abnormal chromatographic responses as the inspection can be a useful diagnostic tool.

NOTE: To maximize batches calibration RSDs are held to the strictest method reported, the RSD used for all methods is 15%

9.2.3.2.8 EPA 624.1

Calculate the mean (average) and relative standard deviation (RSD) of the response factors. If the RSD is less than 35%, the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to fit a linear or quadratic regression of response ratios vs. concentration ratios. If used the regression must be weighted inversely proportional to concentration. The coefficient of determination (R2) of the weighted regression must be greater than 0.920 (this value roughly corresponds to the RSD limit of 35%). Alternatively, the relative standard error may be used as an acceptance criterion. As with the RSD, the RSE must be less than 35%. If an RSE less than 35% cannot be achieved for a quadratic regression, system performance is unacceptable, and the system must be adjusted and re-calibrated.

NOTE: Using capillary columns and current instrumentation, it is quite likely that a laboratory can calibrate the target analytes in this method and achieve a linearity metric (either RSD or RSE) well below 35%. Therefore, laboratories are permitted to use more stringent acceptance criteria for calibration than described here (e.g., to harmonize their application of this method with those from other sources).

STATE NOTE: South Carolina does not allow the use of quadratic regression for compounds that have previously demonstrated linearity.

9.2.3.3 Initial Calibration Verification

Calibration Verification for EPA Methods 8260B, 624.1 and SM 6200B:

9.2.3.3.1 SSCV's

After a successful calibration, a Second Source Calibration Verification (SSCV) or Initial Calibration Verification (ICV) must be analyzed to verify the calibration. This standard must be made from a second source, preferable from a different vendor than the calibration standards. The second source calibration standard must perform within following criteria:

CCC and SPCC compounds	± 30%
Other compounds (non-poor performers)	± 40%
Poor Performers (8.3.2	in-house LCS limits

9.2.4 Continuing Calibration Verification

9.2.4.1 Internal Standards and Surrogates – Soil/Water

The autosampler adds 1µL of the IS/surrogate mix to each sample. The addition of 1µL of the surrogate spiking/internal standard solution is equivalent of 16µg/L of each surrogate/internal standard. Internal standard and surrogate standard are contained within the same spiking mix. Internal Standards are listed Section 8.4.1 and Surrogates are listed in Section 8.3.1.

SAC NOTE: During analysis, 5µL of this solution is added to 5mL of sample, resulting in a concentration of 50 µg/L

Tabulation of the Internal Standards

Tabulate the area response of the characteristic ions (see Appendix C) against each compound's concentration and each internal standard concentration. Then calculate the response factor (RF) for the quantifying ion of each compound relative to the appropriate internal standard according to the calculation provided in Section 9.1. The internal standards used should permit most of the compounds of interest in a chromatogram to have retention times of 0.80 to 1.20, relative to one of the internal standards. The average RF must be calculated and recorded for each compound.

9.2.4.2 System Performance Check Compounds (SPCCs) – Soil/Water

A system performance check must be made before the calibration curve can be used. The minimum relative response factor for volatile SPCCs are as follows:

Chloromethane	0.10
1,1-Dichlorethane	0.10
Bromoform	0.10
Chlorobenzene	0.30
1,1,2,2-Tetrachloroethane	0.30

These compounds are typically used to check compound instability and to check for degradation caused by contaminated lines or active sites in the system. Examples of these occurrences are:

Compound	Effect on stability
Chloromethane	This compound is the most likely compound to be lost if the purge flow is too fast.
Bromoform	This compound is one of the compounds most likely to be purged very poorly if the purge flow is too slow. Cold spots and/or active sites in the transfer lines may adversely affect response. Response of the quantitation ion (m/z 173) is directly affected by the tuning of BFB at ions m/z 174/176. Increasing the m/z 174/176 ratio relative to m/z 95 may improve bromoform response.
1,1,2,2-Tetrachlorethane and 1,1-Dichloroethane	Contaminated transfer lines degrade these compounds in purge-and-trap systems. Active sites in trapping materials also can cause problems.

Adjust the purge gas (Helium or Argon) flow rate to 25-40mL/min on the purge-and-trap device. Optimize the flow rate to provide the best response for chloromethane and bromoform. Excessive flow rate reduces chloromethane response, whereas insufficient flow reduces bromoform response.

9.2.4.3 CCC's

The curve must be verified daily by a calibration standard known as the Continuing Calibration Verification standard (CCV) and is analyzed every 12 hours. This standard is prepared at or near the mid-point of the calibration curve. A maximum of 20% criteria would be expected for CCC analytes (Listed in Section 8.2.7.1) and n-Hexane when requested as a target analyte.

Compounds on average response factor use % difference,

$$\% \text{ Difference} = (RF_{v} - Rf_{ave}) / Rf_{ave} \times 100\%$$

Compounds on regression fit model use percent drift,

% Drift = (Calculated conc - Theoretic conc) / Theoretic conc x 100%

Criteria for both is $\leq$20%.

9.2.4.4 SPCC's

The SPCC's must have a minimum response factor as stated in Section 8.2.6. If these criteria are exceeded, then corrective action is required.

9.2.4.5 All Target Analytes and Non-CCC's

When analyzing 8260B and 624.1 concurrently, calibration verifications are evaluated using both the 8260B criteria (sections. 8.3.1.2 through 8.3.1.3 and the 624.1 criteria (Appendix F). For analytes not on the 624.1 list, all target analytes (except for the poor performers (9.2.4.7) must meet a maximum of 40% drift from the calibration curve. The analyst evaluates all analytes carefully and the experience of the analyst weighs heavily when determining the usability of the data.

Poor performers are allowed a maximum of 50% drift from the calibration curve. See section 9.2.4.7 for a listing of poor performing analytes.

STATE NOTE: For South Carolina 624.1 samples, the target analytes reported must agree with the compound list found in the EPA 624.1 published method.

Calibration Verification for EPA Method 8260C/D:

9.2.4.6 SSCV's

After a successful calibration, a Second Source Calibration Verification (SSCV) or Initial Calibration Verification (ICV) must be analyzed to verify the calibration. This standard must be made from a second source, preferable from a different vendor than the calibration standards. The second source calibration standard must perform within following criteria:

All compounds	± 30%
Poor Performers (9.2.4.7)	in-house LCS limits

9.2.4.7 Target Analytes

The curve must be verified initially by a calibration standard known as the Continuing Calibration Verification standard (CCV) and is analyzed every 12 hours). This standard is prepared at or near the mid-point of the calibration curve. A maximum of 20% criteria would be expected for all target analytes and n-Hexane when requested as a target analyte.

If the percent difference (average RSD) or percent drift (linear regression models) for a compound is less than or equal to 20%, then the initial calibration for that compound is assumed to be valid. Due to the large numbers of compounds that may be analyzed by this method, some compounds will fail to meet the criteria. If the criterion is not met (i.e., greater than 20% difference or drift) for more than 20% of the compounds included in the initial calibration, then corrective action must be taken prior to the analysis of samples. In cases where compounds fail, they may still be reported as non-detects if it can be demonstrated that there was adequate sensitivity to detect the compound at the applicable quantitation limit. For situations when the failed compound is present, a reporting level verification is analyzed. Reference QUA-12 *CCV Criteria for 8260C and 8270D* for assessing reporting level verification.

All compounds must have a minimum response factor. If these criteria are exceeded, then corrective action is required. The minimum response factors are generated in house based off historical data.

Poor Performers:

The poor performers are as follows:

Propene
Dichlorodifluoromethane
Carbon Disulfide
Bromomethane
2-Chloroethylvinyl Ether
Acrolein
Vinyl acetate
trans-1, 4-dichloro-2-butene

Chloroethane
1,3-Butadiene
1,2-Dibromo-3-chloropropane
1- Methylnaphthalene
2- Methylnaphthalene
Acetone
Pentachloroethane
Tert-butyl Formate
Alcohols (Ethanol, TBA, TAA, ETBA, Butanol)
Iodomethane
Naphthalene
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Cyclohexanone
Methyl cyclohexane

9.2.4.8 Laboratory Control Standard (LCS): A laboratory control sample (LCS) should be included with each analytical batch. The LCS consists of an aliquot of a clean (control) matrix similar to the sample matrix and of the same weight or volume. The LCS is spiked with the same analytes at the same concentrations as the matrix spike, when appropriate. When the results of the matrix spike analysis indicate a potential problem due to the sample matrix itself, the LCS results are used to verify that the laboratory can perform the analysis in a clean matrix. Also note the LCS for water sample matrices is typically prepared in organic-free reagent water similar to the continuing calibration verification standard. In these situations, a single analysis can be used for both the LCS and continuing calibration verification.

- QC Limits are found in the LIMS for LCS and MS/MSD.
- If the stated criteria are exceeded, then corrective action is required.
- See Section 12.9.1, on marginal exceedances.

STATE NOTE: All **South Carolina** DHEC compliance testing, the LCS responses must be within 70 – 130% for Method 8260 and within the limits given in Appendix F for Method 624.1. High failures are acceptable for 8260 or 624.1, as long as the sample results are below detection level. Qualifiers cannot be used therefore low failures require a batch re-analysis. See Section 11 for QC evaluation. For samples analyzed from South Carolina that are not utilized for compliance purposes, in house established acceptance limits are utilized to demonstrate controlled analyses.

STATE NOTE: For EPA Region IV only (AL, FL, GA, KY, MS, NC, SC, TN), when running Acrolein and Acrylonitrile by V624.1, the QC criteria from EPA Method 603 should be used for control demonstration. The LCS criteria from EPA Method 603 include Acrolein recovery within 88-118% and Acrylonitrile recovery within 71-135%.

9.2.4.9 Internal Standard Evaluation

When a calibration is performed at the beginning of an analytical run:

The internal standard areas must be evaluated against the mid-point of the curve. Samples are analyzed within a 12-hour window; the internal standards of those samples are evaluated against mid-point of the curve.

Then a CCV is analyzed, this is compared to the mid-point of the initial calibration curve. Addition samples are analyzed within a 12-hour window; the internal standards of those samples are evaluated against the previous acceptable CCV.

When an analytical run is started using a passing ICV (which is compared against the initial calibration mid-point to verify the calibration curve): Samples are analyzed within a 12-hour window, the internal standards of those samples are evaluated against the daily CCV. Then a CCV is analyzed, this is compared to the mid-point of the curve. Additional samples are analyzed within a 12-hour window; the internal standards of those samples are evaluated against the previous acceptable CCV.

9.3 Sample Preparation

Screening the sample prior to purge-and-trap analysis provides guidance on whether sample dilution is necessary and prevents contamination of the purge-and-trap system by screening of 5mL of sample using an HNU or equivalent portable PID.

9.3.1 Homogenization and SubSampling

Compositing samples prior to GC/MS analysis – Site or project-specific requirements may require compositing of samples, which is performed according to the instructions below. Compositing of samples is only performed at the request of the client.

9.3.1.1 All vials for the sample are combined in an appropriately sized volumetric flask that will allow for the least amount of headspace. (If 4 vials are to be composited then a 200mL volumetric flask will be used to combine the samples.). Practice special precautions to maintain zero headspace in the syringe.

9.3.1.2 The samples must be cooled to 4 ° C or less during composition to minimize the loss of volatiles. Sample vials may be placed in a tray of ice to prevent volatile loss during this process.

9.3.1.3 Invert the volumetric flask three (3) times. Pour the volume out of the volumetric flask into the original 40mL VOA vial containers. The sample is now ready to be analyzed.

NOTE: Samples are not routinely composited; however, if site-specific requirements state procedures for compositing samples, the laboratory makes every effort to comply with those requirements.

9.4 Analysis

9.4.1 Example Analytical Sequence

9.4.1.1 Gas chromatographic analysis:

9.4.1.1.1 Typical sequence order for loading the autosampler with calibration:

Sample/QC Type	Use
Cleanup Blank	Verify system is contamination free
BFB Tune	Tuning criteria
Calibration standard(s)	Initial volatiles calibration and 5-point for GRO (if analyzed)
Second Source Calibration Verification (SSCV) or Initial Calibration Verification (ICV)	Verify initial calibration with second source.
Laboratory Control Sample	Laboratory blank, spiked with known amount(s) of analyte of interest
Matrix Spike/Matrix Spike Dup.	Sample spiked with known number(s)(s) of analytes of interest
Method blank	Ensure that carry over has not occurred from the calibration standard and that the analytical system does not show contamination above the established detection limits
12-hour window	Client samples
Continuing Calibration Verification (CCV)	Single-point calibration verification standard, if needed.
12-hour window	Client samples

9.4.1.1.2 Typical sequence order for loading the autosampler with calibration verification only:

Sample/QC Type	Use
Cleanup Blank	Verify system is contamination free
BFB Tune	Tuning criteria
Initial Calibration Verification (ICV)	Verify initial calibration.
Laboratory Control Sample	Laboratory blank, spiked with known amount(s) of analyte of interest
Matrix Spike/Matrix Spike Dup.	Sample spiked with known amount(s) of analytes of interest
Method blank	Ensure that carry over has not occurred from the calibration standard and that the analytical system does not show contamination above the established detection limits
12-hour window	Client samples
Continuing Calibration Verification (CCV)	Single-point calibration verification standard, if needed.
12-hour window	Client samples

9.4.2 All samples and standard solutions must be allowed to warm to ambient temperature before analysis.

9.4.3 BFB tuning criteria and GC/MS calibration criteria must be met before analyzing samples

Load the unopened VOA vial onto the autosampler for analysis.

9.4.4 After the sample has been analyzed on the instrument, check the pH of the sample using the remaining sample in the VOA vial. Use universal pH paper and record the sample pH to the nearest whole pH unit. Samples not passing the pH requirements are flagged with a “G1” qualifier. All samples that report 2-CEVE as a target analyte and have a pH < 2 are qualified with a “G2”.

STATE NOTE: For West Virginia compliance samples, check for residual chlorine after sample analysis. Samples containing residual chlorine must be flagged as such.

Sample Dilution -- When necessary, samples can be diluted before purging. This can be performed in a clean 50mL volumetric flask. The sample is measured through the use of an appropriate microliter syringes and added to the flask which is then filled with reagent water to the meniscus.

Surrogate/Internal Standards – The autosampler adds 1µL of the IS/surrogate mix to each sample. The addition of 1µL of the surrogate spiking/internal standard solution is equivalent to 16µg/L of each surrogate standard. Internal standard and surrogate standard are contained within the same spiking mix.

SAC NOTE: During analysis, 5µL of this solution is added to 5mL of sample, resulting in a concentration of 50 µg/L of each surrogate and internal standard.

If the initial analysis of a sample or a dilution of the sample has a concentration of analytes that exceeds the initial calibration range, the sample must be re-analyzed at a higher dilution. All dilutions must keep the response of the major constituents (previously saturated peaks) in the upper half of the linear range of the curve. Secondary ion quantitation is allowed only when there are sample interferences with the routinely quantitated primary ion. When a sample is analyzed that has saturated the detector, the samples following must be analyzed for contamination. If any sample shows contamination, they must be re-analyzed.

9.4.5 GC/MS Analysis - Water-miscible liquids

9.4.5.1 Water-miscible liquids are analyzed as water samples after first diluting them at least 25-fold with laboratory water.

9.4.5.2 Initial and serial dilutions can be prepared by pipetting a known amount of the sample to a 50mL volumetric flask and diluting to volume with organic-free reagent water. Transfer immediately to a clean/baked 40mL vial using a 5mL syringe.

9.4.5.3 Alternatively, prepare dilutions directly in a clean 40mL vial filled with organic-free reagent water by adding at least 0.5µL, but not more than 25mLs of liquid sample. The sample is ready for addition of internal and surrogate standards. Proceed with Section 9.2.4.1.

9.4.6 GC/MS Analysis - Sediment/soil and waste samples

These samples may contain percent quantities of purgeable organics that will contaminate the purge-and-trap system and require extensive cleanup and instrument downtime. The screening of samples is highly recommended. Screening data should be used in conjunction with site-specific DQOs, if known, to determine whether to use the low-concentration method (0.005 - 1mg/Kg) or the high-concentration method (>1mg/Kg).

9.4.6.1 Low-concentration method -- This is designed for samples containing individual purgeable compounds of <1mg/Kg. It is limited to sediment/soil samples and waste that is of a similar consistency (granular and porous). The low-concentration method is based on purging a heated sediment/soil sample mixed with organic-free reagent water containing the surrogate and internal standards. All QC samples and standards are to be analyzed under the same conditions as the samples, using 5g of glass beads or equivalent blank matrix.

STATE NOTE: This option cannot be used for South Carolina samples. Please refer to ENV-SOP-MTJL-0129 that addresses Method 5035 for sample preparation.

9.4.6.2 Use a 5g sample if the expected concentration is <0.1mg/Kg, or a 1g sample for expected concentrations between 0.1 and 1mg/Kg.

9.4.6.3 The GC/MS system must be set up prior to the preparation of the sample to avoid loss of volatiles from standards and samples. Both the initial and daily calibration standards must be heated to 40°C purge temperature.

9.4.6.4 The sample consists of the entire contents of the sample container. Do not discard any supernatant liquids. Mix the contents (using slow but precise movement to limit the loss of volatiles) of the sample container with a narrow metal spatula. Weigh the amount determined into a tared purge device. Note and record the actual weight to the nearest 0.1 g.

9.4.6.5 Add nanopure water to the purging vial, which contains the weighed amount of sample, and place the vial in the purge-and-trap system.

NOTE: Prior to the placement of the vial, the procedures in Sections 9.4.6.5 must be performed rapidly and without interruption to avoid loss of volatile organics. These steps must be performed in a laboratory free of solvent fumes.

9.4.7 High-concentration method -- The method is based on extracting the sediment/soil with methanol. A waste sample is either extracted or diluted, depending on its solubility in methanol. Wastes (i.e., petroleum and coke wastes) that are soluble in methanol are diluted. An aliquot of the extract is added to organic-free reagent water containing surrogate and internal standards. This may be purged at higher temperatures than ambient temperature as long as all calibration standards, field samples, and associated QC samples are purged at the same temperature and the laboratory demonstrates acceptable method performance. All samples with an expected concentration of >1.0 mg/Kg must be analyzed by this method.

STATE NOTE: This method is not suitable for samples from South Carolina, North Carolina, or Indiana. South Carolina does not recognize the practices in sections 9.4.7.1 and 9.4.7.2 5035 must be used for all high-level soil samples, see ENV-SOP-MTJL-0129.

9.4.7.1 The sample (for volatile organics) consists of the entire contents of the sample container. Do not discard any supernatant liquids. Mix the contents (using slow but precise movement to limit the loss of volatiles) of the sample container with a narrow metal spatula. For sediment/soil and solid wastes that are insoluble in methanol, weigh 10g (wet weight) of sample into a tared 40mL vial. Use a top-loading balance. Note and record the actual weight to 0.1g. For waste that is soluble in methanol, tetraglyme, or PEG, weigh 10g (wet weight) into a 40mL vial.

9.4.7.2 Add 10mL Methanol and vortex. See ENV-SOP-MTJL-0129.

NOTE: Sections 9.4.7.1 and 9.4.7.2 must be performed rapidly and without interruption to avoid loss of volatile organics. These steps must be performed in a laboratory free from solvent fumes.

9.4.7.3 The GC/MS system must be set up as in Sections 9.

9.4.7.4 If a screening procedure was followed, use the estimated concentration to determine the appropriate volume. If the sample was submitted as a high-concentration sample, start with 200µL.

9.4.7.5 In a clean/baked vial filled with reagent water, inject the corresponding aliquot of methanol extract. Immediately cap and place in the autosampler. The autosampler adds 1µL of the IS/surrogate mix to all of the samples.

9.4.7.6 Proceed with the analysis as outlined in Sections 9. Analyze all blanks on the same instrument as that used for the samples.

9.4.7.7 For a matrix spike in the high-concentration of sediment/soil samples, Add a 200µL aliquot of this extract to 5mL of organic-free reagent water for purging (as per Section 9.4.7.6) in a clean/baked 40mL VOA vial and add 20µL spiking solution, 1µL internal and surrogate standard solution (IS/Surr solution added by autosampler).

9.4.7.8 Data generated from soil samples prepared in methanol on Agilent™ 5977A or 5977B instruments (with an extractor ion or high efficiency source) may be reported to low-level MDL/RL values due to the enhanced sensitivity associated with these instruments.

10.0 DATA ANALYSIS AND CALCULATIONS

10.1 Qualitative Identification

The qualitative identification of compounds determined by this method is based on retention time, and on comparison of the sample mass spectrum, after background correction, with characteristic ions in a reference mass spectrum. The reference mass spectrum must be generated by the laboratory using the conditions of this method. All hits must be visually compared to the reference spectrum for confirmation. The characteristic ions from the reference mass spectrum are defined to be the three ions of greatest relative intensity, or any ions over 30% relative intensity if less than three such ions occur in the reference spectrum. Compounds are identified as present when the criteria below are met.

The intensities of the characteristic ions of a compound maximize in the same scan or within one scan of each other. Selection of a peak by a data system target compound search routine where the search is based on the presence of a target chromatographic peak containing ions specific for the target compound at a compound-specific retention time is accepted as meeting this criterion.

The RRT of the sample component is within + 0.06 RRT units of the RRT of the standard component.

The relative intensities of the characteristic ions agree within 30% of the relative intensities of these ions in the reference spectrum. (Example: For an ion with an abundance of 50% in the reference spectrum the corresponding abundance in a sample spectrum can range between 20% and 80%.)

Structural isomers that produce very similar mass spectra are identified as individual isomers if they have sufficiently different GC retention times. Sufficient GC resolution is achieved if the height of the valley between two isomer peaks is less than 25% of the sum of the two peak heights. Otherwise, structural isomers are identified as isomeric pairs.

Identification is hampered when sample components are not resolved chromatographically and produce mass spectra containing ions contributed by more than one analyte. When gas chromatographic peaks obviously represent more than one sample component (i.e., a broadened peak with shoulder(s) or a valley between two or more maxima), appropriate selection of analyte spectra and background spectra are important. Examination of extracted ion current profiles of appropriate ions can aid in the selection of spectra, and in qualitative identification of compounds. When analytes co-elute (i.e., only one chromatographic peak is apparent), the identification criteria can be met, but each analyte spectrum contains extraneous ions contributed by the co-eluting compound.

10.1.1 Tentatively Identified Compounds (TICS)

TIC's - Tentatively Identified Compounds

Periodically, clients may request additional identification of compounds that are not normally calibrated. This identification is limited to the compounds in the current mass spectral library employed by Pace National.

For samples containing components not associated with the calibration standards, a library search may be made for the purpose of tentative identification. The necessity to perform this type of identification is determined by the type of analyses being conducted. At the client request, when serving the role of QA (or referee) laboratory, tentatively identified compounds (TICs) must always be reported. Guidelines for making tentative identification are:

(1) Relative intensities of major ions in the reference spectrum (ions >10% of the most abundant ion) should be present in the sample spectrum.

(2) The relative intensities of the major ions should agree within 15% to be consistent with target compound list identification. (Example: For an ion with an abundance of 50% in the standard spectrum the corresponding sample ion abundance must be between 20 and 80%).

(3) Molecular ions present in the reference spectrum should be present in the sample spectrum.

(4) Ions present in the sample spectrum but not in the reference spectrum should be reviewed for possible background contamination or presence of co-eluting compounds.

(5) Ions present in the reference spectrum but not in the sample spectrum must be reviewed for possible subtraction from the sample spectrum because of background contamination or co-eluting peaks. Data system library reduction programs can sometimes create these discrepancies.

Computer generated library search routines must not use normalization routines that would misrepresent the library or unknown spectra when compared to each other. Only after visual comparison of sample with the nearest library searches does the mass spectral interpretation specialist assign a tentative identification.

10.1.1.1 Routinely, Pace National employs a minimum Q value of 85% for tentative identifications and a minimum concentration of 10ppb. Peaks below a Q value of 85% but above 10ppb may be reported as “Unknown”. Any identified peaks below 10ppb are removed as these could result from baseline noise or other interferences, not necessarily attributable to the field sample or reliably quantifiable using GCMS technology. Additionally, any peaks that are attributable to instrument contamination (e.g., siloxanes) are also removed.

10.1.1.2 If multiple TICs, with same exact name, exist for a sample, the LIMS will only display the TIC with the highest quality match per sample.

10.1.1.3 TIC names assigned as “Unknown” may initially have the same name as another “Unknown” until parsed and displayed in LIMS where it is given a hyphen and incremental number which then becomes a unique TIC (e.g., Unknown-1).

10.1.1.4 When reporting “Total TIC” for any client sample, only concentrations per above requirements will be used to sum the Total TIC concentration.

10.1.2 Manual Integration

Manual changes to automated integration are called manual integration. Manual integration is sometimes necessary to correct inaccurate automated integrations but must never be used to meet QC criteria or to substitute for proper instrument maintenance and/or method set-up. To assure that all manual integrations are performed consistently and are ethically justified, all manual integrations must be performed, reviewed, and recorded in accordance with corporate SOP ENV-SOP-CORQ-0006, *Manual Integration.*

10.2 Quantitative Identification

When a compound has been identified, the quantitation of that compound is based on the integrated abundance from the EICP of the primary characteristic ion. Quantitation is accomplished using the internal standard technique, as described in Section 9. The internal standard used must be the one nearest the retention time of that of a given analyte.

Sediment/soil samples are reported on a dry weight basis, while sludge and wastes are reported on a wet weight basis. The percent dry weight of the sample (see Section 9.7) must be reported along with the data in either instance. At Pace National, the dry weight conversion calculations for sample reporting are performed by the LIMS system. [Dry weight only when requested]. The LIMS Final Client Report represents the reporting basis as either wet weight or dry weight, depending upon the calculation used.

10.2.1 Concentration of Target Analytes in Water and Water-Miscible Waste

$$\text{Concentration}(\text{ug}/\text{L}) = \frac{(A_x)(I_s)(D)}{(A_{is})(\text{ave.RF})(V_s)}$$

where:
A_x = Area (or height) of the peak for the analyte in the sample.
A_{is} = Area (or height) of the peak for the internal standard.
I_s = Mass (amount) of the internal standard in the concentrated sample extract (ng). This is not just the mass injected into the instrument, but the total mass of internal standard in the concentrated extract.
D = Dilution factor if the sample or extract was diluted prior to analysis. If no dilution was made, D = 1. The dilution factor is always dimensionless.
ave.RF = Mean response factor from the initial calibration.
V_s = Volume of the aqueous sample extracted or purged (mL). If units of liters are used for this term, multiply the results by 1000.

10.2.2 Concentration of Target Analytes in Sediment/Soil, Sludge, and Waste

10.2.2.1 High-concentration procedure

$$\text{Concentration}(\text{ug}/\text{L}) = \frac{(A_x)(I_s)(V_t)}{(A_{is})(\text{ave.RF})(V_i)(W_s)}$$

where:
A_x, I_s, A_{is}, ave.RF are the same as in water and water-miscible waste above.
Vt = Volume of total extract (µL) (use 10,000µL or a factor of this when dilutions are made).
Vi= Volume of extract added (µL) for purging.
Ws = Weight of sample extracted or purged (g). The wet weight or dry weight may be used, depending upon the specific applications of the data.

10.2.2.2 Low-concentration procedure

$$\text{Concentration}(\text{ug}/\text{L}) = \frac{(A_x)(I_s)(V_t)}{(A_{is})(\text{ave.RF})(V_i)(W_s)}$$

where:

A, I_s, A_{is}, RF are the same as in water and water-miscible waste above.

V_t = Volume of total extract (µL) (use 10,000µL or a factor of this when dilutions are made).

V_i = Volume of extract added (µL) for purging.

W_s = Weight of sample extracted or purged (g). The wet weight or dry weight may be used, depending upon the specific applications of the data.

10.2.2.3 Soil Weight determination with Methanol (samples received with MeOH).

$$\text{SoilWeight} = \text{VialTotalWeight}(\text{vial, soil, MeOH}) - \text{TareVialWeight} - \text{MeOHWeight}.$$

10.2.3 In order to report results for volatiles analysis of samples prepared in methanol containing significant moisture (>10%) content on an "as received" basis, the calculated concentration needs to be corrected using the total solvent/water mixture volume represented as Vt. This total solvent/water volume is calculated as follows:

$$\mu\text{L solvent/water } V_t = \left[\frac{\text{mL of solvent} + (\%\text{ moisture} \times \text{g of sample})}{100}\right] \times 1000\ \mu\text{L/mL}$$

10.2.4 Percent Error (%Error)

$$\%Error = \frac{x_i - x'_i}{x_i} * 100$$

where:

x'_i = Measured amount of analyte at the calibration level *i*, in mass or concentration units

x_i = True amount of analyte at calibration level *i*, in mass or concentration units

10.2.5 Relative Standard Error (%RSE) – As an alternative to using the average response factor when using Method 624.1, the quality of the calibration may be evaluated using the Relative Standard Error (RSE). The acceptance criterion for the RSE is the same as the acceptance criterion for Relative Standard Deviation (RSD), in the method. RSE is calculated as:

$$\%RSE = 100 \times \frac{\sum_{i=1}^{n}\left[\frac{x'_i - x_i}{x_i}\right]^2}{(n-p)}$$

where:

x'i = Calculated concentration at level i

xi = Actual concentration of the calibration level i

n = number of calibration points

p = Number of terms in the fitting equation (average = 1; linear = 2; quadratic = 3)

10.3 Calculations

See the Laboratory Quality Assurance Manual for equations for common calculations.

11.0 QUALITY CONTROL AND METHOD PERFORMANCE

11.1 Quality Control

The following QC samples are prepared and analyzed with each batch of samples. Refer to Appendix B for acceptance criteria and required corrective action.

QC Item	Frequency
Method Blank (MB)	1 per batch of 20 or fewer samples. If batch exceeds, 20 samples, every 20.
Laboratory Control Sample (LCS)	1 per batch of 20 or fewer samples. If batch exceeds, 20 samples, every 20.
Laboratory Control Sample Duplicate (LCSD)	As needed
Matrix Spike (MS)	1 per batch of 20 or fewer samples. If batch exceeds, 20 samples, every 20.
Matrix Spike Duplicate (MSD)	1 per batch of 20 or fewer samples. If batch exceeds, 20 samples, every 20.
Sample Duplicate	Not required for this method
Trip Blank	As requested by client
Surrogate	All field and QC samples
Internal Standard	All field and QC samples

11.2 Instrument QC

The following Instrument QC checks are performed. Refer to Appendix B for acceptance criteria and required corrective action.

QC Item	Frequency
Tune	Prior to ICAL and every 12-hour period of sample analysis
Initial Calibration	At instrument setup and prior to sample analysis
Initial Calibration Verification	After each ICAL prior to sample analysis
Initial Calibration Blank	After each ICAL prior to sample analysis and as needed
Continuing Calibration Verification	Daily before analysis, after every 12-hour period of sample analysis and at the end of the analytical sequence
Continuing Calibration Blank	After each CCV and as needed to verify the system is contamination free
RT Window	Once per ICAL and at the beginning of the analytical sequence
Relative Retention Time	With each sample
Breakdown Check	Not required for this method

11.3 Method Performance

11.3.1. Method Validation

11.3.1.1 Detection Limits**11.3.1.2** Method 624.1 Requirements

11.3.1.2.1 Establish MDLs for the analytes of interest using the MDL procedure at 40 CFR part 136, appendix B. The laboratory's MDLs must be equal to or lower than those listed in Table 1 for those analytes which list MDL values, or lower than one-third the regulatory compliance limit, whichever is greater. For MDLs not listed in Table 1, the laboratory must determine the MDLs using the MDL procedure at 40 CFR part 136, appendix B under the same conditions used to determine the MDLs for the analytes listed in Table 1. All procedures used in the analysis must be included in the DOC.

624.1 Purgeable Analytes	MDL (ug/L)	Limit for s (%)	Range for $\overline{X}$ (%)
Acrolein		30	50-150
Acrylonitrile		30	50-150
Benzene	4.4	33	75-125
Bromodichloromethane	2.2		
Bromoform	4.7		
Bromomethane		90	D-242
Carbon tetrachloride	2.8	26	65-125
Chlorobenzene	6.0	29	82-137
Chloroethane		47	42-202
2-Chloroethylvinyl ether		130	D-252
Chloroform	1.6	32	68-121
Chloromethane		472	D-230
Dibromochloromethane	3.1	30	69-133
1,2-Dichlorobenzene		31	59-174
1,3-Dichlorobenzene		24	75-144
1,4-Dichlorobenzene		31	59-174
1,1-Dichloroethane	4.7	24	71-143
1,2-Dichloroethane	2.8	29	72-137
1,1-Dichloroethene	2.8	40	19-212
trans-1,2-Dichloroethene	1.6	27	68-143
1,2-Dichloropropane	6.0	69	19-181
cis-1,3-Dichloropropene	5.0	79	5-195
trans-1,3-Dichloropropene		52	38-162
Ethylbenzene	7.2	34	75-134
Methylene chloride	2.8	192	D-205
1,1,2,2-Tetrachloroethane	6.9	36	68-136
Tetrachloroethene	4.1	23	65-133
Toluene	6.0	22	75-134
1,1,1-Trichloroethane	3.8	21	69-151
1,1,2-Trichloroethane	5.0	27	75-136
Trichloroethene	1.9	29	75-138
Trichlorofluoromethane		50	45-158
Vinyl chloride		100	D-218

11.3.1.3 Prepare and analyze four LCSs by adding an appropriate volume of the second source standard (Section 7.5.2.1) to each of four aliquots of reagent water.

11.3.1.4 Calculate the average percent recovery ($\overline{X}$) and the standard deviation of the percent recovery (s) for each analyte using the four results.

11.3.1.5 For each analyte, compare s and $\overline{X}$ with the corresponding acceptance criteria for precision and recovery in Section 10.1.1.1. For analytes not listed, DOC QC acceptance criteria must be developed by the laboratory. Alternatively, acceptance criteria for analytes not listed may be based on laboratory control charts. If s and $\overline{X}$ for all analytes of interest meet the acceptance criteria, system performance is acceptable, and analysis of blanks and samples may begin. If any individual s exceeds the precision limit or any individual $\overline{X}$ falls outside the range for recovery, system performance is unacceptable for that analyte.

NOTE: The large number of analytes present, a substantial probability that one or more will fail at least one of the acceptance criteria when many or all analytes are determined simultaneously. Therefore, the analyst is permitted to conduct a ‘‘re-test’’ as described here.

When one or more of the analytes tested fail at least one of the acceptance criteria, repeat the test for only the analytes that failed. If results for these analytes pass, system performance is acceptable, and analysis of samples and blanks may proceed. If one or more of the analytes again fail, system performance is unacceptable for the analytes that failed the acceptance criteria. Correct the problem and repeat the test. To maintain the validity of the test and re-test, system maintenance and/or adjustment is not permitted between this pair of tests.

11.3.1.6 Batches

11.3.1.6.1 Extraction Batches:

Extraction batches are defined as sets of 1 - 20 samples. Extraction batches must include the following: 1 method blank, 1 Laboratory Control Sample (LCS)), 1 Matrix Spike/Spike Duplicate (MS/MSD) pair (if sufficient sample is available). Exceptions are made for waste dilution samples where the minimum batch QC must include a blank, and an LCS.

Additional instructions on Batch QC including required frequency and corrective actions can be found in Section 12 while acceptance criteria are found in the LIMS.

STATE NOTE: For samples from FL, AZ, MN, and MA, 1 Laboratory Control Sample/Laboratory Control Sample Duplicate pair (LCS/LCSD) is required per batch.

11.3.1.6.2 Analytical Batches (sequences):

Analytical batches analysis must include the following: 1 Initial Calibration Verification (ICV) and BFB tune at the beginning of run, and/or 1 Continuing Calibration Verification (CCV) and BFB tune every 12 hours.

11.3.1.7 Perform BFB tune every 12 hours for 624.1, 8260B, 8260C, and 6200B. BFB tuning for method 8260D is prior to calibration curve. Tuning acceptance criteria are presented in Section 9.1.2.1.4. Once the data is acquired, the following options are available for acquiring the spectra for reference to meet the BFB tuning requirements. It is recommended that each initial tune verification utilize the “Autofind” function and be set up to look at three scans (the apex &+1 scan) and average the three scans then perform background subtraction. If Autofind is not utilized, select the mass spectrum at the peak apex for evaluation, or use an average mass spectrum across the entire BFB peak. Background subtraction is conducted using a single scan prior to the elution of BFB but no more than 20 scans prior. No part of the BFB peak or any other discrete peak should be subtracted.

If a tune cannot be achieved that meets the criteria in Section 9.1.2.1.4 retune the mass spectrometer and run a new calibration or maintenance may be necessary.

11.3.1.7.1 Method 624.1 Requirements

11.3.1.7.1.1 Verify calibration after the criteria for BFB are met and prior to analysis of a blank or sample. After verification, analyze a blank to demonstrate freedom from contamination and carry-over at the MDL. Tests for BFB, the CCV, and the blank are outside of the 12-hour shift, and the 12-hour shift includes samples and matrix spikes and matrix spike duplicates. The total time for analysis of BFB, the CCV, the blank, and the 12-hour shift must not exceed 14 hours.

11.3.1.8 Run a minimum of a 5-point initial calibration curve (3-point can be used if 624/6200B are being run independently of 8260B), using the primary source standards each time major instrument maintenance occurs, or if the CCV does not meet acceptance criteria. Acceptance criteria for initial calibration are presented in Section 9.2. Calibration is verified by analyzing Second Source Calibration Verification (SSCV) standard; acceptance criteria for the SSCV are presented in Section 9.2.3.3.1.

11.3.1.8.1 Method 624.1

If the RSD is less than 35%, the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to fit a linear or quadratic regression of response ratios vs. concentration ratios. If used, the regression must be weighted inversely proportional to concentration. The coefficient of determination (R2) of the weighted regression must be greater than 0.920 (this value roughly corresponds to the RSD limit of 35%). Alternatively, the relative standard error may be used as an acceptance criterion.

As with the RSD, the RSE must be less than 35%. If an RSE less than 35% cannot be achieved for a quadratic regression, system performance is unacceptable, and the system must be adjusted and re-calibrated.

STATE NOTE: South Carolina does not allow the use of quadratic regression for compounds that have previously demonstrated linearity.

11.3.1.9 Run a mid-point Continuing Calibration Verification (CCV) using the primary source standards every 12 hours before sample analysis and every 12 hours during an analytical sequence for 8260B, 8260C, 8260D, 624.1 and 6200B. See sections 9.2.4-9.2.4.5 for acceptance criteria.

11.3.1.10 Retention Time Evaluation

11.3.1.10.1 Internal standard retention time - The retention times of the internal standards in the calibration verification standard must be evaluated immediately after or during data acquisition. If the retention time for any internal standard changes by more than 10 seconds from that in the mid-point standard level of the most recent initial calibration sequence, then the chromatographic system must be inspected for malfunctions and corrections must be made, as required. When corrections are made, reanalysis of samples analyzed while the system was malfunctioning is required.

11.3.1.10.2 Evaluation of retention times - The relative retention time (RRT) of each target analyte in each calibration standard should agree within 0.06 RRT units. Late-eluting target analytes usually have much better agreement.

11.3.1.11 Instrument maintenance must be performed routinely to optimize instrument performance and improve chromatography. Commonly performed maintenance includes baking traps and columns, polishing detector windows, changing injection port liners, changing pump oil, etc. A new calibration curve must be analyzed following any major maintenance performed on the analytical system.

11.3.1.12 METHOD BLANK - The analyst must confirm that this blank was analyzed at the required frequency of 1 per batch of 20 samples. The method blank must not exhibit any contamination of any analyte above the method detection limit for any of the method target analytes.

11.3.1.12.1 If more than one instrument blank or method blanks are analyzed, evaluate, and assess the blank and field samples under the same conditions for possible mid-level standard carryover using the subsequent blank after the mid-level standard on a per analyte basis.

11.3.1.12.2 Method 624.1 – If any analyte of interest is found in the blank at a concentration greater than the MDL for the analyte, at a concentration greater than one-third the regulatory compliance limit, or at a concentration greater than one-tenth the concentration in a sample analyzed during the 12-hour shift, whichever is greater; analysis of samples must be halted, and samples affected by the blank must be re-analyzed. If, however, continued re-testing results in repeated blank contamination, the laboratory must document and report the failures (e.g., as qualifiers on results), unless the failures are not required to be reported as determined by the regulatory/control authority. Results associated with blank contamination for an analyte regulated in a discharge cannot be used to demonstrate regulatory compliance.

11.3.1.13 LABORATORY CONTROL SAMPLES - Assess that the LCS was prepared at the required frequency of 1 per batch of 20. If the same injection is used for the LCS and the CCV, ensure that no more than 20 samples are analyzed in conjunction. Routine LCS Control limits are presented in the LIMS.

STATE NOTE: For all samples analyzed from South Carolina, the LCS/LCSD RPD must be <20%, recoveries must be 70-130% in a soil matrix, and recoveries must be within the following limits in a water matrix:

Benzene	70 – 130%
Bromodichloromethane	70 – 130%
Bromoform	70 – 130%
Bromomethane	70 – 130%
Carbon tetrachloride	70 – 130%
Chlorobenzene	70 – 130%
Chloroethane	70 – 130%
2-Chloroethyl vinyl ether	70 – 130%
Chloroform	70 – 130%
Chloromethane	70 – 130%
Dibromochloromethane	70 – 130%
Dichlorodifluoromethane	70 – 130%
1,2-Dichlorobenzene	70 – 130%
1,3-Dichlorobenzene	70 – 130%
1,4-Dichlorobenzene	70 – 130%
1,1-Dichloroethane	70 – 130%
1,2-Dichloroethane	70 – 130%
1,1-Dichloroethene	70 – 130%
Trans-1,2-Dichloroethene	70 – 130%
1,2-Dichloropropane	70 – 130%
Cis-1,3-Dichloropropene	70 – 130%
Trans-1,3-Dichloropropene	70 – 130%
Ethyl benzene	70 – 130%
Methylene chloride	70 – 130%
Methyl tert-butyl ether	70 – 130%
1,1,2,2-Tetrachloroethane	70 – 130%
Tetrachloroethene	70 – 130%
Toluene	70 – 130%
1,1,1-Trichloroethane	70 – 130%

1,1,2-Trichloroethane	70 – 130%
Trichloroethene	71 – 130%
Trichlorofluoromethane	70 – 130%
Vinyl chloride	70 – 130%
Xylenes, total	70 – 130%

11.3.1.14 Method 624.1 Requirements

11.3.1.14.1 Compare the percent recovery (Q) for each analyte with its corresponding QC acceptance criterion in the following table. For analytes of interest not listed in the following table, use QC acceptance criteria developed for the LCS. If the recoveries for all analytes of interest fall within their respective QC acceptance criteria, analysis of blanks and field samples may proceed. If any individual Q falls outside the range, proceed according to Section 8.3.5.1.4.

624.1 Purgeable Analytes	Range for Q (%)
Acrolein	60-140
Acrylonitrile	60-140
Benzene	65-135
Bromodichloromethane	65-135
Bromoform	70-130
Bromomethane	15-185
Carbon tetrachloride	70-130
Chlorobenzene	65-135
Chloroethane	40-160
2-Chloroethylvinyl ether	D-225
Chloroform	70-135
Chloromethane	D-205
Dibromochloromethane	70-135
1,2-Dichlorobenzene	65-135
1,3-Dichlorobenzene	70-130
1,4-Dichlorobenzene	65-135
1,1-Dichloroethane	70-130
1,2-Dichloroethane	70-130
1,1-Dichloroethene	50-150
trans-1,2-Dichloroethene	70-130
1,2-Dichloropropane	35-165
cis-1,3-Dichloropropene	25-175
trans-1,3-Dichloropropene	50-150
Ethylbenzene	60-140
Methylene chloride	60-140
1,1,2,2-Tetrachloroethane	60-140
Tetrachloroethene	70-130
Toluene	70-130
1,1,1-Trichloroethane	70-130
1,1,2-Trichloroethane	70-130
Trichloroethene	65-135
Trichlorofluoromethane	50-150
Vinyl chloride	5-195

11.3.1.14.2 Repeat the test only for those analytes that failed to meet the acceptance criteria (Q). If these analytes now pass, system performance is acceptable, and analysis of blanks and samples may proceed. Repeated failure, however, will confirm a general problem with the measurement system. If this occurs, repeat the test using a fresh LCS or an LCS prepared with a fresh QC check sample concentrate, or perform and document system repair. Subsequent to repair, repeat the calibration verification/LCS test. If the acceptance criteria for Q cannot be met, re-calibrate the instrument. To maintain the validity of the test and re-test, system maintenance and/or adjustment is not permitted between the pair of tests

11.3.1.15 MATRIX SPIKE/MATRIX SPIKE DUPLICATE ASSESSMENT: Assess that matrix spike/matrix spike duplicates were analyzed at required frequency of 1 per batch of 20 if volume allows.

- The analyst also verifies that the samples were spiked at the appropriate level.
- The order of preference for spiking levels is as follows:

1) If the target analyte concentrations are known, spike to increase the background concentration by a factor of approximately two
2) If an action level exists, spike at this level
3) If neither of the first two conditions applies, spike at a level that corresponds between the low and mid-level calibration standards.
4) All RPD results must be within the indicated control limits found in the LIMS.

Acceptance criteria are that all %Recovery and/or RPD results must be within the indicated control limits on the appropriate MS control charts. See the LIMS for LCS/LCSD & MS/MSD limits and QC acceptance.

STATE NOTE: For all water samples analyzed from South Carolina, the MS/MSD recoveries must be within the most stringent limits comparing in-house derived recovery limits to those given in Table 3 of Method 608. The following are the current water limits:

Benzene	58.6 - 133%
Bromodichloromethane	69.2 – 127%
Bromoform	66.3 – 140%
Bromomethane	16.6 – 183%
Carbon tetrachloride	70 – 139%
Chlorobenzene	70.1 – 130%
Chloroethane	33.3 – 155%
2-Chloroethyl vinyl ether	5 – 149%
Chloroform	66.1 – 133%

Chloromethane	40.7 – 139%
Dibromochloromethane	69.2 – 127%
Dichlorodifluoromethane	42.2 – 146%
1,2-Dichlorobenzene	77.4 – 127%
1,3-Dichlorobenzene	67.9 – 136%
1,4-Dichlorobenzene	74.4 – 123%
1,1-Dichloroethane	64 – 134%
1,2-Dichloroethane	60.7 – 132%
1,1-Dichloroethene	48.8 – 144%
Trans-1,2-Dichloroethene	61 – 132%
1,2-Dichloropropane	69.7 – 132%
Cis-1,3-Dichloropropene	71.1 – 129%
Trans-1,3-Dichloropropene	66.3 – 136%
Ethyl benzene	62.7 – 136%
Methylene chloride	61.5 – 125%
Methyl tert-butyl ether	61.4 – 136%
1,1,2,2-Tetrachloroethane	64.9 – 145%
Tetrachloroethene	64 – 141%
Toluene	67.8 – 124%
1,1,1-Trichloroethane	58.7 – 134%
1,1,2-Trichloroethane	74.1 – 130%
Trichloroethene	71 – 148%
Trichlorofluoromethane	39.9 – 165%
Vinyl chloride	44.3 – 143%
Xylenes, total	65.6 – 133%

11.3.1.16 Method 624.1 Requirements

11.3.1.16.1 Spike at least 5% of the samples in duplicate from each discharge being monitored to assess accuracy (recovery and precision). If direction cannot be obtained from the data user, the laboratory must spike at least one sample in duplicate per extraction batch of up to 20 samples with the analytes in the table in Section 11.3.1.1.1. Spiked sample results should be reported only to the data user whose sample was spiked, or as requested or required by a regulatory/control authority, or in a permit.

11.3.1.16.2 If the concentration of a specific analyte will be checked against a regulatory concentration limit, the concentration of the spike should be at that limit; otherwise, the concentration of the spike should be one to five times higher than the background concentration, at or near the mid-point of the calibration range, or at the concentration in the LCS whichever concentration would be larger.

11.3.1.16.3 Compare the percent recoveries (P1 and P2) and the RPD for each analyte in the MS/MSD aliquots with the corresponding QC acceptance criteria in the following table. A laboratory may develop and apply QC acceptance criteria more restrictive than the presented criteria if desired.

624.1 Purgeable Analytes	Range for P1, P2 (%)	Limit for RPD
Acrolein	40-160	60
Acrylonitrile	40-160	60
Benzene	37-151	61
Bromodichloromethane	35-155	56
Bromoform	45-169	42
Bromomethane	D-206	61
Carbon tetrachloride	70-140	41
Chlorobenzene	37-160	53
Chloroethane	14-230	78
2-Chloroethylvinyl ether	D-305	71
Chloroform	51-138	54
Chloromethane	D-273	60
Dibromochloromethane	53-149	50
1,2-Dichlorobenzene	18-190	57
1,3-Dichlorobenzene	59-156	43
1,4-Dichlorobenzene	18-190	57
1,1-Dichloroethane	59-155	40
1,2-Dichloroethane	49-155	49
1,1-Dichloroethene	D-234	32
trans-1,2-Dichloroethene	54-156	45
1,2-Dichloropropane	D-210	55
cis-1,3-Dichloropropene	D-227	58
trans-1,3-Dichloropropene	17-183	86
Ethylbenzene	37-162	63
Methylene chloride	D-221	28
1,1,2,2-Tetrachloroethane	46-157	61
Tetrachloroethene	64-148	39
Toluene	47-150	41
1,1,1-Trichloroethane	52-162	36
1,1,2-Trichloroethane	52-150	45
Trichloroethene	70-157	48
Trichlorofluoromethane	17-181	84
Vinyl chloride	D-251	66

11.3.1.16.4 If any individual P falls outside the designated range for recovery in either aliquot, or the RPD limit is exceeded, the result for the analyte in the unspiked sample is suspect.

11.3.1.16.5 If in-house QC limits are developed, at least 80% of the analytes tested in the MS/MSD must have in-house QC acceptance criteria that are tighter than those in Section 10.10.1.3 and the remaining analytes (those other than the analytes included in the 80%) must meet the acceptance criteria in Section 11.3.1.1.1. If an in-house QC limit for the RPD is greater than the limit in Section 10.10.1.3, then the limit in the table must be used. Similarly, if an in-house lower limit for recovery is below the lower limit in Section 11.3.1.1.1, then the lower limit in the table must be used, and if an in-house upper limit for recovery is above the upper limit in Section 11.3.1.1.1, then the upper limit in the table must be used.

11.3.1.17 SURROGATE EVALUATION: Check the surrogate calculations for correctness for all samples, blanks, ICV/CCV/SSCV, LCS/LCSD, MS and MSD. Acceptance criteria can be found in the LIMS: The surrogate recoveries for all QC samples must be within established control limits.

11.3.1.17.1 Method 624.1 – Spike the surrogates into all samples, blanks, LCSs, and MS/MSDs. Compare surrogate recoveries against limits must be developed by the laboratory. In-house QC acceptance criteria must be updated at least every two years. If any recovery fails its criteria, attempt to find, and correct the cause of the failure.

11.3.1.18 INTERNAL STANDARD AREA COUNT: When a calibration is performed at the beginning of an analytical run, the internal standard areas must be evaluated against the mid-point of the curve. Internal standard responses must be -50% to 200% to be acceptable. Samples are analyzed within a 12-hour window; the internal standards of those samples are evaluated against mid-point of the curve. Then a CCV is analyzed, this is compared to the mid-point of the initial calibration curve. Addition samples are analyzed within a 12-hour window; the internal standards of those samples are evaluated against the previous acceptable CCV. When an analytical run is started using a passing ICV (which is compared against the initial calibration mid-point to verify the calibration curve): Samples are analyzed within a 12-hour window, the internal standards of those samples are evaluated against the daily CCV. Then a CCV is analyzed, this is compared to the mid-point of the curve. Additional samples are analyzed within a 12-hour window; the internal standards of those samples are evaluated against the previous acceptable CCV.

CLIENT NOTE: For Marathon, the internal standard area counts for all calibration standards, QC samples, and samples for quantitation must not change by a factor of greater than (-50% to +130%) as per section 9.2.4

11.3.1.18.1 Method 624.1 – The responses of each internal standard in each sample, blank, and MS/MSD must be within 50% to 200% (1/2 to 2×) of its respective response in the mid-point calibration standard. If, as a group, all internal standards are not within this range, perform and document system repair, repeat the calibration verification/LCS test, and re-analyze the affected samples. If a single internal standard is not within the 50% to 200% range, use an alternative internal standard for quantitation of the analyte referenced to the affected internal standard. It may be necessary to use the data system to calculate a new response factor from calibration data for the alternative internal standard/analyte pair. If an internal standard fails the 50–200% criteria and no analytes are detected in the sample, ignore the failure, or report it if required by the regulatory/control authority.

11.3.1.19 SECOND SOURCE: The second source calibration verification or initial calibration verification standard must be analyzed following each new initial calibration to verify the validity of the calibration standards. The recovery of the analytes in the SSCV (ICV) must be within 30% of the expected concentration for CCC and SPCC compounds and within 40% for non-CCC/SPCC compounds. Poor performers listed in section 9.2.4.7 must recover within in-house calculated LCS recovery acceptance limits.

STATE NOTE: For all samples analyzed from South Carolina, the SSCV must recover ±30% for all target analytes.

STATE NOTE: For all samples analyzed from Minnesota, the reporting limit must be verified at least monthly. The reporting limit verification (RLV) must recovery within ±40% of the expected concentration. If these criteria are not met, the RLV may be re-analyzed once, instrument maintenance can be performed, or a higher concentration standard can be analyzed. If a higher concentration standard is utilized, the reporting limit must be raised to the higher level verified.

11.3.1.19.1 Method 624.1 Calibration verification/LCS—The working calibration curve or RF must be verified immediately after calibration and at the beginning of each 12-hour shift by the measurement of an LCS. The LCS must be from a source different from the source used for calibration, but may be the same as the sample prepared for the DOC.

11.3.1.20 The laboratory participates in semi-annual proficiency testing that meets and/or exceeds the requirements of the Quality Control Sample as listed in the published Standard Method SM 6200B-2011, *Volatile Organic Compounds,* and SM 6020-2011, *Quality Assurance/Quality Control*.

11.3.1.21 For sample analyzed per the requirements of Method 8000D, the LLOQ (see Section 12.7.1) must be verified at least annually, and whenever significant changes are made to the preparation and/or analytical procedure, to demonstrate quantitation capability at lower analyte concentration levels.

11.3.1.21.1 The LLOQ verification (to be performed after the initial calibration) is prepared by spiking a clean control material with the analyte(s) of interest at 0.5-2 times the LLOQ concentration level(s).

11.3.1.21.2 The LLOQ check is carried through the same preparation and analytical procedures as environmental samples and other QC samples.

11.3.1.21.3 It is recommended to analyze the LLOQ verification on every instrument where data is reported; however, at a minimum, the lab must rotate the verification among similar analytical instruments such that all are included within three (3) years.

11.3.1.21.4 Recovery of target analytes in the LLOQ verification must be within established in-house limits or within other such project-specific acceptance limits to demonstrate acceptable method performance at the LLOQ. Until the laboratory has sufficient data to determine acceptance limits, the LCS criteria ± 20% (i.e., lower limit minus 20% and upper limit plus 20%) may be used for the LLOQ acceptance criteria.

12.0 DATA REVIEW AND CORRECTIVE ACTION

12.1 Data Review

Pace's data review process includes a series of checks performed at different stages of the analytical process by different people to ensure that SOPs were followed, the analytical record is complete and properly documented, proper corrective actions were taken for QC failure and other nonconformance(s), and that test results are reported with proper qualification.

The review steps and checks that occur as employee's complete tasks and review their own work is called primary review.

All data and results are also reviewed by an experienced peer or supervisor. Secondary review is performed to verify SOPs were followed, that calibration, instrument performance, and QC criteria were met and/or proper corrective actions were taken, qualitative ID and quantitative measurement is accurate, all manual integrations are justified and documented in accordance with the Pace ENV's SOP for manual integration, calculations are correct, the analytical record is complete and traceable, and that results are properly qualified.

A third-level review, called a completeness check, is performed by reporting or project management staff to verify the data report is not missing information and project specifications were met.

Refer to laboratory SOP ENV-SOP-MTJL-0038, *Data Review* for specific instructions and requirements for each step of the data review process.

12.2 Corrective Action

Corrective action is expected any time QC or sample results are not within acceptance criteria. If corrective action is not taken or was not successful, the decision/outcome must be documented in the analytical record. The primary analyst has primary responsibility for taking corrective action when QA/QC criteria are not met. Secondary data reviewers must verify that appropriate action was taken and/or that results reported with QC failure are properly qualified.

Corrective action is also required when carryover is suspected and when results are over range.

Samples analyzed after a high concentration sample must be checked for carryover and reanalyzed if carryover is suspected. Carryover is usually indicated by low concentration detects of the analyte in successive samples analyzed after the high concentration sample.

Sample results at concentrations above the upper limit of quantitation must be diluted and reanalyzed. The result in the diluted samples should be within the upper half of the calibration range. Results less than the mid-range of the calibration indicate the sample was over diluted and analysis should be repeated with a lower level of dilution. If dilution is not performed, any result reported above the upper range is considered a qualitative measurement and must be qualified as an estimated value.

Refer to Appendix B for a complete summary of QC, acceptance criteria, and recommended corrective actions for QC associated with this test method.

12.3 SITE-SPECIFIC requirements and STATE SPECIFIC criteria must be reviewed and used, if known, for data review.

12.4 All data must undergo a primary review by the analyst. The analyst must check the performance of the initial calibration, mid-point check standard, and continuing calibrations to ensure that they meet the criteria of the method. The analyst must review any sample that has quantifiable compounds and make sure that they have been confirmed. The analyst must also verify that reported results are derived from quantitation between the MDL and the highest standard of the initial calibration curve. All calculations must be checked (any dilutions, %solids, etc.). Data must be checked for the presence or absence of appropriate flags. Comments must be noted when data is flagged.

12.5 Tune Check - A successful BFB tune must be achieved prior to initial calibration or daily calibration verification. If a tune does not meet the acceptance criteria detailed above, then re-inject the tuning solution. If the failure persists, instrument maintenance or detector adjustment is required. The instrument is equipped with detector adjustments in routines called “Autotunes” that can make minor adjustments to m/z ratios and detector setting and can align the analytical system to return the system to peak performance. If after performing the Autotune routine, the injected tuning standard still fails, the system may require injector and/or detector cleaning, column cutting or replacement, injection liner cleaning or replacement, or other maintenance as specified by the manufacturer.

12.6 INITIAL AND CONTINUING CALIBRATION VERIFICATION STANDARD: An Initial Calibration Verification (ICV) standard is analyzed before sample analysis can begin and a continuing calibration verification (CCV) standard was analyzed every 12 hours and meets the criteria in Section 9.0. If these criteria are exceeded and analysis of a second consecutive (immediate) calibration verification fails to produce results within acceptance criteria, corrective actions shall be performed. The laboratory shall demonstrate acceptable performance after the final round of corrective action with two consecutive calibration verifications, or a new initial instrument calibration shall be performed.

Method 8000D: To determine calibration function acceptability, refit the initial calibration data back to the calibration model and calculate %Error (see Section 10.2.4). Percent error between the calculated and expected amounts of an analyte must be $\leq$30% for all standards. For some data uses, $\leq$50% may be acceptable for the lowest calibration point.

12.7 METHOD BLANK: Blank contamination above the report limit – All samples containing detectable amounts above the reporting limit must be re-analyzed or qualified. Samples with no detectable amounts above the reporting limit do not require re-analysis, but the samples must be qualified with blank contamination and it must be mentioned in the case narrative in the data package.

General guidelines for qualifying sample results with regard to method blank quality are as follows:

- If the method blank concentration is less than the MDL and sample results are greater than the RL, then no qualification is required.
- No qualification is necessary when an analyte is detected in the method blank but not in the associated samples.

- If the concentration in a sample is more than ten times the concentration in the method blank, then no qualification is required.
- If the method blank concentration is greater than the MDL but less than the RL and sample results are greater than the MDL, then qualify associated sample results to indicate that analyte was detected in the method blank.
- If the method blank concentration is greater than the RL, further corrective action and qualification is required. An analyst should consult their supervisor for further instruction.

Instrument blanks may be injected at any time in the sequence to verify absence of contamination. The source of contamination must be investigated and reduced or eliminated. Any time contamination is noted in the method blank, the situation and impact on the data should be discussed in the case narrative.

12.7.1 **Method 8000D:** When samples that are extracted together are analyzed on separate instruments or in separate analytical shifts, the method blank associated with those samples (e.g., extracted with the samples) must be analyzed on at least one of those instruments. A solvent blank must be analyzed on all other instruments on which the set of samples was analyzed to demonstrate the instrument is not contributing contaminants to the samples. At least one method blank or instrument blank must be analyzed on every instrument after calibration standard(s) and prior to the analysis of any samples.

When sample extracts are subjected to cleanup procedures, the associated method blank must also be subjected to the same cleanup procedures.

Results of the method blank should be less than the LLOQ for the analyte or less than the level of acceptable blank contamination specified in the approved QAPP or other appropriate systematic planning document. Blanks are generally considered to be acceptable if target analyte concentrations are less than one-half the LLOQ or are less than project-specific requirements.

When new reagents or chemicals are received, the lab should monitor the blanks associated with samples for any signs of contamination. It is not necessary to test every new batch of reagents or chemicals prior to sample preparation if the source shows no prior problems. However, if reagents are changed during a preparation batch, separate blanks need to be prepared for each set of reagents.

12.8 LABORATORY CONTROL SAMPLES - If the recovery does not meet criteria, see section 12.9 for marginal failures. If it is still out of control limits, then all field and QC samples in the batch must be re-analyzed.

Qualifiers must be applied to any LCS compound that does not meet these criteria and are considered out of control. The percent difference for all method target analytes must be within QC RPD limits. If not, re-analyze the duplicate(s) or prepare a new calibration curve, as necessary.

STATE NOTE: **SOUTH CAROLINA DHEC Compliance LCS:** responses must be within 70 – 130% for Method 8260 and within the limits given in Appendix F for Method 624. Qualifiers cannot be used. (If an LCS standard is above the acceptable QC criteria and all samples being reported are below the reporting limit, the data is acceptable based on a high bias with undetectable levels in the field samples. Any positive samples require reanalysis.) Failures require a batch re-analysis. For samples analyzed from South Carolina that are not utilized for compliance purposes, in house established acceptance limits are utilized to demonstrate controlled analyses.

12.9 LCS/LCSD & MS/MSD CRITERIA

12.9.1 Quality control criteria must be checked for the LCS and LCSD.

LCS samples that do not pass the acceptable QC criteria must be re-analyzed. LCS failures can meet marginal exceedance criteria below. Normal compound list for 8260/624.1 contains typical 90 analytes; therefore, only five analytes can be considered as marginal exceedances. If the failure persists, re-prepare and re-analyze the entire sample batch.

When a large number of analytes exist in the LCS, it is statistically possible for a few analytes to be outside of control limits. Upper and lower marginal exceedance (ME) limits are established by +/- four times the standard deviation. The number of marginal exceedance is based on the number of analytes in the LCS.

Number of allowable marginal exceedances:

>90 analytes, 5 analytes allowed in the ME limit
71 – 90 analytes, 4 analytes allowed in the ME limit
51 – 70 analytes, 3 analytes allowed in the ME limit
31 – 50 analytes, 2 analytes allowed in the ME limit
11 – 30 analytes, 1 analyte allowed in the ME limit
< 11 analytes, no analyte allowed in the ME limit

Marginal exceedances must be random events.

STATE NOTE: For South Carolina DHEC compliance samples, marginal exceedances do not apply. All outliers in QC require corrective action when possible and the data must be flagged when necessary.

12.9.2 **Method 8000D:** If, as in compliance monitoring, the concentration of a specific analyte in the sample is being checked against a regulatory concentration limit or action level, the spike should be at or below the limit, or 1 - 5 times the background concentration (if historical data are available), whichever concentration is higher. If historical data are not available, a background sample of the same matrix from the site may be submitted for matrix spiking purposes to ensure that high concentrations of target analytes and/or interferences will not prevent calculation of recoveries. If the background sample concentration is very low or non-detect, a spike of greater than five (5) times the background concentration is still acceptable. To assess data precision with duplicate analyses, it is preferable to use a low concentration field sample to prepare a MS/MSD for organic analyses. This spiking procedure will be performed when project-specific instructions are received from the client.

If the concentration of a specific analyte in a sample is not being checked against a limit specific to that analyte, then the analyst may spike the matrix spike or MS/MSD sample(s) at the same concentration as the reference sample at 20 times the estimated LLOQ in the matrix of interest, or at a concentration near the middle of the calibration range. It is suggested that a background sample of the same matrix from the site be submitted as a sample for matrix spiking purposes.

NOTE: Preparing the spiking solution from the same source as the calibration standards helps minimize additional variability due to differences between sources. Typically, spiking concentrations are near the middle of the calibration range.

To develop precision and bias data for the spiked compounds, the analyst has two choices: analyze the original sample, and an MS/MSD pair; or analyze the original sample, a duplicate sample, and one spiked sample. If samples are not expected to contain the target analytes of concern, then the laboratory may use a MS/MSD pair. If samples are expected to contain the target analytes of concern, then the laboratory may use one matrix spike and a duplicate analysis of an unspiked field sample as an alternative to the MS/MSD pair.

The laboratory should use 70 - 130% as interim acceptance criteria for recoveries of spiked analytes, until in-house LCS limits are developed. Where in-house limits have been developed for matrix spike percent recoveries, the LCS results should be similar to or tighter than those limits, as the LCS is prepared in a clean matrix.

12.10 MATRIX SPIKE ASSESSMENT: If acceptance criteria are not met, perform the following corrective actions as appropriate.

- If both LCS and MS/MSD recoveries are unacceptable, then the entire batch of field and QC samples must be re-analyzed.
- If the MS/MSD is unacceptable, but the LCS is acceptable, then a potential matrix effect has been identified. Reported data must be flagged. Reasonable attempts must be made to address matrix interference.
- If analyst error appears to be the root cause of the failure (i.e., no spiked) reanalysis of the MS/MSD and parent is required if volume permits.

Acceptance criteria are that all RPD results must be within the current control limits found in the LIMS. If these conditions are not met, perform the following corrective actions as appropriate.

- Re-analyze the sample to verify a matrix effect only if analyst error appears to be the root cause.
- If the duplicate precision is still unacceptable, and LCS precision is acceptable, then a potential matrix effect has been identified.

STATE NOTE: South Carolina DHEC compliance analyses require that all target compounds meet the established MS/MSD criteria. No qualifiers can be applied, except in the circumstance where matrix interference is apparent.

PROJECT SPECIFIC CRITERIA (Non-South Carolina Samples): Acceptance criteria are that all %Recovery and/or RPD results meet project-established goals.

12.11 SURROGATE EVALUATION: If the surrogate recoveries are outside limits for Blank, ICV/CCV/SSCV, and LCS/LCSD, re-analysis must be performed for verification. If recoveries are still outside control limits, corrective action is necessary. All samples associated with batch or sequence needs to be re-analyzed. The surrogate recoveries for all field samples must be within established control limits. If more than two surrogate recoveries are outside limits, re-analysis must be performed for verification. If recoveries are still outside control limits, corrective action is necessary which includes qualifying data with J1 (outside upper limit) or J2 (outside lower limit). When surrogates fail, data is qualified with J1 (outside upper limit) or J2 (outside lower limit).

12.12 INTERNAL STANDARD AREA COUNT: If the area response for any of the internal standards changes by a factor of two (-50% to +100%) as per section 9.2.4, the mass spectrometer must be inspected for malfunctions and corrections must be made, as appropriate. In the event the internal standard area counts fail these criteria, the following corrective actions should be considered.

- Check to be sure there are no errors in the internal standards preparation or addition. Also check instrument performance.
- If any internal standard fails high (> +100%), sample must be re-analyzed with possible dilution. If recoveries are still outside control limits, corrective action is necessary which includes qualifying compounds with associated internal standard with J9 (IS high, data is likely to show low bias).
- If more than two internal standard fails low « -50%), sample must be re-analyzed. If recoveries are still outside control limits, corrective action is necessary which includes qualifying compounds with associated internal standard with J8 (IS low, data is likely to show high bias).
- If one or two internal standard criteria fails low « -50%), corrective action is necessary which includes qualifying compounds with associated internal standard with J8 (IS low, data is likely to show high bias).

12.13 CALIBRATION RANGE: The analyst must verify all reported results are derived from analytical results that are below the highest standard of the initial calibration curve and above the low standard. Values reported below the low standard are to be reported as estimated values (J values). For samples that exceed the calibration curve, dilute and analyze an appropriate sample aliquot.

12.14 SECOND SOURCE (SSCV) or Initial Calibration Verification (ICV): If the SSCV does not meet acceptance criteria, if can be reanalyzed once. If the failure persists, a new initial calibration curve must be prepared and analyzed.

12.15 Data that does not meet acceptable QC criteria may be acceptable for use in certain circumstances.

12.15.1 If a method blank contains an amount of target analyte, but all samples are non-detected or the samples contain analyte at a level that is greater than 10 times the level present in the blank, the data is reported with the appropriate “B” flag.

12.15.1.1 When comparing analyte contamination in the blank to possible analyte contamination in the field sample, utilize the sample concentration without applying the multiplier value unless the same multiplier has been applied to the quantitation of the target analytes in the blank.

12.15.2 If the sample surrogate is above the acceptable QC range, but the samples are non-detected for all target analytes, flag the sample with a J1 and report. If the surrogate is below the acceptable QC range, re-analyze the sample if the surrogate still fails, re-extract and re-analyze or flag data.

12.15.3 Matrix spike failures must be flagged with "J5" (high) or "J6" (low), when QC limits are exceeded. If there is an RPD failure, the data is flagged with a “J3”.

12.16 Quantitation and manual integration of all QC samples and client samples must follow the procedures outlined in ENV-SOP-CORQ-0006, *Manual Integration*. “Before” and “After” quantitation reports must be printed in order to verify that any manual integration is performed properly and consistently.

12.17 Data must be checked to ascertain if it conforms to accepted practices. All sample analytical results used for final data reporting must be between the low standard and the high calibration standard. Values falling above the high standard must be diluted and re-analyzed.

12.17.1 Site specific DQO's may require values below the reporting limit but above the method detection limit be reported as "UJ" or estimated value. The reporting limit is the concentration of the lowest standard used in the calibration.

12.17.2 All tentatively identified compounds (TICs) are reported with a "J" qualifier for estimated value and an "N" for presumptive evidence of material.

12.18 For samples analyzed per the requirements of Method 8000D, reported concentrations of target analytes between the MDL and the LLOQ must be qualified as estimated.

13.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Pace proactively seeks ways to minimize waste generated during our work processes. Some examples of pollution prevention include but are not limited to: reduced solvent extraction, solvent capture, use of reusable cycletainers for solvent management, and real-time purchasing.

The EPA requires that laboratory waste management practice to be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner in accordance with Pace's Chemical Hygiene Plan / Safety Manual.

13.1 The EPA requires that laboratory waste management practice to be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner. See *ENV-SOP-MTJL-0051, Waste Management Plan.*

13.2 See ENV-SOP-MTJL-0046, *Environmental Sustainability & Pollution Prevention*.

14.0 MODIFICATIONS

A modification is a change to a reference test method made by the laboratory. For example, changes in stoichiometry, technology, quantitation ions, reagent or solvent volumes, reducing digestion or extraction times, instrument runtimes, etc. are all examples of modifications. Refer to Pace ENV corporate SOP ENV-SOP-CORQ-0011 *Method Validation and Instrument Verification* for the conditions under which the procedures in test method SOPs may be modified and for the procedure and document requirements.

14.1 Adjustments to the concentrations of standards/spiking solutions, standards providers, and quality control are subject to change to better meet client/project/regulatory needs or to improve laboratory method performance.

14.2 Modifications to this method are noted in the body of the text as state notes. Compliance analyses performed in conjunction with specific state requirements must be performed as noted within the specific state(s) note listed.

14.3 Heated purge may be used for all samples regardless of matrix or method.

15.0 RESPONSIBILITIES

Pace ENV employees that perform any part this procedure in their work activities must have a signed Read and Acknowledgement Statement in their training file for this version of the SOP. The employee is responsible for following the procedures in this SOP and handling temporary departures from this SOP in accordance with Pace's policy for temporary departure.

Pace supervisors/managers are responsible for training employees on the procedures in this SOP and monitoring the implementation of this SOP in their work area.

16.0 Attachments

16.1 Appendix A: Target Analyte List and Routine LOQ

16.2 Appendix B: QC Summary

16.3 Appendix C: Characteristic Masses (m/z) for Purgeable Organic Compounds as printed from SW-846 Method 8260B Table 5

16.4 Appendix D: Potential Compounds to be Analyzed by this Procedure

16.5 Appendix E: The SIM Mode

16.6 Appendix F: EPA 624.1 CCC Criteria

16.7 Appendix G: EPA 8260C Minimum Relative Response Factor Criteria for Initial and Continuing Calibration Verification

16.8 Appendix H: EPA 8260D (Table 4) Guidance Response Factors Criteria From EPA Contract Laboratory Program (Min RF

16.9 Appendix I: Laboratory Control Standard and Matrix Spike Typically Spiked Compounds

16.10 Appendix J: DoD Requirements

17.0 REFERENCES

17.1 *Determinative Chromatographic Separations*, SW-846 Method 8000B, Revision 2, December 1996.

17.2 *Determinative Chromatographic Separations*, SW-846 Method 8000C, Revision 3, March 2003.

17.3 *Determinative Chromatographic Separations*, SW-846 Method 8000D, Revision 4, July 2014.

17.4 *Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)*, SW-846 Method 8260B, Revision 2, December 1996.

17.5 *Purgeables*, 40 CFR 136, EPA Method 624/

17.6 *Volatile Organic Compounds by the Purge and Trap Capillary-Column Gas Chromatographic/Mass Spectrometric Method*, SM 6200B, 20th edition.

17.7 Policy Document, NELAC Standard, Chapter 2: Proficiency Testing Program Standard and the relevant section of NELAC Standard Chapter 5 National Environmental Laboratory Accreditation Conference

17.8 *Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)*, SW-846 Method 8260C, Revision 3, August 2006.

17.9 *Volatile Organic Compounds by the Purge and Trap Capillary-Column Gas Chromatographic/Mass Spectrometric Method*, SM 6200B-2011.

17.10 *Purgeables by GC/MS*, EPA Method 624.1, Federal Register, Volume 82, Number 165, August 28, 2017.

17.11 40 Code of Federal Regulations §136.6(b)(4)(j).

17.12 *Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry,* SW-846 Method 8260D, Revision 4, June 2018.

18.0 Revision history

This Version:

Section	Description of Change
All	Complete SOP reformat.

This document supersedes the following document(s):

Document Number	Title	Version
ENV-SOP-MTJL-0100	Volatile Organic Compounds by GC/MS (EPA 8260B, 8260C, 624, 624.1 and SM 6200B)	04

Appendix A: Target Analyte List and Routine LOQ

Compound	Water		Low Soil		High Soil	
	RL	Units	RL*	Units	RL	Units
1,1,1,2-Tetrachloroethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,1,1-Trichloroethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,1,2,2-Tetrachloroethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,1,2-Trichloroethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,1-Dichloroethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,1-Dichloroethene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,1-Dichloropropene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,2,3-Trichlorobenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,2,3-Trichloropropane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,2,4-Trichlorobenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,2,4-Trimethylbenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,2-Dibromo-3-Chloropropane	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
1,2-Dibromoethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,2-Dichlorobenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,2-Dichloroethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,2-Dichloropropane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,3,5-Trimethylbenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,3-Butadiene	0.002	mg/L	0.002	mg/Kg	0.125	mg/Kg
1,3-Dichlorobenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,3-Dichloropropane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
1,4-Dichlorobenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
2,2,4-Trimethyl Pentane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
2,2-Dichloropropane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
2-Butanone (MEK)	0.01	mg/L	0.01	mg/Kg	0.5	mg/Kg
2-Chloroethyl vinyl ether	0.05	mg/L	0.05	mg/Kg	2.5	mg/Kg
2-Chlorotoluene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
4-Chlorotoluene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
4-Ethyltoluene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
4-Methyl-2-pentanone (MIBK)	0.01	mg/L	0.01	mg/Kg	0.5	mg/Kg
Acetone	0.05	mg/L	0.05	mg/Kg	2.5	mg/Kg
Acrolein	0.05	mg/L	0.05	mg/Kg	2.5	mg/Kg
Acrylonitrile	0.01	mg/L	0.01	mg/Kg	0.5	mg/Kg
Benzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Bromobenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Bromodichloromethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Bromoform	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Bromomethane	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Carbon tetrachloride	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Chlorobenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Chlorodibromomethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Chloroethane	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg

Compound	Water		Low Soil		High Soil	
	RL	Units	RL*	Units	RL	Units
Chloroform	0.005	mg/L	0.005	mg/Kg	0.1	mg/Kg
Chloromethane	0.0025	mg/L	0.0025	mg/Kg	0.05	mg/Kg
cis-1,2-Dichloroethene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
cis-1,3-Dichloropropene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Dibromomethane	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Dichlorodifluoromethane	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Dicyclopentadiene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Di-isopropyl ether	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Ethylbenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Hexachlorobutadiene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Hexane	0.01	mg/L	0.01	mg/Kg	0.5	mg/Kg
Isopropylbenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Methyl tert-butyl ether	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Methylene Chloride	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Naphthalene	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
n-Butylbenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
n-Propylbenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
p-Isopropyltoluene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Propene	0.0025	mg/L	0.0025	mg/Kg	0.125	mg/Kg
sec-Butylbenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Styrene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
tert-Butylbenzene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Tetrachloroethene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Toluene	0.001	mg/L	0.001	mg/Kg	0.25	mg/Kg
trans-1,2-Dichloroethene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
trans-1,3-Dichloropropene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Trichloroethene	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Trichlorofluoromethane	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Vinyl chloride	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Xylenes, Total	0.003	mg/L	0.003	mg/Kg	0.15	mg/Kg
Additional Compounds						
1,4-Dioxane+	0.1	mg/L	0.1	mg/Kg	5	mg/Kg
2-Butanol	0.05	mg/L	0.05	mg/Kg	2.5	mg/Kg
2-Hexanone	0.01	mg/L	0.01	mg/Kg	0.5	mg/Kg
2-Propanol	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Acetonitrile	0.05	mg/L	0.05	mg/Kg	2.5	mg/Kg
Allyl Chloride	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Bromoethane	0.01	mg/L	0.001	mg/Kg	0.05	mg/Kg
Carbon Disulfide	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Chloroprene	0.05	mg/L	0.05	mg/Kg	2.5	mg/Kg
Cyclohexanone	0.01	mg/L	0.01	mg/Kg	0.5	mg/Kg
Dichlorofluoromethane	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Di-isopropyl ether	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg

Compound	Water		Low Soil		High Soil	
	RL	Units	RL*	Units	RL	Units
Ethanol	0.1	mg/L	0.1	mg/Kg	2.5	mg/Kg
Ethyl methacrylate	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Ethyl tert-butyl ether	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Iodomethane	0.01	mg/L	0.01	mg/Kg	0.5	mg/Kg
Isobutanol	0.1	mg/L	0.1	mg/Kg	5	mg/Kg
Isobutanol	0.1	mg/L	0.001	mg/Kg	0.05	mg/Kg
Methacrylonitrile	0.05	mg/L	0.05	mg/Kg	2.5	mg/Kg
Methyl Methacrylate	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Pentachloroethane	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Propionitrile	0.05	mg/L	0.05	mg/Kg	2.5	mg/Kg
Tert Amyl Alcohol	0.05	mg/L	0.05	mg/Kg	0.25	mg/Kg
Tert Butyl Ethyl Alcohol	0.1	mg/L	0.1	mg/Kg	5	mg/Kg
Tert-Amyl Methyl Ether	0.001	mg/L	0.001	mg/Kg	0.05	mg/Kg
Tert-Butyl Alcohol	0.05	mg/L	0.05	mg/Kg	2.5	mg/Kg
Tert-Butyl Formate	0.02	mg/L	0.02	mg/Kg	1	mg/Kg
Tetrahydrofuran	0.005	mg/L	0.005	mg/Kg	0.25	mg/Kg
Trans-1,4-Dichloro-2-butene	0.0025	mg/L	0.0025	mg/Kg	0.125	mg/Kg
Vinyl Acetate	0.01	mg/L	0.01	mg/Kg	2.5	mg/Kg

RLs are based on a 5mL purge volume

Low Soil - Using a 5g soil sample to 5mL water – See Method 5035 (ENV-SOP-MTJL-0129) Section 8.2.4.1

High Soil – Using 200uL extract from 10g soil sample to 10mL methanol; see Method 5035 (ENV-SOP-MTJL-0129) Sect. 8.3.1.2

+ 1,4-Dioxane has a RL of .002 when run using the SIM mode.

Appendix B: QC Summary

QC Item	Frequency	Acceptance Criteria	Corrective Action	Qualification
ICAL	At instrument set up, after CCV failure	Must meet one of curve fit options presented in Section 9.0. For any curve fit other than Average RF (RSD), curve must also pass RSE test at the low and midpoint calibration standard.	Identify and correct source of problem, repeat	None. Do not proceed with analysis
ICV	After Each ICAL	All analytes must be within ± 30% recovery (%R) of the true value with the exception of poor performers which must be within in-house limits.	Identify source of problem, re-analyze. If repeat failure, repeat ICAL. Analysis may proceed if it can be demonstrated that the ICV exceedance has no impact on analytical measurements. For example, the ICV %R is high, CCV is within criteria, and the analyte is not detected in sample(s).	Qualify analytes with ICV out of criteria.
RT Window Position (Daily)	Once per ICAL and at the beginning of the analytical window.	Position is set using the mid-point of the ICAL on the day ICAL is performed; otherwise mid-point of CCV is used	NA	NA
RT Window Study	At method set-up and after major instrument maintenance	Window is ± 3 times the standard deviation among three data points across 72 hours.	NA	NA
CCV	Daily, before sample analysis, after every X, and at end of analytical window.	Opening CCV: All analytes within ± 20 %D Ending CCV: All analytes within ± 50 %D	See Section 12 for required corrective actions based on circumstance.	Qualify analytes with CCV out of of criteria.
Internal Standards	Every field sample, standard and QC sample	Must meet criteria specified in Section 9.0.	Troubleshoot instrument performance. Reanalyze samples.	Qualify outages and explain in case narrative.
Surrogate	All field and QC samples.	Routine limits are presented in the LIMS	Correct problem, then reprep and reanalyze all failed samples for all surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference is present, reanalysis may not be necessary, but the client must be notified prior to reporting data and the failures must be discussed in the case narrative.	Qualify all associated analytes if acceptance criteria are not met and explain in the case narrative.

Method Blank	One per preparatory batch.	No analytes detected above the MDL for any of the method target analytes	Correct problem. If required, reprep and reanalyze MB and all samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.
LCS	One per preparatory batch.	Routine LCS control limits are presented in the LIMS	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available	Qualify all associated analytes if acceptance criteria are not met and explain in the case narrative.
MS/MSD	One per preparatory batch.	All RPD results must be within the indicated control limits found in the LIMS.	Examine the project specific requirements. Contact the client as to additional measures to be taken.	Qualify all associated analytes if acceptance criteria are not met and explain in the case narrative.
Trip Blank	1 per cooler	No analytes detected above the MDL for any of the method target analytes	Examine the project specific requirements. Contact the client as to additional measures to be taken.	NA
Tune Standard	Prior to ICAL and prior to each 12-hour period of sample analysis.	Specific ion abundance criteria of BFB from method.	Retune instrument and verify.	Flagging is not appropriate.
Performance Check	Prior to ICAL	Must meet the minimum, average RF criteria for each analyte according to Section 9.2.3.2.4-9.2.3.2.7	Identify source of problem and troubleshoot instrument performance. Repeat ICAL.	None. Do not proceed with analysis

Appendix C: Characteristic Masses (m/z) for Purgeable Organic Compounds as printed from SW-846 Method 8260B Table 5

Compound	Primary Characteristic Ion	Secondary Characteristic Ion(s)
Acetone	58	43
Acetonitrile	41	40, 39
Acrolein	56	55, 58
Acrylonitrile	53	52, 51
Allyl alcohol	57	58, 39
Allyl chloride	76	41, 39, 78
Benzene	78	-
Benzyl chloride	91	126, 65, 128
Bromoacetone	136	43, 138, 93, 95
Bromobenzene	156	77, 158
Bromochloromethane	128	49, 130
Bromodichloromethane	83	85, 127
Bromoform	173	175, 254
Bromomethane	94	96
1,3-Butadiene	39	54
iso-Butanol	74	43
n-Butanol	56	41
2-Butanone	72	43
n-Butylbenzene	91	92, 134
sec-Butylbenzene	105	134
tert-Butylbenzene	119	91, 134
Carbon disulfide	76	78
Carbon tetrachloride	117	119
Chloral hydrate	82	44, 84, 86, 111
Chloroacetonitrile	48	75
Chlorobenzene	112	77, 114
1-Chlorobutane	56	49
Chlorodibromomethane	129	208, 206
Chloroethane	64 (49*)	66 (51*)
2-Chloroethanol	49	44, 43, 51, 80
Bis(2-chloroethyl) sulfide	109	111, 158, 160
2-Chloroethyl vinyl ether	63	65, 106
Chloroform	83	85
Chloromethane	50 (49*)	52 (51*)
Chloroprene	53	88, 90, 51
3-Chloropropionitrile	54	49, 89, 91
2-Chlorotoluene	91	126
4-Chlorotoluene	91	126
Dicyclopentadiene	66	132
1,2-Dibromo-3-chloropropane	157**	75, 155
Dibromochloromethane	129	127
1,2-Dibromoethane	107	109, 188
Dibromomethane	93	95, 174
1,2-Dichlorobenzene	146	111, 148
1,2-Dichlorobenzene-d4	152	115, 150
1,3-Dichlorobenzene	146	111, 148

Compound	Primary Characteristic Ion	Secondary Characteristic Ion(s)
1,4-Dichlorobenzene	146	111, 148
cis-1,4-Dichloro-2-butene	75	53, 77, 124, 89
trans-1,4-Dichloro-2-butene	53	88, 75
Dichlorodifluoromethane	85	87
1,1-Dichloroethane	63	65, 83
1,2-Dichloroethane	62	98
1,1-Dichloroethene	96	61, 63
cis-1,2-Dichloroethene	96	61, 98
trans-1,2-Dichloroethene	96	61, 98
1,2-Dichloropropane	63	112
1,3-Dichloropropane	76	78
2,2-Dichloropropane	77	97
1,3-Dichloro-2-propanol	79	43, 81, 49
1,1-Dichloropropene	75	110, 77
cis-1,3-Dichloropropene	75	77, 39
trans-1,3-Dichloropropene	75	77, 39
1,2,3,4-Diepoxybutane	55	57, 56
Diethyl ether	74	45, 59
1,4-Dioxane	88	58, 43, 57
Epichlorohydrin	57	49, 62, 51
Ethanol	31	45, 27, 46
Ethyl acetate	88	43, 45, 61
Ethylbenzene	91	106
Ethylene oxide	44	43, 42
Ethyl methacrylate	69	41, 99, 86, 114
4-Ethyltoluene	105	120
Hexachlorobutadiene	225	223, 227
Hexachloroethane	201	166, 199, 203
Hexane	57	86, 56
2-Hexanone	43	58, 57, 100
2-Hydroxypropionitrile	44	43, 42, 53
Iodomethane	142	127, 141
Isobutyl alcohol	43	41, 42, 74
Isopropylbenzene	105	120
p-Isopropyltoluene	119	134, 91
Malononitrile	66	39, 65, 38
Methacrylonitrile	41	67, 39, 52, 66
Methyl acrylate	55	85
Methyl-t-butyl ether	73	57
Methylene chloride	84	86, 49
Methyl ethyl ketone	72	43
Methyl iodide	142	127, 141
Methyl methacrylate	69	41, 100, 39
4-Methyl-2-pentanone	100	43, 58, 85
Naphthalene	128	-
Nitrobenzene	123	51, 77
2-Nitropropane	46	-
2-Picoline	93	66, 92, 78
Pentachloroethane	167	130, 132, 165, 169
Propargyl alcohol	55	39, 38, 53

Compound	Primary Characteristic Ion	Secondary Characteristic Ion(s)
Propene	41	39, 42
Propiolactone	42	43, 44
Propionitrile (ethyl cyanide)	54	52, 55, 40
n-Propylamine	59	41, 39
n-Propylbenzene	91	120
Pyridine	79	52
Styrene	104	78
1,2,3-Trichlorobenzene	180	182, 145
1,2,4-Trichlorobenzen	180	182, 145
1,1,1,2-Tetrachloroethane	131	133, 119
1,1,2,2-Tetrachloroethane	83	131, 85
Tert-butyl formate	59	57, 41
Tetrachloroethene	164	129, 131, 166
Toluene	92	91
1,1,1-Trichloroethane	97	99, 61
1,1,2-Trichloroethane	83	97, 85
Trichloroethene	95	97, 130, 132
Trichlorofluoromethane	151	101, 153
1,2,3-Trichloropropane	75	77
1,2,4-Trimethylbenzene	105	120
1,3,5-Trimethylbenzene	105	120
Vinyl acetate	43	86
Vinyl chloride	62	64
o-Xylene	106	91
m-Xylene	106	91
p-Xylene	106	91
Internal Standards/Surrogates:		
1,4-Difluorobenzene	114	63
1,4-Dichlorobenzene-d4	152	115, 150
1,1,2-Trichloroethane-d3	100	
4-Bromofluorobenzene	95	174, 176
Chloroform-d1	84	
Dibromofluoromethane	113	
4-Bromofluorobenzene	95	174, 176
Chloroform-d1	84	
Dibromofluoromethane	113	
Dichloroethane-d4	102	
Toluene-d8	98	
Pentafluorobenzene	168	
Fluorobenzene	96	77

* Characteristic ion for an ion trap mass spectrometer (to be used when ion-molecule reactions are observed).

** Primary ion modified due to coelution.

Appendix D: Potential Compounds to be Analyzed by this Procedure

Acetone
Acetonitrile
Acrolein
Acrylonitrile
Allyl alcohol
Allyl chloride
Benzene
Benzyl chloride
Bromoacetone
Bromochloromethane (I.S.)
Bromodichloromethane
4-Bromofluorobenzene (Surr.)
Bromoform
Bromomethane
2-Butanone
Carbon disulfide
Carbon tetrachloride
Chloral hydrate
Chlorobenzene
Chlorobenzene d-5 (I.S.)
Chlorodibromomethane
2-Propanol
Chloroethane
2-Chloroethanol
bis-(2-Chloroethyl) sulfide
2-Chloroethyl vinyl ether
Chlorofrom
Chloromethane
Chloroprene
3-Chloropropionitrile
1,2- Dibromo-3-chloropropane
1,2-Dibromoethane
Dibromomethane
1,4-Dichloro-2-butene
dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,2-Dichloroethane d-4 (surr.)
1,1-Dichloroethene
Trans-1,2-dichloroethene
Cis-1,2-dichloroethene
1,2-dichloropropane
Dicyclopentadiene
1,4-Dioxane
Epichlorohydrin
Ethanol
Ethylbenzene
Ethylene oxide
Ethyl methacrylate
n-Hexane
2-Hexanone
2-Hydroxypropionitrile
Iodomethane
Isobutylalcohol
Malononitrile
Methacrylonitrile
Methylene chloride
Methyl iodide
Methyl methacrylate
4-methyl-2-pentanone
Pentachloroethane
2-Picoline
Propargyl alcohol
Propene
B-propiolactone
Propionitrile
n-Propylamine
Pyridine
Styrene
1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
Tetrachloroethene
Toluene
1,3-Butadiene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethene
Trichlorofluoromethane
1,2,3-Trichloropropane
Vinyl acetate
Vinyl chloride
Xylene (total)
1,2,3,4-Diepoxybutane
4-Ethyltoluene

Appendix E: The SIM Mode:

An alternate way of running compounds to achieve lower detection limits is by way of the Single Ion Monitoring (SIM) method. The SIM method allows the Mass spec to dwell on certain ions rather than scanning the full range of masses from 35 to 300. This process allows for much lower detection limit of desired compounds. This method is only for the detection of known compounds while a TIC cannot be performed while running the SIM method. Currently 1,4-Dioxane is the only compound that is analyzed using the SIM method in the volatiles laboratory.

Appendix F: EPA 624.1 CCC Criteria:

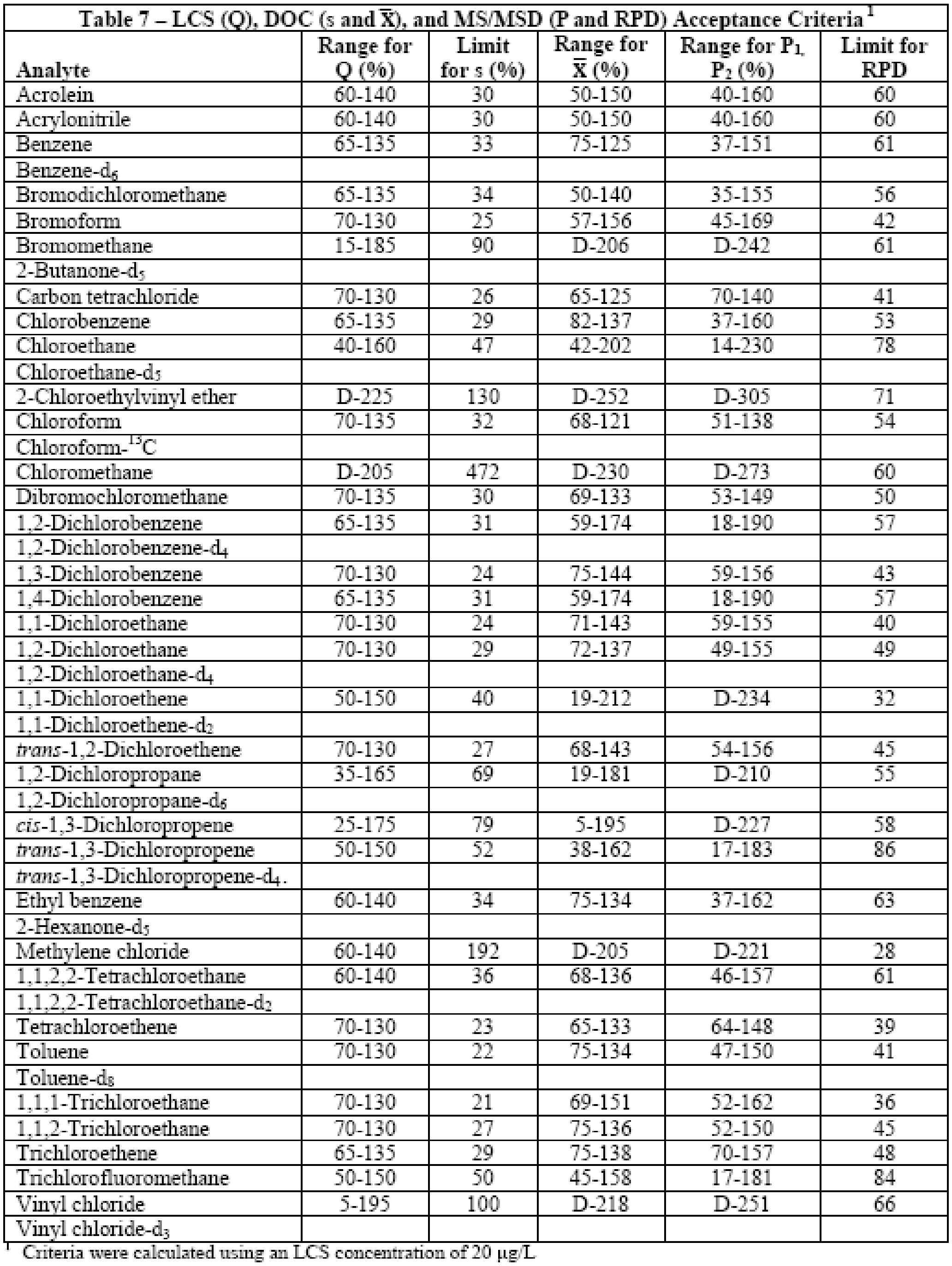


Table 7 – LCS (Q), DOC (s and $\bar{X}$), and MS/MSD (P and RPD) Acceptance Criteria[1]

Analyte	Range for Q (%)	Limit for s (%)	Range for $\bar{X}$ (%)	Range for P_1, P_2 (%)	Limit for RPD
Acrolein	60-140	30	50-150	40-160	60
Acrylonitrile	60-140	30	50-150	40-160	60
Benzene	65-135	33	75-125	37-151	61
Benzene-d_6					
Bromodichloromethane	65-135	34	50-140	35-155	56
Bromoform	70-130	25	57-156	45-169	42
Bromomethane	15-185	90	D-206	D-242	61
2-Butanone-d_5					
Carbon tetrachloride	70-130	26	65-125	70-140	41
Chlorobenzene	65-135	29	82-137	37-160	53
Chloroethane	40-160	47	42-202	14-230	78
Chloroethane-d_5					
2-Chloroethylvinyl ether	D-225	130	D-252	D-305	71
Chloroform	70-135	32	68-121	51-138	54
Chloroform-^{13}C					
Chloromethane	D-205	472	D-230	D-273	60
Dibromochloromethane	70-135	30	69-133	53-149	50
1,2-Dichlorobenzene	65-135	31	59-174	18-190	57
1,2-Dichlorobenzene-d_4					
1,3-Dichlorobenzene	70-130	24	75-144	59-156	43
1,4-Dichlorobenzene	65-135	31	59-174	18-190	57
1,1-Dichloroethane	70-130	24	71-143	59-155	40
1,2-Dichloroethane	70-130	29	72-137	49-155	49
1,2-Dichloroethane-d_4					
1,1-Dichloroethene	50-150	40	19-212	D-234	32
1,1-Dichloroethene-d_2					
trans-1,2-Dichloroethene	70-130	27	68-143	54-156	45
1,2-Dichloropropane	35-165	69	19-181	D-210	55
1,2-Dichloropropane-d_6					
cis-1,3-Dichloropropene	25-175	79	5-195	D-227	58
trans-1,3-Dichloropropene	50-150	52	38-162	17-183	86
trans-1,3-Dichloropropene-d_4.					
Ethyl benzene	60-140	34	75-134	37-162	63
2-Hexanone-d_5					
Methylene chloride	60-140	192	D-205	D-221	28
1,1,2,2-Tetrachloroethane	60-140	36	68-136	46-157	61
1,1,2,2-Tetrachloroethane-d_2					
Tetrachloroethene	70-130	23	65-133	64-148	39
Toluene	70-130	22	75-134	47-150	41
Toluene-d_8					
1,1,1-Trichloroethane	70-130	21	69-151	52-162	36
1,1,2-Trichloroethane	70-130	27	75-136	52-150	45
Trichloroethene	65-135	29	75-138	70-157	48
Trichlorofluoromethane	50-150	50	45-158	17-181	84
Vinyl chloride	5-195	100	D-218	D-251	66
Vinyl chloride-d_3					

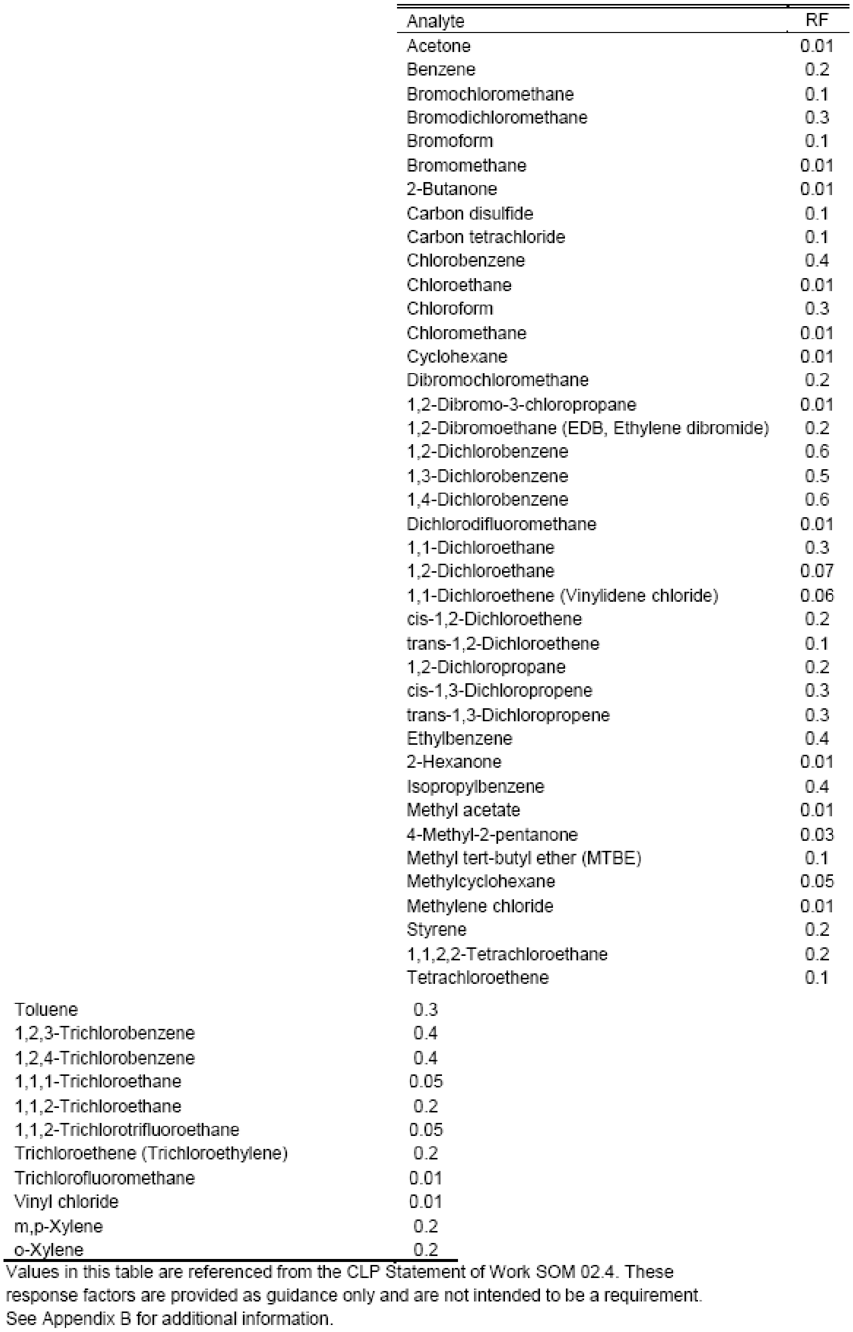
[1] Criteria were calculated using an LCS concentration of 20 µg/L

Appendix G: EPA 8260C Minimum Relative Response Factor Criteria for Initial and Continuing Calibration Verification:

Volatile Compound	Minimum Response Factor (RF)
Dichlorodifluoromethane	0.100
Chloromethane	0.100
Vinyl chloride	0.100
Bromomethane	0.100
Chloroethane	0.100
Trichlorofluoromethane	0.100
1,1-Dichloroethene	0.100
1,1,2-Trichloro-1,2,2-trifluoroethane	0.100
Acetone	0.100
Carbon disulfide	0.100
Methyl Acetate	0.100
Methylene chloride	0.100
trans-1,2-Dichloroethene	0.100
cis-1,2-Dichloroethene	0.100
Methyl tert-Butyl Ether	0.100
1,1-Dichloroethane	0.200
2-Butanone	0.100
Chloroform	0.200
1,1,1-Trichloroethane	0.100
Cyclohexane	0.100
Carbon tetrachloride	0.100
Benzene	0.500
1,2-Dichloroethane	0.100
Trichloroethene	0.200
Methylcyclohexane	0.100

Volatile Compound	Minimum Response Factor (RF)
1,2-Dichloropropane	0.100
Bromodichloromethane	0.200
cis-1,3-Dichloropropene	0.200
trans-1,3-Dichloropropene	0.100
4-Methyl-2-pentanone	0.100
Toluene	0.400
1,1,2-Trichloroethane	0.100
Tetrachloroethene	0.200
2-Hexanone	0.100
Dibromochloromethane	0.100
1,2-Dibromoethane	0.100
Chlorobenzene	0.500
Ethylbenzene	0.100
meta-/para-Xylene	0.100
ortho-Xylene	0.300
Styrene	0.300
Bromoform	0.100
Isopropylbenzene	0.100
1,1,2,2-Tetrachloroethane	0.300
1,3-Dichlorobenzene	0.600
1,4-Dichlorobenzene	0.500
1,2-Dichlorobenzene	0.400
1,2-Dibromo-3-chloropropane	0.050
1,2,4-Trichlorobenzene	0.200

Appendix H: EPA 8260D (Table 4) Guidance Response Factors Criteria From EPA Contract Laboratory Program (Min RF):



Analyte	RF
Acetone	0.01
Benzene	0.2
Bromochloromethane	0.1
Bromodichloromethane	0.3
Bromoform	0.1
Bromomethane	0.01
2-Butanone	0.01
Carbon disulfide	0.1
Carbon tetrachloride	0.1
Chlorobenzene	0.4
Chloroethane	0.01
Chloroform	0.3
Chloromethane	0.01
Cyclohexane	0.01
Dibromochloromethane	0.2
1,2-Dibromo-3-chloropropane	0.01
1,2-Dibromoethane (EDB, Ethylene dibromide)	0.2
1,2-Dichlorobenzene	0.6
1,3-Dichlorobenzene	0.5
1,4-Dichlorobenzene	0.6
Dichlorodifluoromethane	0.01
1,1-Dichloroethane	0.3
1,2-Dichloroethane	0.07
1,1-Dichloroethene (Vinylidene chloride)	0.06
cis-1,2-Dichloroethene	0.2
trans-1,2-Dichloroethene	0.1
1,2-Dichloropropane	0.2
cis-1,3-Dichloropropene	0.3
trans-1,3-Dichloropropene	0.3
Ethylbenzene	0.4
2-Hexanone	0.01
Isopropylbenzene	0.4
Methyl acetate	0.01
4-Methyl-2-pentanone	0.03
Methyl tert-butyl ether (MTBE)	0.1
Methylcyclohexane	0.05
Methylene chloride	0.01
Styrene	0.2
1,1,2,2-Tetrachloroethane	0.2
Tetrachloroethene	0.1
Toluene	0.3
1,2,3-Trichlorobenzene	0.4
1,2,4-Trichlorobenzene	0.4
1,1,1-Trichloroethane	0.05
1,1,2-Trichloroethane	0.2
1,1,2-Trichlorotrifluoroethane	0.05
Trichloroethene (Trichloroethylene)	0.2
Trichlorofluoromethane	0.01
Vinyl chloride	0.01
m,p-Xylene	0.2
o-Xylene	0.2

Values in this table are referenced from the CLP Statement of Work SOM 02.4. These response factors are provided as guidance only and are not intended to be a requirement. See Appendix B for additional information.

Appendix I: Laboratory Control Standard and Matrix Spike Typically Spiked Compounds

STANDARD ANALYTE LIST

1,1,1,2-TETRACHLOROETHANE
1,1,1-TRICHLOROETHANE
1,1,2,2-TETRACHLOROETHANE
1,1,2-TRICHLOROETHANE
1,1,2-TRICHLOROTRIFLUOROETHANE
1,1-DICHLOROETHANE
1,1-DICHLOROETHENE
1,1-DICHLOROPROPENE
1,2,3-TRICHLOROBENZENE
1,2,3-TRICHLOROPROPANE
1,2,3-TRIMETHYLBENZENE
1,2,4-TRICHLOROBENZENE
1,2,4-TRIMETHYLBENZENE
1,2-DIBROMO-3-CHLOROPROPANE
1,2-DIBROMOETHANE
1,2-DICHLOROBENZENE
1,2-DICHLOROETHANE
1,2-DICHLOROPROPANE
1,3,5-TRICHLOROBENZENE
1,3,5-TRIMETHYLBENZENE
1,3-BUTADIENE
1,3-DICHLOROBENZENE
1,3-DICHLOROPROPANE
1,4-DICHLOROBENZENE
1-METHYLNAPHTHALENE
2,2,4-TRIMETHYLPENTANE
2,2-DICHLOROPROPANE
2-BUTANONE (MEK)
2-CHLOROETHYL VINYL ETHER
2-CHLOROTOLUENE
2-HEXANONE
2-METHYLNAPHTHALENE
4-CHLOROTOLUENE
4-ETHYLTOLUENE
4-METHYL-2-PENTANONE (MIBK)
ACETONE
ACROLEIN*ACRYLONITRILE*
CHLORODIBROMOMETHANE
CHLOROETHANE
CHLOROFORM
CHLOROMETHANE
CIS-1,2-DICHLOROETHENE
CIS-1,3-DICHLOROPROPENE
DIBROMOMETHANE
DICHLORODIFLUOROMETHANE
DICHLOROFLUOROMETHANE
DICYCLOPENTADIENE
DI-ISOPROPYL ETHER
ETHYL ETHER
ETHYLBENZENE
HEXACHLORO-1,3-BUTADIENE
IODOMETHANE
ISOPROPYLBENZENE
M&P-XYLENE
METHYL TERT-BUTYL ETHER
METHYLENE CHLORIDE
NAPHTHALENE
N-BUTYLBENZENE
N-HEXANE
N-PROPYLBENZENE
O-XYLENE
P-ISOPROPYLTOLUENE
PROPENE
SEC-BUTYLBENZENE
STYRENE
TERT-BUTYLBENZENE
TETRACHLOROETHENE
TETRAHYDROFURAN
TOLUENE
TPH (GC/MS) LOW FRACTION
TRANS-1,2-DICHLOROETHENE
TRANS-1,3-DICHLOROPROPENE
TRANS-1,4-DICHLORO-2-BUTENE
TRICHLOROETHENE

STANDARD ANALYTE LIST

ACRYLONITRILE*BENZENE
BENZENEBROMOBENZENE
BROMOBENZENE
BROMOCHLOROMETHANE
BROMODICHLOROMETHANE
BROMOFORM
BROMOMETHANE
CARBON DISULFIDE
CARBON TETRACHLORIDE
CHLOROBENZENE

TRICHLOROFLUOROMETHANE
VINYL ACETATE
VINYL BROMIDE
VINYL CHLORIDE
XYLENES, TOTAL

SURROGATE LIMITS

4-BROMOFLUOROBENZENE
2,2-DICHLOROETHANE-D4
TOLUENE-D8

Appendix J: DoD Requirements

1.0 Equipment/Instrument Maintenance

Instrument maintenance must be performed routinely to optimize instrument performance and improve chromatography. Commonly performed maintenance includes baking traps and columns, changing injection port liners, changing pump oil, etc. A new calibration curve must be analyzed following any major maintenance performed on the analytical system.

2.0 Computer Hardware and Software

Software name and version: HP Chemstation G1701CA Version C.00.00 or equivalent

3.0 Troubleshooting

Table 1. GCMS Troubleshooting Guide

Problem	Cause	Treatment
Peaks broaden and tail	Poor column installation causing dead volume in the injector	Reinstall column in injector. Check seal at ferrule. Check insertion depth. Ensure a good column cut.
	Solvent flashing in hot injector	Reduce injection speed on hot injectors and if possible, reduce injector temperature
	Injector not being purged properly after splitless injection	For splitless injection, the vent flow should be 70 ml/min, and the injector should be switched to the split mode 0.5_1.5 min after injection.
Tailing sample peaks for active components	Active sites in the injector insert or liner	Change or clean the injector insert
	Active sites or degraded phase in column	Remove the front 15 cm of the column and reinstall. If retention times are changing or cutting the column does not help, replace the column.
	Injector not hot enough for higher boiling compounds	Increase the injector temperature and lower the injection speed. Check that the graphite ferrule is free of cracks and the septum support is tight.
Low response and tailing of high boiling point compounds	Injector is not hot enough to vaporize high boilers	Increase injector temperature
	Interface/ion source not getting to adequate temperature	Change the manifold heater
Leading sample peaks	Column overload due to excess amount of component injected	Dilute the sample or do split injection
	Degradation of stationary phase	Change the column
	Carrier gas velocity too low	Increase carrier gas flow rate
Poor chromatographic resolution	Column temperature or program not optimized	Modify method by changing temperature ramp segment slopes

Table 1. GCMS Troubleshooting Guide

Problem	Cause	Treatment
	Carrier gas flow rate not optimized	Decrease carrier gas linear velocity
	Stationary phase has degraded	Replace the column
Peak splitting, especially low boilers	Sample is flashing in the injector simulating two injections	Lower injector temperature
Retention times shift in chromatogram	Unstable carrier gas flow controller/regulator	Check pneumatics for leaks. Replace flow controller/ regulator if necessary.
	Column contamination or degradation	Condition or replace column
	Leaks at septum or column to injector connection	Replace septum regularly and check that the septum nut and the capillary column nut are tight
Cannot reach operating vacuum	Analyzer contaminated by diffusion pump oil	Shut down and clean mass spec
	Major air leak around column fitting into interface	Replace column ferrule and reseat compression fitting
No tune peaks	Cal gas valve not open	Open cal gas valve
	PFTBA solenoid valve stuck open. All PFTBA has evaporated.	Have solenoid replaced. Put fresh PFTBA in the cal gas vial.
Analysis sensitivity has decreased	Background has increased	Check column bleed, septum bleed, pump oil, and ion source contamination
	Detector needs replacement	Replace detector
	Defective syringe	Try a new or proven syringe
	“Blown” septum or other massive leaks at the inlet or with carrier gas flow. Poor peak shapes usually result from bad leaks.	Find and fix leaks and adjust gas flow.
	Purge flow or split ratio too high	Adjust gas flow rates

4.0 Other Requirements

4.1 All hardcopy laboratory notebooks must be reviewed by the Supervisor, or their designee, on a monthly basis.

4.2 If not self-explanatory (e.g., a typo or transposed number), corrections to technical and quality records shall also include a justification for the change.

4.3 A storage blank must be stored with all volatile organic samples, regardless of suspected concentration levels.

4.4 A person performing a manual integration must sign and date each manually integrated chromatogram and record the rationale for performing manual integration. Electronic signatures are acceptable.

4.5 The results of calibration and verification of support equipment must be within the specifications required of the application for which this equipment is used, or the equipment must be removed from service until repaired. Calibration and verification records, including those of established correction factors, must be maintained. In the absence of method-specific requirements, the minimum requirements are as follows:

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Balance calibration check [Using two standard weights that bracket the expected mass]	Daily prior to use	Top-loading balance: ±2% or ±0.02g, whichever is greater Analytical balance: ±0.1% or ±0.5 mg, whichever is greater
Verification of standard mass [Using weights traceable to the International System of Units (SI) through a NMI	Every 5 years	Certificate of Calibration from ISO/IEC 17025 accredited calibration laboratory
Monitoring of refrigerator/freezer temperatures	Daily (i.e., 7 days per week) [use MIN/MAX thermometers or data loggers equipped with notification of out of control event capabilities if personnel not available to record daily]	Refrigerators: 0˚C to 6˚C Freezers: ≤-10˚C
Thermometer verification check [Using a thermometer traceable to the SI through an NMI] [Performed at two temperatures that bracket the target temperature(s). Assume linearity between the two bracketing temperatures.] [If only a single temperature is used, at the temperature of use]	Liquid in glass: Before first use and annually Electronic: Before first use and quarterly	Apply correction factors or replace thermometer
Volumetric labware	Class B: By lot before first use Class A and B: Upon evidence of deterioration	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on 10 replicate measurements)
Non-volumetric labware [Applicable only when used for measuring initial sample volume and final extract/ digestates volume]	By lot before first use or upon evidence of deterioration	Bias: Mean within ±3% of nominal volume Precision: RSD ≤3% of nominal volume (based on 10 replicate measurements)
Mechanical volumetric pipette	Quarterly	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on minimum of 3 replicate measurements) [Note: for variable volume pipettes, the nominal volume is the volume of use]

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Glass microliter syringe	Upon receipt and upon evidence of deterioration	General Certificate of Bias & Precision upon receipt Replace if deterioration is evident
Drying oven temperature check	Daily prior to and after use	Within ±5% of set temperature
Water purification system	Daily prior to use	See method blank criteria given in Section 4.20 of this addendum

4.6 The expiration date of the prepared standard shall not exceed the expiration date of the primary standard. All containers must bear a preparation date.

4.7 To avoid preparing non-representative samples, the laboratory shall not "target" within a relatively small mass range (e.g., 1.00 ± 0.01g) because such targeting will produce non-representative subsamples if the sample has high heterogeneity. The laboratory shall not manipulate the sample material so the sample aliquot weighs exactly 1.00g ± 0.01g, as an example.

4.8 In the absence of project-specific requirements, the minimum standard data qualifiers to be used are:

U Analyte was not detected and is reported as less than the LOD or as defined by the customer. The LOD has been adjusted for any dilution or concentration of the sample.

J The reported result is an estimated value (e.g., matrix interference was observed, or the analyte was detected at a concentration outside the quantitation range).

B Blank contamination. The recorded result is associated with a contaminated blank.

N Non-target analyte. The analyte is a tentatively identified compound using mass spectrometry or any non-customer requested compounds that are tentatively identified.

Q One or more quality control criteria failed (e.g., LCS recovery, surrogate spike recovery, or CCV recovery).

Additional data qualifiers may be used, or different letters or symbols to denote the qualifiers listed above, as long as they are appropriately defined and their use is consistent with project-specific requirements (e.g., QSM 5.0, the contract, and project-planning documents).

4.9 If the time of the sample collection is not provided, assume the most conservative time of day. For the purpose of batch processing, the start and stop dates and times of the batch preparation shall be recorded.

4.10 Each preparation method listed on the scope of accreditation must have quarterly LOD/LOQ verifications. However, not all possible combinations of preparation and cleanup techniques are required to have LOD/LOQ verifications. If LOD/LOQ verifications are not performed on all combinations, the laboratory must base the

LOD/LOQ verifications on the worst-case basis (preparation method with all applicable cleanup steps).

4.11 After each MDL determination, the laboratory must establish the LOD by spiking a quality system matrix at a concentration of at least two (2) times but no greater than four times the MDL. This spike concentration establishes the LOD and the concentration at which the LOD shall be verified. It is specific to each suite of analyte, matrix, and method (including sample preparation). The following requirements apply to the initial LOD establishment and to the LOD verifications:

- The apparent signal to noise (S/N) ratio at the LOD must be at least three and the results must meet all method requirements for analyte identification (e.g., ion abundance, second column confirmation, or pattern recognition). For data systems that do not provide a measure of noise, the signal produced by the verification sample must produce a result that is at least three standard deviations greater than the mean method blank concentration. This is initially estimated based on a minimum of four method blank analyses and later established with a minimum of 20 method blank results.
- If the LOD verification fails, then the laboratory must repeat the MDL determination and LOD verification or perform and pass two consecutive LOD verifications at a higher spike concentration and set the LOD at the higher concentration.
- The laboratory shall maintain documentation for all MDL determinations and LOD verifications.
- The DL and LOD must be reported for all analyte-matrix-methods suites unless it is not applicable to the test or specifically excluded by project requirements.

4.12 The LOD shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOD verifications on a one per batch basis. All verification data will be in compliance, reported, and available for review.

4.13 For DoD, at a minimum, the LOQ shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOQ verifications on a one per batch basis.

4.14 All initial instrument calibrations must be verified with a standard obtained from a second manufacturer prior to analyzing any samples. The use of a standard from a second lot obtained from the same manufacturer (independently prepared from different source materials) is acceptable for use as a second source standard. The concentration of the second source standard shall be at or near the midpoint of the calibration range. The acceptance criteria for the initial calibration verification must be at least as stringent as those for the continuing calibration verification.

4.15 Exclusion of calibration points without documented scientifically valid technical justification is not permitted.

4.16 The concentration of the CCV standard shall be greater than the low calibration standard and less than or equal to the midpoint of the calibration range.

4.17 All CCVs analyzed must be evaluated and reported. If a CCV fails, reanalysis or corrective actions must be taken.

- If a CCV fails, the laboratory can immediately analyze two additional consecutive CCVs (immediately is defined as starting a consecutive pair within one hour; no samples can be run between the failed CCV and the two additional CCVs). This approach allows for spurious failures of analytes to be reported without reanalysis of samples. Any corrective actions that change the dynamics of the system (e.g., clip column, clean injection port, run blanks) requires that all samples since the last acceptable CCV be reanalyzed.

- Both of these CCVs must meet acceptance criteria in order for the samples to be reported without reanalysis.
- If either of these two CCVs fail or if the laboratory cannot immediately analyze two CCVs, the associated samples cannot be reported and must be reanalyzed.
- Corrective action(s) and recalibration must occur if the above scenario fails. All affected samples since the last acceptable CCV must be reanalyzed.
- Flagging of data for a failed CCV is only appropriate when the affected samples cannot be reanalyzed. The laboratory must notify the client prior to reporting data associated with a failed CCV.

4.18 The results of all MS/MSDs must be evaluated using the same acceptance criteria used for the DoD LCS limits (see Tables 3 and 4) or project limits, if specified. If the specific analyte(s) are not available in the Tables 3 and 4, the laboratory shall use their LCS in-house limits (see the LIMS) as a means of evaluating MS/MSDs. The MS and MSD must be spiked with all reported analytes.

4.19 Surrogate spike results shall be compared with DoD LCS limits (see Tables 3 and 4) or acceptance criteria specified by the client. If these criteria are not available, the laboratory shall compare the results with its in-house statistically established LCS criteria (see the LIMS).

4.20 The method blank shall be considered to be contaminated if:

- The concentration of any target analyte (chemical of concern) in the blank exceeds 1/2 the LOQ and is greater than 1/10th the amount measured in any associated sample, or 1/0th the regulatory limit, whichever is greater.
- The concentration of any common laboratory contaminant in the blank exceeds the LOQ.
- If a method blank is contaminated as described above, then the laboratory shall reprocess affected samples in a subsequent preparation batch, except when sample results are below the LOD. If insufficient sample volume remains for reprocessing, the results shall be reported with appropriate data qualifiers.

4.21 Sporadic Marginal Exceedances are not allowed for target analytes (chemicals of concern as identified by a project) without project-specific approval. Target analytes are considered those few analytes that are critical for the success of a project (such as risk drivers) where sporadic marginal exceedances cannot be allowed. Laboratories should consult with clients whenever long lists of analytes are requested for analysis to determine if marginal exceedances will not be allowed.

4.22 DoD considers the same analyte exceeding the LCS control limit two (2) out of three (3) consecutive LCS to be indicative of non-random behavior, which requires corrective action and reanalysis of the LCS.

Table 3. LCS Control Limits – Method 8260 Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
630-20-6	1,1,1,2-Tetrachloroethane	11115	101.1	7.8	78	125
71-55-6	1,1,1-Trichloroethane	12156	101.6	9.4	73	130
79-34-5	1,1,2,2-Tetrachloroethane	11670	97	8.9	70	124
79-00-5	1,1,2-Trichloroethane	11772	99.7	7.2	78	121
76-13-1	1,1,2-Trifluoro-1,2,2-trichloroethane [Freon-113]	9760	100.8	11.7	66	136
75-34-3	1,1-Dichloroethane	11856	100.4	8.1	76	125
75-35-4	1,1-Dichloroethene	12352	100.3	10.1	70	131
563-58-6	1,1-Dichloropropene	10793	100.5	8.3	76	125
87-61-6	1,2,3-Trichlorobenzene	10572	97.8	10.6	66	130
96-18-4	1,2,3-Trichloropropane	10925	99.1	8.8	73	125
526-73-8	1,2,3-Trimethylbenzene	1948	99.8	6	82	118
120-82-1	1,2,4-Trichlorobenzene	10980	98	10.4	67	129
95-63-6	1,2,4-Trimethylbenzene	11085	98.7	7.9	75	123
96-12-8	1,2-Dibromo-3-chloropropane	11380	96.6	11.7	61	132
106-93-4	1,2-Dibromoethane	11408	100.1	7.3	78	122
95-50-1	1,2-Dichlorobenzene	11785	99.1	7.2	78	121
107-06-2	1,2-Dichloroethane	12328	100.5	9.2	73	128
17060-07-0	1,2-Dichloroethane-d4	5951	103.1	10.8	71	136
540-59-0	1,2-Dichloroethene	7748	99.9	7.3	78	122
78-87-5	1,2-Dichloropropane	12145	99.5	7.8	76	123
354-23-4	1,2-Dichlorotrifluoroethane [Freon 123a]	1269	97.8	11.3	64	132
108-70-3	1,3,5-Trichlorobenzene	4723	99.4	9.6	71	128
108-67-8	1,3,5-Trimethylbenzene	11080	98.4	8.4	73	124
541-73-1	1,3-Dichlorobenzene	11619	98.9	7.4	77	121
142-28-9	1,3-Dichloropropane	10713	99.1	7.3	77	121
542-75-6	1,3-Dichloropropene	3714	101.6	8.1	77	126
106-46-7	1,4-Dichlorobenzene	11848	97.5	7.6	75	120
105-05-5	1,4-Diethylbenzene	1896	96.6	5.9	79	114
123-91-1	1,4-Dioxane	7698	96.4	13.7	55	138
544-10-5	1-Chlorohexane	2543	100.4	9.8	71	130
594-20-7	2,2-Dichloropropane	10703	99.7	11.1	67	133
78-93-3	2-Butanone [MEK]	11514	99.6	16.3	51	148
126-99-8	2-Chloro-1,3-butadiene	6667	99	11.3	65	133
110-75-8	2-Chloroethyl vinyl ether	6957	96.1	17.6	43	149
95-49-8	2-Chlorotoluene	10838	98.5	7.9	75	122
591-78-6	2-Hexanone	11004	99.1	15.4	53	145
79-46-9	2-Nitropropane	4969	98.3	17.1	47	150
67-63-0	2-Propanol [Isopropyl alcohol]	1696	99.8	13.4	60	140
460-00-4	4-Bromofluorobenzene	6267	98.9	6.8	79	119
106-43-4	4-Chlorotoluene	10785	98.3	8.6	72	124
108-10-1	4-Methyl-2-pentanone [MIBK]	11364	99.6	11.6	65	135
67-64-1	Acetone	11089	99.6	21.4	36	164
75-05-8	Acetonitrile	5697	98.5	14.8	54	143
107-02-8	Acrolein [Propenal]	7528	101.1	18	47	155

Table 3. LCS Control Limits – Method 8260 Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
107-13-1	Acrylonitrile	8293	99.7	11.4	65	134
107-05-1	Allyl chloride	6908	101.1	11.2	68	135
71-43-2	Benzene	12853	99.2	7.4	77	121
100-44-7	Benzyl chloride	2743	92.1	9.4	64	120
108-86-1	Bromobenzene	10974	99.3	7.3	78	121
74-97-5	Bromochloromethane	11023	101.4	7.8	78	125
75-27-4	Bromodichloromethane	11850	101	8.5	75	127
75-25-2	Bromoform	11890	99.1	10.8	67	132
74-83-9	Bromomethane	11416	98.3	15	53	143
75-15-0	Carbon disulfide	11132	97.9	11.5	63	132
56-23-5	Carbon tetrachloride	12090	102.3	10.7	70	135
108-90-7	Chlorobenzene	12382	99.7	6.9	79	120
124-48-1	Chlorodibromomethane	11852	100.2	8.7	74	126
75-00-3	Chloroethane	11444	98.8	13.3	59	139
67-66-3	Chloroform	12344	100.3	7.6	78	123
74-87-3	Chloromethane	11876	93.3	14.3	50	136
156-59-2	cis-1,2-Dichloroethene	11645	99.9	7.6	77	123
10061-01-5	cis-1,3-Dichloropropene	11805	99.8	8.7	74	126
1476-11-5	cis-1,4-Dichloro-2-butene	977	106	12.4	69	143
110-82-7	Cyclohexane	8827	98.9	10.6	67	131
108-94-1	Cyclohexanone	3764	93.2	20.9	30	156
1868-53-7	Dibromofluoromethane	2142	98.1	6.8	78	119
74-95-3	Dibromomethane	10913	101.1	7.9	78	125
75-71-8	Dichlorodifluoromethane [Freon-12]	11467	88.9	20.1	29	149
75-05-8	Acetonitrile	5697	98.5	14.8	54	143
107-02-8	Acrolein [Propenal]	7528	101.1	18	47	155
107-13-1	Acrylonitrile	8293	99.7	11.4	65	134
107-05-1	Allyl chloride	6908	101.1	11.2	68	135
71-43-2	Benzene	12853	99.2	7.4	77	121
100-44-7	Benzyl chloride	2743	92.1	9.4	64	120
108-86-1	Bromobenzene	10974	99.3	7.3	78	121
74-97-5	Bromochloromethane	11023	101.4	7.8	78	125
75-27-4	Bromodichloromethane	11850	101	8.5	75	127
75-25-2	Bromoform	11890	99.1	10.8	67	132
74-83-9	Bromomethane	11416	98.3	15	53	143
75-15-0	Carbon disulfide	11132	97.9	11.5	63	132
56-23-5	Carbon tetrachloride	12090	102.3	10.7	70	135
108-90-7	Chlorobenzene	12382	99.7	6.9	79	120
124-48-1	Chlorodibromomethane	11852	100.2	8.7	74	126
75-00-3	Chloroethane	11444	98.8	13.3	59	139
67-66-3	Chloroform	12344	100.3	7.6	78	123
74-87-3	Chloromethane	11876	93.3	14.3	50	136
156-59-2	cis-1,2-Dichloroethene	11645	99.9	7.6	77	123
10061-01-5	cis-1,3-Dichloropropene	11805	99.8	8.7	74	126
1476-11-5	cis-1,4-Dichloro-2-butene	977	106	12.4	69	143

Table 3. LCS Control Limits – Method 8260 Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
110-82-7	Cyclohexane	8827	98.9	10.6	67	131
108-94-1	Cyclohexanone	3764	93.2	20.9	30	156
1868-53-7	Dibromofluoromethane	2142	98.1	6.8	78	119
74-95-3	Dibromomethane	10913	101.1	7.9	78	125
75-71-8	Dichlorodifluoromethane [Freon-12]	11467	88.9	20.1	29	149
75-43-4	Dichlorofluoromethane	717	100.8	18	47	155
60-29-7	Diethyl ether	6283	99.6	9.6	71	129
108-20-3	Diisopropyl ether	8542	98.3	9.7	69	127
64-17-5	Ethanol	3958	102.2	18.9	45	159
141-78-6	Ethyl acetate	4516	95.4	14.5	52	139
97-63-2	Ethyl methacrylate	7075	98.9	9.9	69	129
637-92-3	Ethyl tert-butyl ether	7514	98.9	9.1	72	126
100-41-4	Ethylbenzene	12427	99.1	7.7	76	122
462-06-6	Fluorobenzene	689	97.3	5.4	81	114
142-82-5	Heptane	5420	93.4	14.9	49	138
87-68-3	Hexachlorobutadiene	10264	98.1	12.4	61	135
67-72-1	Hexachloroethane	3265	102.5	10.1	72	133
110-54-3	Hexane	7116	93.6	16.1	45	142
74-88-4	Iodomethane	9457	100.9	10.1	71	131
78-83-1	Isobutyl alcohol	6162	97.5	12.6	60	135
108-21-4	Isopropyl acetate [Acetic acid]	2885	94.2	12.2	58	131
98-82-8	Isopropylbenzene	11596	100.8	11.1	68	134
179601-23-1	m/p-Xylene [3/4-Xylene]	10612	100.4	7.7	77	124
126-98-7	Methacrylonitrile	6736	99.2	11.1	66	132
79-20-9	Methyl acetate	8320	98.7	15.2	53	144
80-62-6	Methyl methacrylate	7050	98.4	11.9	63	134
1634-04-4	Methyl tert-butyl ether [MTBE]	11253	98.9	8.7	73	125
108-87-2	Methylcyclohexane	8565	99.4	11.2	66	133
75-09-2	Methylene chloride	12024	98.9	9.7	70	128
123-86-4	n-Butyl acetate	2981	95.1	11	62	128
71-36-3	n-Butyl alcohol	4800	92.9	12.6	55	131
104-51-8	n-Butylbenzene	10921	98.7	9.7	70	128
103-65-1	n-Propylbenzene	10947	98.9	8.8	73	125
91-20-3	Naphthalene	10602	95.6	11.2	62	129
95-47-6	o-Xylene	11940	100	7.7	77	123
99-87-6	p-Isopropyltoluene [p-Cymene]	10953	100.3	9	73	127
76-01-7	Pentachloroethane	5957	102	11.1	69	135
107-12-0	Propionitrile [Ethyl cyanide]	6734	101	11.1	68	134
135-98-8	sec-Butylbenzene	10960	99	8.8	73	126
100-42-5	Styrene	11809	100.2	8	76	124
994-05-8	tert-Amyl methyl ether [TAME]	7153	99.8	8.9	73	126
75-65-0	tert-Butyl alcohol	7492	100.5	10.7	68	133
98-06-6	tert-Butylbenzene	10974	98.8	8.6	73	125

Table 3. LCS Control Limits – Method 8260 Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
127-18-4	Tetrachloroethene	12091	100.5	9.2	73	128
109-99-9	Tetrahydrofuran	8039	98	12.4	61	135
108-88-3	Toluene	12499	99.3	7.3	77	121
2037-26-5	Toluene-d8	6232	100.7	5.2	85	116
156-60-5	trans-1,2-Dichloroethene	11849	99.2	8.6	74	125
10061-02-6	trans-1,3-Dichloropropene	11805	100.9	9.8	71	130
110-57-6	trans-1,4-Dichloro-2-butene	8307	98.6	12.3	62	136
79-01-6	Trichloroethene	12440	100.2	7.6	77	123
75-69-4	Trichlorofluoromethane [Freon-11]	11530	101	13.1	62	140
108-05-4	Vinyl acetate	7260	100.3	16.9	50	151
75-01-4	Vinyl chloride	12129	95.6	13.2	56	135
1330-20-7	Xylenes [total]	8623	100.7	7.7	78	124
104-51-8	n-Butylbenzene	10921	98.7	9.7	70	128
103-65-1	n-Propylbenzene	10947	98.9	8.8	73	125
91-20-3	Naphthalene	10602	95.6	11.2	62	129
95-47-6	o-Xylene	11940	100	7.7	77	123
99-87-6	p-Isopropyltoluene [p-Cymene]	10953	100.3	9	73	127
76-01-7	Pentachloroethane	5957	102	11.1	69	135
107-12-0	Propionitrile [Ethyl cyanide]	6734	101	11.1	68	134
135-98-8	sec-Butylbenzene	10960	99	8.8	73	126
100-42-5	Styrene	11809	100.2	8	76	124
994-05-8	tert-Amyl methyl ether [TAME]	7153	99.8	8.9	73	126
75-65-0	tert-Butyl alcohol	7492	100.5	10.7	68	133
98-06-6	tert-Butylbenzene	10974	98.8	8.6	73	125
127-18-4	Tetrachloroethene	12091	100.5	9.2	73	128
109-99-9	Tetrahydrofuran	8039	98	12.4	61	135
108-88-3	Toluene	12499	99.3	7.3	77	121
2037-26-5	Toluene-d8	6232	100.7	5.2	85	116
156-60-5	trans-1,2-Dichloroethene	11849	99.2	8.6	74	125
10061-02-6	trans-1,3-Dichloropropene	11805	100.9	9.8	71	130
110-57-6	trans-1,4-Dichloro-2-butene	8307	98.6	12.3	62	136
79-01-6	Trichloroethene	12440	100.2	7.6	77	123
75-69-4	Trichlorofluoromethane [Freon-11]	11530	101	13.1	62	140
108-05-4	Vinyl acetate	7260	100.3	16.9	50	151
75-01-4	Vinyl chloride	12129	95.6	13.2	56	135
1330-20-7	Xylenes [total]	8623	100.7	7.7	78	124

Table 4. LCS Control Limits – Method 8260 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
630-20-6	1,1,1,2-Tetrachloroethane	24511	101.1	7.6	78	124
71-55-6	1,1,1-Trichloroethane	28223	102.7	9.6	74	131
79-34-5	1,1,2,2-Tetrachloroethane	27450	96.4	8.3	71	121
79-00-5	1,1,2-Trichloroethane	27338	99.5	6.5	80	119
76-13-1	1,1,2-Trifluoro-1,2,2-trichloroethane [Freon-113]	21122	103	11.1	70	136
75-34-3	1,1-Dichloroethane	28154	101.3	8	77	125
75-35-4	1,1-Dichloroethene	29436	101	10	71	131
563-58-6	1,1-Dichloropropene	23631	102	7.8	79	125
87-61-6	1,2,3-Trichlorobenzene	24271	98.7	10.1	69	129
96-18-4	1,2,3-Trichloropropane	24525	97.5	8	73	122
526-73-8	1,2,3-Trimethylbenzene	2965	100.9	6.2	82	120
120-82-1	1,2,4-Trichlorobenzene	25290	99.8	10.1	69	130
95-63-6	1,2,4-Trimethylbenzene	27917	99.6	8	76	124
96-12-8	1,2-Dibromo-3-chloropropane	24955	94.9	11.1	62	128
106-93-4	1,2-Dibromoethane	29096	99	7.2	77	121
95-50-1	1,2-Dichlorobenzene	27583	99.4	6.5	80	119
107-06-2	1,2-Dichloroethane	32965	100.3	9.2	73	128
17060-07-0	1,2-Dichloroethane-d4	8673	99.5	6.1	81	118
540-59-0	1,2-Dichloroethene	18667	100.2	7.1	79	121
78-87-5	1,2-Dichloropropane	27787	100.1	7.2	78	122
354-23-4	1,2-Dichlorotrifluoroethane [Freon 123a]	3144	103.1	10.9	70	136
108-70-3	1,3,5-Trichlorobenzene	10037	102.1	9.2	75	130
108-67-8	1,3,5-Trimethylbenzene	27820	99.5	8.1	75	124
106-99-0	1,3-Butadiene	1202	100.6	19.2	43	158
541-73-1	1,3-Dichlorobenzene	26951	99.7	6.5	80	119
142-28-9	1,3-Dichloropropane	23811	99.1	6.5	80	119
542-75-6	1,3-Dichloropropene	9784	99.9	7.6	77	123
106-46-7	1,4-Dichlorobenzene	27715	98.3	6.5	79	118
105-05-5	1,4-Diethylbenzene	1980	98.4	6.4	79	118
123-91-1	1,4-Dioxane	17866	99	13.4	59	139
544-10-5	1-Chlorohexane	5790	99.6	8	76	124
540-84-1	2,2,4-Trimethylpentane [Isooctane]	5432	95.2	12.3	58	132
594-20-7	2,2-Dichloropropane	23775	99.7	13.2	60	139
75-85-4	2-Butanol	4332	92.7	9.1	66	120
78-93-3	2-Butanone [MEK]	26659	99.6	14.6	56	143
126-99-8	2-Chloro-1,3-butadiene	15673	100	11.7	65	135
110-75-8	2-Chloroethyl vinyl ether	18225	94.7	14.7	51	139
95-49-8	2-Chlorotoluene	23750	100	7.2	79	122
591-78-6	2-Hexanone	25368	97.9	13.5	57	139
91-57-6	2-Methylnaphthalene	3754	79.4	20.9	17	142
79-46-9	2-Nitropropane	10213	92.6	14.5	49	136
67-63-0	2-Propanol [Isopropyl alcohol]	2034	98.8	14.4	56	142
624-95-3	3,3-Dimethyl-1-butanol	6491	90.9	13.9	49	133

Table 4. LCS Control Limits – Method 8260 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
460-00-4	4-Bromofluorobenzene	9971	99.7	4.9	85	114
106-43-4	4-Chlorotoluene	23616	99.9	7.4	78	122
108-10-1	4-Methyl-2-pentanone [MIBK]	25796	98.5	10.6	67	130
67-64-1	Acetone	25006	99.5	20.1	39	160
75-05-8	Acetonitrile	13308	95.8	15.2	50	142
106-99-0	1,3-Butadiene	1202	100.6	19.2	43	158
541-73-1	1,3-Dichlorobenzene	26951	99.7	6.5	80	119
142-28-9	1,3-Dichloropropane	23811	99.1	6.5	80	119
542-75-6	1,3-Dichloropropene	9784	99.9	7.6	77	123
106-46-7	1,4-Dichlorobenzene	27715	98.3	6.5	79	118
105-05-5	1,4-Diethylbenzene	1980	98.4	6.4	79	118
123-91-1	1,4-Dioxane	17866	99	13.4	59	139
544-10-5	1-Chlorohexane	5790	99.6	8	76	124
540-84-1	2,2,4-Trimethylpentane [Isooctane]	5432	95.2	12.3	58	132
594-20-7	2,2-Dichloropropane	23775	99.7	13.2	60	139
75-85-4	2-Butanol	4332	92.7	9.1	66	120
78-93-3	2-Butanone [MEK]	26659	99.6	14.6	56	143
126-99-8	2-Chloro-1,3-butadiene	15673	100	11.7	65	135
110-75-8	2-Chloroethyl vinyl ether	18225	94.7	14.7	51	139
95-49-8	2-Chlorotoluene	23750	100	7.2	79	122
591-78-6	2-Hexanone	25368	97.9	13.5	57	139
91-57-6	2-Methylnaphthalene	3754	79.4	20.9	17	142
79-46-9	2-Nitropropane	10213	92.6	14.5	49	136
67-63-0	2-Propanol [Isopropyl alcohol]	2034	98.8	14.4	56	142
624-95-3	3,3-Dimethyl-1-butanol	6491	90.9	13.9	49	133
460-00-4	4-Bromofluorobenzene	9971	99.7	4.9	85	114
106-43-4	4-Chlorotoluene	23616	99.9	7.4	78	122
108-10-1	4-Methyl-2-pentanone [MIBK]	25796	98.5	10.6	67	130
67-64-1	Acetone	25006	99.5	20.1	39	160
75-05-8	Acetonitrile	13308	95.8	15.2	50	142
107-02-8	Acrolein [Propenal]	16380	96.8	19.3	39	155
107-13-1	Acrylonitrile	20173	99	11.9	63	135
107-05-1	Allyl chloride	15758	99	10.4	68	130
71-43-2	Benzene	34376	99.4	6.9	79	120
100-44-7	Benzyl chloride	10675	90.1	15.9	42	138
108-86-1	Bromobenzene	23762	99.7	6.7	80	120
74-97-5	Bromochloromethane	24356	100.8	7.5	78	123
75-27-4	Bromodichloromethane	26888	101.8	7.8	79	125
75-25-2	Bromoform	27675	97.8	10.8	66	130
74-83-9	Bromomethane	26717	97	14.7	53	141
75-15-0	Carbon disulfide	25719	98.8	11.5	64	133
56-23-5	Carbon tetrachloride	28870	103.8	10.7	72	136
108-90-7	Chlorobenzene	29802	100	6.1	82	118
124-48-1	Chlorodibromomethane	27424	100	8.5	74	126
75-45-6	Chlorodifluoromethane	7197	84.4	14.9	40	129

Table 4. LCS Control Limits – Method 8260 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
75-00-3	Chloroethane	27069	99	13	60	138
67-66-3	Chloroform	29373	101.1	7.5	79	124
74-87-3	Chloromethane	27697	94.5	15	50	139
156-59-2	cis-1,2-Dichloroethene	27935	100.1	7.5	78	123
10061-01-5	cis-1,3-Dichloropropene	27197	99.5	8	75	124
1476-11-5	cis-1,4-Dichloro-2-butene	1524	101.5	14.9	57	146
110-82-7	Cyclohexane	20438	100.4	10	71	130
1868-53-7	Dibromofluoromethane	5702	99.1	6.5	80	119
74-95-3	Dibromomethane	24473	101.1	7.3	79	123
75-71-8	Dichlorodifluoromethane [Freon-12]	25410	92	20.1	32	152
107-02-8	Acrolein [Propenal]	16380	96.8	19.3	39	155
107-13-1	Acrylonitrile	20173	99	11.9	63	135
107-05-1	Allyl chloride	15758	99	10.4	68	130
71-43-2	Benzene	34376	99.4	6.9	79	120
100-44-7	Benzyl chloride	10675	90.1	15.9	42	138
108-86-1	Bromobenzene	23762	99.7	6.7	80	120
74-97-5	Bromochloromethane	24356	100.8	7.5	78	123
75-27-4	Bromodichloromethane	26888	101.8	7.8	79	125
75-25-2	Bromoform	27675	97.8	10.8	66	130
74-83-9	Bromomethane	26717	97	14.7	53	141
75-15-0	Carbon disulfide	25719	98.8	11.5	64	133
56-23-5	Carbon tetrachloride	28870	103.8	10.7	72	136
108-90-7	Chlorobenzene	29802	100	6.1	82	118
124-48-1	Chlorodibromomethane	27424	100	8.5	74	126
75-45-6	Chlorodifluoromethane	7197	84.4	14.9	40	129
75-00-3	Chloroethane	27069	99	13	60	138
67-66-3	Chloroform	29373	101.1	7.5	79	124
74-87-3	Chloromethane	27697	94.5	15	50	139
156-59-2	cis-1,2-Dichloroethene	27935	100.1	7.5	78	123
10061-01-5	cis-1,3-Dichloropropene	27197	99.5	8	75	124
1476-11-5	cis-1,4-Dichloro-2-butene	1524	101.5	14.9	57	146
110-82-7	Cyclohexane	20438	100.4	10	71	130
1868-53-7	Dibromofluoromethane	5702	99.1	6.5	80	119
74-95-3	Dibromomethane	24473	101.1	7.3	79	123
75-71-8	Dichlorodifluoromethane [Freon-12]	25410	92	20.1	32	152
75-43-4	Dichlorofluoromethane	1504	101.5	9.8	72	131
60-29-7	Diethyl ether	17189	98.6	10.2	68	129
108-20-3	Diisopropyl ether	22989	97.5	10.3	67	128
64-17-5	Ethanol	9543	99.2	17.1	48	151
141-78-6	Ethyl acetate	9208	96.8	13.9	55	138
97-63-2	Ethyl methacrylate	16674	98.7	9	72	126
637-92-3	Ethyl tert-butyl ether	19841	98.3	9.4	70	127
100-41-4	Ethylbenzene	33325	99.8	7	79	121
462-06-6	Fluorobenzene	1373	97.9	6.1	80	116

Table 4. LCS Control Limits – Method 8260 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
142-82-5	Heptane	11878	94.4	15	49	140
87-68-3	Hexachlorobutadiene	23535	100.1	11.3	66	134
67-72-1	Hexachloroethane	8718	102.9	10.3	72	134
110-54-3	Hexane	15545	95.5	15.9	48	143
74-88-4	Iodomethane	20229	100	10.4	69	131
78-83-1	Isobutyl alcohol	14123	97.7	11.7	63	133
108-21-4	Isopropyl acetate [Acetic acid]	7216	97.8	11.6	63	133
98-82-8	Isopropylbenzene	28636	101.5	9.9	72	131
179601-23-1	m/p-Xylene [3/4-Xylene]	28168	100.5	6.9	80	121
126-98-7	Methacrylonitrile	15982	97.9	11.6	63	133
79-20-9	Methyl acetate	19698	96	13.2	56	136
80-62-6	Methyl methacrylate	16524	97.7	10.2	67	128
1634-04-4	Methyl tert-butyl ether [MTBE]	29660	97.3	8.8	71	124
108-87-2	Methylcyclohexane	20025	101.8	10.1	72	132
75-09-2	Methylene chloride	27659	99.4	8.3	74	124
123-86-4	n-Butyl acetate	7247	96.8	9.4	69	125
75-43-4	Dichlorofluoromethane	1504	101.5	9.8	72	131
60-29-7	Diethyl ether	17189	98.6	10.2	68	129
108-20-3	Diisopropyl ether	22989	97.5	10.3	67	128
64-17-5	Ethanol	9543	99.2	17.1	48	151
141-78-6	Ethyl acetate	9208	96.8	13.9	55	138
97-63-2	Ethyl methacrylate	16674	98.7	9	72	126
637-92-3	Ethyl tert-butyl ether	19841	98.3	9.4	70	127
100-41-4	Ethylbenzene	33325	99.8	7	79	121
462-06-6	Fluorobenzene	1373	97.9	6.1	80	116
142-82-5	Heptane	11878	94.4	15	49	140
87-68-3	Hexachlorobutadiene	23535	100.1	11.3	66	134
67-72-1	Hexachloroethane	8718	102.9	10.3	72	134
110-54-3	Hexane	15545	95.5	15.9	48	143
74-88-4	Iodomethane	20229	100	10.4	69	131
78-83-1	Isobutyl alcohol	14123	97.7	11.7	63	133
108-21-4	Isopropyl acetate [Acetic acid]	7216	97.8	11.6	63	133
98-82-8	Isopropylbenzene	28636	101.5	9.9	72	131
179601-23-1	m/p-Xylene [3/4-Xylene]	28168	100.5	6.9	80	121
126-98-7	Methacrylonitrile	15982	97.9	11.6	63	133
79-20-9	Methyl acetate	19698	96	13.2	56	136
80-62-6	Methyl methacrylate	16524	97.7	10.2	67	128
1634-04-4	Methyl tert-butyl ether [MTBE]	29660	97.3	8.8	71	124
108-87-2	Methylcyclohexane	20025	101.8	10.1	72	132
75-09-2	Methylene chloride	27659	99.4	8.3	74	124
123-86-4	n-Butyl acetate	7247	96.8	9.4	69	125
71-36-3	n-Butyl alcohol	10122	95.1	12	59	131
104-51-8	n-Butylbenzene	24088	101.1	8.8	75	128
109-60-4	n-Propyl acetate	602	100.8	8.3	76	126
103-65-1	n-Propylbenzene	24419	101	8.5	76	126
91-20-3	Naphthalene	27847	94.6	11.3	61	128

Table 4. LCS Control Limits – Method 8260 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
95-47-6	o-Xylene	31776	100	7.2	78	122
99-87-6	p-Isopropyltoluene [p-Cymene]	24335	102	8.5	77	127
76-01-7	Pentachloroethane	11688	101.1	10.7	69	133
109-66-0	Pentane	3915	74.8	19.7	16	134
107-12-0	Propionitrile [Ethyl cyanide]	15701	99.9	12	64	136
135-98-8	sec-Butylbenzene	24191	101.1	8.1	77	126
100-42-5	Styrene	26985	100.5	7.6	78	123
994-05-8	tert-Amyl methyl ether [TAME]	19726	98.1	10.1	68	128
75-65-0	tert-Butyl alcohol	21112	98.6	10.1	68	129
762-75-4	tert-Butyl formate	6651	98.1	11.1	65	132
98-06-6	tert-Butylbenzene	23919	101	7.7	78	124
127-18-4	Tetrachloroethene	29017	101.3	9.3	74	129
109-99-9	Tetrahydrofuran	18021	95	12.8	57	133
108-88-3	Toluene	33510	100.1	6.8	80	121
2037-26-5	Toluene-d8	9809	100.4	3.8	89	112
156-60-5	trans-1,2-Dichloroethene	27663	99.5	8.2	75	124
10061-02-6	trans-1,3-Dichloropropene	27134	100	8.9	73	127
110-57-6	trans-1,4-Dichloro-2-butene	19320	91.5	16.1	43	140
79-01-6	Trichloroethene	30150	101.1	7.3	79	123
75-69-4	Trichlorofluoromethane	26108	103	12.8	65	141
71-36-3	n-Butyl alcohol	10122	95.1	12	59	131
104-51-8	n-Butylbenzene	24088	101.1	8.8	75	128
109-60-4	n-Propyl acetate	602	100.8	8.3	76	126
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79-01-6	Trichloroethene	30150	101.1	7.3	79	123
75-69-4	Trichlorofluoromethane [Freon-11]	26108	103	12.8	65	141
108-05-4	Vinyl acetate	18941	100.2	15.3	54	146
75-01-4	Vinyl chloride	29472	97.4	13.2	58	137
1330-20-7	Xylenes [total]	23426	100.1	7	79	121

Table 5. Quality Control Requirements – Organic Analysis by Gas Chromatography/Mass Spectrometry

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Tune Check	Prior to ICAL and prior to each 12-hour period of sample analysis.	Specific ion abundance criteria of BFB from method.	Retune instrument and verify.	Flagging is not appropriate.	No samples shall be analyzed without a valid tune.
Initial calibration (ICAL) for all analytes (including surrogates)	At instrument set-up, prior to sample analysis	Each analyte must meet one of the three options below: **Option 1:** RSD for each analyte ≤ 15%; **Option 2:** linear least squares regression for each analyte: $r^2 \geq 0.99$; **Option 3**: non-linear least squares regression (quadratic) for each analyte: $r^2 \geq 0.99$.	Correct problem then repeat ICAL.	Flagging is not appropriate.	Minimum 5 levels for linear and 6 levels for quadratic. No samples shall be analyzed until ICAL has passed. If the specific version of a method requires additional evaluation (e.g., RFs or low calibration standard analysis and recovery criteria) these additional requirements must also be met.
Retention Time window position establishment	Once per ICAL and at the beginning of the analytical sequence.	Position shall be set using the midpoint standard of the ICAL curve when ICAL s performed. On days when ICAL is not performed, the initial CCV is used.	NA.	NA.	Calculated for each analyte and surrogate.
Evaluation of Relative Retention Times (RRT)	With each sample.	RRT of each reported analyte within ± 0.06 RRT units.	Correct problem, then rerun ICAL.	NA	After maintenance is performed which may affect retention times, RRTs may be updated based on the daily CCV. RRTs shall be compared with the most recently updated RRTs.

Table 5. Quality Control Requirements – Organic Analysis by Gas Chromatography/Mass Spectrometry

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis	All reported analytes within ± 20% of true value.	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.
Continuing Calibration Verification (CCV)	Daily before sample analysis; after every 12 hours of analysis time; and at the end of the analytical batch run.	All reported analytes and surrogates within ± 20% of true value. All reported analytes and surrogates within ± 50% for end of analytical batch CCV.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat the CCV and all associated samples since the last successful CCV. Alternately, Recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed. If the specific version of a method requires additional evaluation (e.g., average RFs) these additional requirements must also be met.
Internal standards (IS)	Every field sample, standard and QC sample.	Retention time within ± 10 seconds from retention time of the midpoint standard in the ICAL; EICP area within - 50% to +100% of ICAL midpoint standard. On days when ICAL is not performed, the daily initial CCV can be used.	Inspect mass spectrometer and GC for malfunctions and correct problem. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	If corrective action fails in field samples, data must be qualified and explained in the case narrative. Apply Q-flag to analytes associated with the non-compliant IS. Flagging is not appropriate for failed standards.	

Table 5. Quality Control Requirements – Organic Analysis by Gas Chromatography/Mass Spectrometry

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Method Blank (MB)	One per preparatory batch.	No analytes detected > ½ LOQ or > 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater. Common contaminants must not be detected > LOQ.	Correct problem. If required, reprep and reanalyze MB and all samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid method blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Laboratory Control Sample (LCS)	One per preparatory batch.	A laboratory must use the limits in Tables 3 and 4 for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits (see the LIMS) if project limits are not specified.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Must contain all surrogates and all analytes to be reported. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Matrix Spike (MS)	One per preparatory batch.	A laboratory must use the limits in Tables 3 and 4 for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits (see the LIMS) if project limits are not specified.	Examine the project specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	Must contain all surrogates and all analytes to be reported. For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference, i.e., matrix effect or analytical error.

Table 5. Quality Control Requirements – Organic Analysis by Gas Chromatography/Mass Spectrometry

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Matrix Spike Duplicate (MSD) or Matrix Duplicate (MD)	One per preparatory batch.	A laboratory must use the limits in Tables 3 and 4 for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits (see the LIMS) if project limits are not specified. MSD or MD: RPD of all analytes ≤ 20% (between MS and MSD or sample and MD).	Examine the project specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	MSD: Must contain all surrogates and all analytes to be reported. The data shall be evaluated to determine the source of difference. For Sample/MD: RPD criteria only apply to analytes whose concentration in the sample is greater than or equal to the LOQ.
Surrogate Spike	All field and QC samples.	QC acceptance criteria specified by the project, if available; otherwise use limits in Tables 3 and 4 or in-house LCS limits (see the LIMS) if analyte(s) are not listed.	Correct problem, then reprep and reanalyze all failed samples for all surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference is present, reanalysis may not be necessary, but the client must be notified prior to reporting data and the failures must be discussed in the case narrative.	Apply Q-flag to all associated analytes if acceptance criteria are not met and explain in the case narrative.	Alternative surrogates are recommended when there is obvious chromatographic interference.

Document Information

Document Number:	ENV-SOP-MTJL-0215	**Revision:**	08
Document Title:	Determination Metals and Trace Elements in Various Matrices by ICP-AES (EPA Methods 6010B, 6010C, 6010D [ICP-OES], and 200.7) Including Hardness (EPA Methods 200.7 and 6010B/C/D and SM 2340B)		
Department(s):	Metals		

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All Dates and Times are listed in: Central Time Zone

Signature Manifest

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All dates and times are in Central Time Zone.

ENV-SOP-MTJL-0215

QM Approval

Name/Signature	Title	Date	Meaning/Reason
Regina Stone (006490)	Quality Analyst 3	26 Aug 2020, 09:32:37 AM	Approved

Management Approval

Name/Signature	Title	Date	Meaning/Reason
Jeremiah Gupton (006426)	Manager	26 Aug 2020, 10:04:42 AM	Approved
James Burns (006456)	Manager - EHS	26 Aug 2020, 01:21:09 PM	Approved
Heidi Ferrell (006481)	Manager - Operations	26 Aug 2020, 03:36:32 PM	Approved

1.0 SCOPE AND APPLICATION

STATE NOTE: For samples analyzed in conjunction with the Ohio Voluntary Action Program (VAP) please utilize ENV-SOP-MTJL-0214.

1.1 Inductively coupled plasma-atomic emission spectrometry (ICP-AES) determines trace elements, including metals and some non-metals in solution. This procedure follows the guidelines established in EPA method 200.7 and SW-846 Method 6010B, 6010C, and 6010D for drinking water, waste water, ground water, TCLP, SPLP, and STLC leachates, soils, sludge, sediments, solid wastes, oils, and other digestates after appropriate preparatory procedure is performed.

This procedure is also applicable to reporting calculated values for Calcium, Magnesium, and Total Hardness from values determined using EPA methods 200.7 or 6010B/C/D from groundwater, wastewater and drinking waters. Reporting limits for Hardness are derived from the annual MDL studies for Calcium and Magnesium of the appropriate determinative EPA method. The routine reporting limits for each category of hardness are listed in Table 1.2b.

1.2 This method is applicable for the analytes listed in Table 1.2a and b. Detection limits, sensitivity, and the optimum and linear concentration ranges of the elements can vary with the wavelength, spectrometer, matrix, and instrument operating conditions. Table 1.2 also lists the Reporting Limits (RLs), used routinely by Pace Analytical National Center for Testing & Innovation (Pace National).

Table 1.2a: Environmental Analytes and Reporting Limits *(Subject to change, see section 13.1)*

Analyte	Aqueous				Sediment		
	Ground Water/ Wastewater 6010B/C/D/200.7	Drinking Water 200.7*	RL	Units	Solids 6010B/C/D	RL	Units
Aluminum	✓	✓	00.200	mg/L	✓	2.00	mg/Kg
Antimony	✓	✓	0.010	mg/L	✓	1.00	mg/Kg
Arsenic	✓	✓	00.010	mg/L	✓	1.00	mg/Kg
Barium	✓	✓	0.005	mg/L	✓	0.50	mg/Kg
Beryllium	✓	✓	0.002	mg/L	✓	0.20	mg/Kg
Boron	✓	✓	0.050	mg/L	✓	5.0	mg/Kg
Cadmium	✓	✓	0.002	mg/L	✓	0.20	mg/Kg
Calcium	✓	✓	1.000	mg/L	✓	100	mg/Kg
Chromium	✓	✓	0.010	mg/L	✓	1.00	mg/Kg
Cobalt	✓	✓	0.010	mg/L	✓	1.00	mg/Kg
Copper	✓	✓	0.010	mg/L	✓	1.00	mg/Kg
Iron	✓	✓	0.100	mg/L	✓	10.0	mg/Kg
Lead	✓	✓	0.005	mg/L	✓	0.50	mg/Kg
Lithium	✓		0.015	mg/L	✓	1.50	mg/Kg
Magnesium	✓	✓	1.000	mg/L	✓	100	mg/Kg
Manganese	✓	✓	0.010	mg/L	✓	1.00	mg/Kg
Molybdenum	✓	✓	0.005	mg/L	✓	0.50	mg/Kg
Nickel	✓	✓	0.010	mg/L	✓	1.00	mg/Kg

Analyte	Aqueous				Sediment		
	Ground Water/ Wastewater 6010B/C/D/200.7	Drinking Water 200.7*	RL	Units	Solids 6010B/C/D	RL	Units
Potassium	✓	✓	1.000	mg/L	✓	100	mg/Kg
Selenium	✓	✓	0.010	mg/L	✓	1.00	mg/Kg
Silicon	✓	✓	0.050	mg/L	✓	5.00	mg/Kg
Silver	✓	✓	0.005	mg/L	✓	5.00	mg/Kg
Sulfur	✓	✓	1.0	mg/L	✓		mg/Kg
Sodium	✓	✓	1.000	mg/L	✓	100	mg/Kg
Strontium	✓	✓	0.010	mg/L	✓	1.00	mg/Kg
Thallium	✓	✓	0.010	mg/L	✓	1.00	mg/Kg
Tin	✓	✓	0.050	mg/L	✓	5.00	mg/Kg
Titanium	✓	✓	0.050	mg/L	✓	5.00	mg/Kg
Vanadium	✓	✓	0.010	mg/L	✓	1.00	mg/Kg
Zinc	✓	✓	0.050	mg/L	✓	5.00	mg/Kg

**May not meet required Drinking Water Maximum Contamination Levels (MCLs) using this methodology.*

Table 1.2b: Hardness Categories and Reporting Limits

(Subject to change, see section 13.1)

Hardness:	RL (mg/L)
Calcium Hardness	1.25
Magnesium Hardness	0.41
Total Hardness	1.6

1.3 For the determination of total recoverable analytes in aqueous and solid samples, an acid digestion process is required. Environmental samples for analysis by Method 6010B, 6010C, or 6010D including, TCLP or EP leachates, soils, sludge, sediments, and other solid wastes require an acid digestion prior to analysis. Samples are digested by SW-846 methods 3005 (Acid Digestion of Waters for Total Recoverable Metals), 3010 (Acid Digestion of Aqueous Samples), 3015 (Microwave Digestion of Aqueous Samples), 3050 (Acid Digestion of Sediments, Sludge, Soil, and Oils) and 3051 (Microwave Assisted Digestion of Sediments, Sludge, Soil, and Oils). Digestion methods are found in ENV-SOP-MTJL-0217 and ENV-SOP-MTJL-0219.

1.4 The Clean Water Act has approved EPA Method 200.7 for demonstrating compliance on discharge monitoring for NPDES (National Pollution Discharge Elimination System) permits. 40 CFR136.3 has Guidelines for Establishing Test Procedures for Analysis of Pollutants. The National Primary Drinking Water Regulations for inorganic chemical sampling and analytical requirements can be found in 40 CFR141.23. Updates to these regulations can be found in the current Code of the Federal Register.

1.5 To determine dissolved analytes in aqueous samples, a 0.45µm filtration method is employed then the filtered samples are acidified. To reduce potential interferences, dissolved solids must be <0.2% (w/v).

1.6 Analysis without acid digestion can be used for drinking water samples if the samples have been properly preserved with acid and have turbidity of <1 NTU at the time of analysis. These samples must be acidified to match the acid matrix of the calibration standards and analyzed directly. This total recoverable determination procedure is referred to as "direct analysis". Silver concentration cannot be determined from direct analysis when chloride ions are present as a silver chloride precipitate may be formed. The sample must be acid digested to form a soluble silver chloride complex. Some primary drinking water metal contaminants may require sample concentration to meet regulatory drinking water reporting limits criteria[14.2].

Method 6010D – Samples that are not digested necessitate the use of either an internal standard or should be matrix-matched with the standards. If using the former option, the instrument software should be programmed to correct for the intensity differences of the internal standard between samples and standards. **NOTE**: All samples analyzed by Method 6010 are typically digested.

1.7 When determining boron and silicon in aqueous samples, only plastic, PTFE (Teflon™) sample containers and laboratory glassware must be used. For accurate determination of boron in solid samples, only quartz or PTFE tubes must be used during acid digestion with immediate transfer of an aliquot of the final volume of digestate to a plastic centrifuge tube[14.2].

1.8 For the determination of titanium, white plastic and white printed containers must be avoided as titanium dioxide is used as a white pigment.

1.9 The total recoverable sample digestion procedure dissolves and maintains in solution only minimal concentrations of barium in the presence of free sulfate. For the analysis of barium in samples having varying and unknown concentrations of sulfate, analysis must be completed as soon as possible following sample preparation[14.2].

1.10 Detection limits and linear ranges for the elements vary with the wavelength selected, the spectrometer, and the matrix. Table 1.11 provides a list of routinely used wavelengths and the type of spectrometer view used.

Method 6010D – IDLs are necessarily instrument-specific. Therefore, if needed, an IDL must be determined through a separate experimental study for each instrument. IDLs should be established, at a minimum, on an annual basis for each matrix and for each preparatory/determinative method combination used.

TABLE 1.10: WAVELENGTHS
(exact wavelengths vary slightly depending on the instrument)

Analyte	Wavelength (nm)	Type of View
Aluminum	308.215	Radial
Antimony	206.836	Axial
Arsenic	188.979	Axial
Barium	233.527	Axial
Beryllium	313.107	Radial
Boron	249.772	Radial
Cadmium	214.440	Axial
Calcium	317.933	Radial

Analyte	Wavelength (nm)	Type of View
	373.690	
Chromium	205.560	Axial
Cobalt	228.616	Axial
Copper	324.752	Radial
Iron	259.940 271.441	Radial
Lead	220.353	Axial
Lithium	670.784	Radial
Magnesium	279.077	Radial
Manganese	257.610	Axial
Molybdenum	202.031	Axial
Nickel	232.003	Axial
Potassium	766.490	Radial
Phosphorus	177.495	Axial
Selenium	196.026	Axial
Silicon	251.611	Axial
Silver	328.068	Axial
Sodium	589.592 818.326	Radial
Strontium	407.771	Radial
Sulfur	181.972	Axial
Thallium	190.801	Axial
Tin	189.927	Axial
Titanium	334.940	Radial
Vanadium	292.402	Radial
Zinc	213.857	Axial

1.11 Users of the data generated using this method must state the data-quality objectives (DQOs) prior to analysis.

1.12 Any deviations from this SOP must be documented. Deviations are reflected in a case narrative and the method is reported as modified. Per customer requirement, the procedure and QC criteria described in this SOP can be changed/modified. Authorization from the Operations Manager and Project Manager is required for each modification and Regulatory Affairs approval must also be secured for any deviation.

1.13 An MDL study must be completed at least annually or more frequently if major instrumentation changes occur. Method Detection Limits (MDLs) are performed based on ENV-SOP-MTJL-0016. Updated MDL records are filed and stored in a central location within the department.

1.13.1 Limit of Detection (LOD) and Limit of Quantitation (LOQ) studies are completed at the frequency required by the TNI standard per the procedure identified in the ENV-SOP-MTJL-0016, *Method Detection Limits (MDL), Limits of Detection (LOD), and Limits of Quantitation (LOQ).* Should the procedure be utilized for DoD support; then the frequency of these studies must meet the requirements of the current DoD QSM.

1.14 Linear Dynamic Range (LDR) and Inter-element correction factor (IEC) studies must be analyzed semi-annually for each analytical instrument or when there are major changes/repairs to the instrument[14.5, 14.1]. Instrument Detection Limit studies must be analyzed at least quarterly for each analytical instrument[14.5].

2.0 METHOD SUMMARY AND DEFINITIONS

2.1 The analysis described in this method involves multi-elemental determinations by ICP-AES using sequential or simultaneous instruments. The instrument measures characteristic atomic-line emission spectra by optical spectrometry. Samples are aspirated into the nebulizer and the resulting aerosol is transported to the plasma torch. The emission spectra are dispersed by a grating spectrometer separating the light emitted into the distinct wavelengths generated by each element in the sample. A photosensitive device monitors the intensities of each wavelength line in the spectra. The intensity of light on the photosensitive device produces a signal that is measured and processed by a computer system. Due to the many possible wavelengths of light generated by each element and possible overlapping of high intensity peaks, a background correction technique is required for trace element determination. Background intensities must be measured adjacent to the analyte spectra lines during analysis. The position selected for background intensity measurement can be selected on either or both sides of the analyte wavelength line and must be determined by the complexity of the spectrum adjacent to the analyte line. The position used for background correction must be as free from spectral interference as possible and must reflect the same change in background intensity as occurs at the analyte wavelength. Background correction is not required in cases of line broadening where the background correction measurement would actually degrade the analytical result. The possibility of additional interferences should also be recognized and appropriate corrections made.

2.2 Dissolved Analyte - The concentration of analyte in an aqueous sample that has been passed through a 0.45µm membrane filter assembly prior to sample acidification and digestion.

2.3 Total (Total Recoverable) Analyte – The concentration of analyte determined either by ‘‘direct analysis’’ of an unfiltered acid preserved drinking water sample with turbidity of <1 NTU or by analysis of the solution extract of a solid sample or an unfiltered aqueous sample following digestion by refluxing with hot dilute mineral acid(s) as specified in the method

2.4 Instrument Detection Limit (IDL) - The concentration equivalent to the analyte signal which is equal to three times the standard deviation of a series of 10 replicate measurements of the calibration blank signal at the same wavelength. The IDL assures with 99% certainty that a value is above the instrument noise level.

Note: An IDL is a statistical determination without analytes present used to assess background correction protocols and an MDL is determined with low levels of analytes present to determine instrument sensitivity for each analyte.

2.5 Linear Dynamic Range (LDR) - The range over which the instrument response to analyte concentration remains linear.

2.6 Plasma Solution - A solution that is used to determine the optimum torch height relative to the radio frequency (RF) coil for viewing the spectrum.

2.7 Interference Check Sample (ICS) – A series of five solutions (ICSA, ICSAB, ICSA2, LA, & CE) to verify that inter-element interferences are correctly compensated. The ICS checks provide an adequate on-going test of inter-element correction (IEC) factors. These standards are referred to the Spectra Interference Check (SIC) in EPA Method 200.7

2.7.1 ICSA – A solution containing only the interfering analytes at high concentrations.

2.7.2 ICSAB – A solution containing interferents plus other method analytes at the level of concern, which corresponds to the project specific action limits.

2.7.3 ICSA2 – A solution containing interfering analytes not contained in the ICSA.

2.7.4 LA – A solution containing Lanthinum at a high concentration.

2.7.5 CE – A solution containing Cerium at a high concentration.

2.8 Water Sample - For the purpose of this method, a sample taken from one of the following sources: drinking water, surface water, ground water, storm water, industrial or domestic wastewater.

2.9 Preparation Batch - For method 6010B/C/D/ EPA 200.7 (WW only): A group of samples (not to exceed twenty) of a similar matrix, which have been digested at the same time using the same digestion process and have all necessary QC associated with them. For method 200.7 (DW only): A group of samples (not to exceed ten) of similar matrix, which have been digested at the same time using the same digestion process and have all necessary associated QC.

2.10 Analytical batch - A group of samples that are analyzed in the same sequence with all appropriate preparation and analytical QC.

2.11 Inter-element correction (IEC) coefficient - analyte concentration equivalent arising from a given interferent's concentration.

2.12 Serial Dilution - a dilution and reanalysis of a field sample that is performed once per batch of samples. One sample is diluted 5X and reanalyzed.

2.13 Post Spike – A second aliquot of a field sample that is spiked with known concentrations of target analytes and analyzed to assess recovery of the spike. A post spike must be analyzed when the MS and/or MSD fail due to a suspected matrix effect. One sample is spiked after digestion and analyzed per batch.

2.14 Lower Limit of Quantitation (LLOQ) - A term associated with analysis per the requirements of Method 6010D; the lowest point of quantitation which, in most cases, is the lowest concentration in the calibration curve.

2.15 See the current Quality Assurance Manual for other definitions associated with terms found in this document.

3.0 HEALTH AND SAFETY

3.1 The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

3.2 The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets (SDS) for all hazardous chemicals are available to all personnel. Employees must abide by the environmental, health, and safety (EHS) policies and procedures specified in this SOP and in the Pace National Chemical Hygiene / Safety Manual.

3.3 Personal protective equipment (PPE) such as safety glasses and/or side shields, gloves, a laboratory coat, and shoes that are not cloth, canvas, and/or perforated must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure. When handling glass, needles, knives, or any material with a potential sharp edge, employees must use cut-resistant gloves.

3.4 Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids, bases, or oxidizers in a fume hood whenever possible with the appropriate PPE designed for handing these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

3.5 Spill kits are located in each laboratory department. Employees are to familiarize themselves with the location and contents of each spill kit in their area.

3.6 Universal precautions should be observed when performing any tests or procedures. Hard surfaces, instrument surfaces may be contaminated and should be handled according to good laboratory practices.

3.7 Contact your supervisor or local EHS coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure. Any accidents involving personnel or sample supplies are to be reported immediately to either the Manager and/or to the Safety Officer.

4.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

4.1 All samples must have been collected using a sampling plan that addresses the considerations of this method.

4.2 Samples submitted for analysis that do not meet the requirements contained within this section must be addressed before performing the logging process within the laboratory. In some cases, exceeding the appropriate preservation and storage criteria can cause significant bias in the resulting data. Clients may need to resubmit samples where the conditions during shipment cause uncertainty regarding sample integrity. If samples do not meet the requirements for preservation, sampling, shipment and storage and the client approves the completion of the analytical process, sample results can be qualified per the ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

4.3 Prior to the collection of an aqueous sample, consideration must be given to the type of data required, (i.e., dissolved or total recoverable), so that appropriate preservation and pre-treatment steps can be taken. The pH of all aqueous samples must be assessed immediately prior to sample digestion or "direct analysis" to ensure the sample has been properly preserved. If the field sample is properly preserved, the sample can be held up to 6 months prior to analysis.

4.4 For the determination of dissolved elements, the sample must be filtered through a 0.45µm pore diameter membrane filter to remove the suspended elements or particles. This filtration must take place at the time of collection or as soon thereafter as practically possible. Glass or plastic filtering apparatus are recommended to avoid possible contamination. Only plastic apparatus must be used when the determinations of boron and silica are critical. Use a portion of the filtered sample to rinse the filter flask, discard this portion and collect the required volume of filtrate. Acidify the filtrate with (1:1) nitric acid: water immediately following filtration to pH <2.

4.5 For the determination of total recoverable elements in aqueous samples, samples must not be filtered, but acidified with (1:1) nitric acid: water to pH <2. Preservation may be done at the time of collection; however, to avoid the hazards of strong acid use in the field, possible transport restrictions, or possible contamination, it is recommended that the samples be returned to the laboratory within two weeks of collection and acid preserved upon receipt in the laboratory. Following acidification, the sample must be mixed and equilibrated for 24 hours. The pH is verified at <2 prior to withdrawing an aliquot for acid digestion or "direct analysis". If, for reasons such as high alkalinity, the sample pH is verified to be >2, more acid must be added and the sample equilibrated for another sixteen hours until verified to be pH <2.

4.6 Solid samples require no preservation prior to analysis. Solid samples can be held up to six months from the time of sample collection until preparation and analysis.

4.7 For aqueous samples, a field blank must be prepared and analyzed as required by the data user. Use the same container and preservative as is used in field sample collection. The sample holding time is six (6) months from the date and time of collection until analysis. Samples are preserved to pH <2 with nitric acid.

5.0 INTERFERENCES

5.1 Spectral interferences are caused by background emission from continuous or recombination phenomena, stray light from the line emission of high concentration elements, overlap of a spectral line from another element, or unresolved overlap of molecular band spectra.

5.1.1 Subtracting the background emission determined by measurement(s) adjacent to the analyte wavelength peak can usually compensate for background emission and stray light. The location(s) selected for the measurement of background intensity is determined by the complexity of the spectrum adjacent to the wavelength peak. The location(s) used for routine measurement must be free of off-line spectral interference (inter-element or molecular) or adequately corrected to reflect the same change in background intensity as occurs at the wavelength peak. Changes in background correction must be saved in the instrument method. Background correction can be established by scanning the following three solutions: 1) blank (same as calibration blank); 2) solution, containing analytes at significant concentration to raise a signal above background signal (CCV solution may be used) at mid-range of the curve; 3) solution(s) containing most common interfering elements at high concentration and other interferents as well (ICSAB solution may be used).

5.1.2 Spectral overlaps can be compensated for by equations that correct for inter-element contributions, which involve measuring the interfering elements. When operative and uncorrected, these interferences produce false-positive determinations and are reported as analyte concentrations. Users may apply inter-element correction factors determined on their instruments within tested concentration ranges to compensate (offline or online) for the effects of interfering elements. Consult the method for specific identified interferences.

5.1.3 When inter-element corrections are applied, there is a need to verify their accuracy by analyzing spectral interference check solutions. The IEC's are established by analyzing a solution of the interfering element at a high concentration within the LDR limit, measuring the analyte concentration equivalents arising from the interfering element, calculating the interference factor as analyte reading in mg/L, then dividing by the interfering element concentration. The IEC's are changed in the stored ICP instrument method. Inter-element corrections vary for the same emission line among instruments because of differences in resolution, as determined by the grating plus the entrance and exit slit widths, and by the order of dispersion. Inter-element corrections also vary depending upon the choice of background correction points. Selecting a background correction point where an interfering emission line may appear should be avoided. Inter-element corrections that constitute a major portion of an emission signal may not yield accurate data. Users must not forget that some samples might contain uncommon elements that could contribute spectral interferences.

5.1.4 Interference effects must be evaluated for each individual instrument. For each instrument, intensities vary not only with optical resolution but also with operating conditions (such as power, viewing height and argon flow rate). To determine the appropriate location for offline background correction, the user must scan the area on either side of the peak adjacent to the wavelength and record the apparent emission intensity from all other method analytes. The location selected for background correction must be either free from offline inter-element spectral interference or a computer routine must be used for their automatic correction on all determinations.

5.2 Physical interferences are effects associated with the sample nebulization and transport processes. Changes in viscosity and surface tension can cause significant inaccuracies, especially in samples containing high dissolved solids or high acid concentrations. If physical interferences are present, they must be reduced by such means as using a high-solids nebulizer, diluting the sample, using a peristaltic pump, or using an appropriate internal standard element. Another problem that can occur with high dissolved solids is salt buildup at the tip of the nebulizer, which affects aerosol flow rate and causes instrumental drift. This can be controlled using a high-solids nebulizer, wetting the argon prior to nebulization, using a tip washer, or diluting the sample. Also, it has been reported that better control of the argon flow rates, especially for the nebulizer, improves instrument stability and precision. This is accomplished with the use of mass flow controllers.

5.3 Chemical interferences include molecular-compound formation, ionization effects, and solute-vaporization effects. Normally, these effects are not significant with the ICP-AES technique. If observed, they can be minimized by careful selection of operating conditions (such as incident power and observation height), by buffering of the sample, by matrix matching and by standards addition procedures. Chemical interferences are highly dependent on matrix type.

5.4 Memory interferences result when analytes in a previous sample contribute to the signals measured in a new sample. Memory effects can result from sample deposition on the uptake tubing to the nebulizer and from the buildup of sample material in the plasma torch and spray chamber. The site where these effects occur is dependent on the element and can be minimized by flushing the system with a rinse blank between samples. The possibility of memory interferences must be recognized within an analytical run and suitable rinse times must be used to reduce them.

5.5 Linear Dynamic Range (LDR) study is performed by analyzing a solution of each element at maximal concentration unless the result falls outside 10% RPD. The highest calibration standard for each analyte cannot be greater than the LDR for that analyte. If an interferent is found greater than the LDR and an IEC factor is established between the interferent and analyte of interest, the sample must be diluted for proper correction of inter-element interferences. Instrument methods with different calibration standard concentrations require separate LDR studies.

5.6 Background correction is performed as needed and LDR and IEC studies are completed as required by each published analytical method and whenever significant changes to instrumentation are made. Background, or blank matrix, subtraction is not performed for environmental samples.

6.0 EQUIPMENT AND SUPPLIES

6.1 Inductively coupled plasma emission spectrometer:

6.1.1 Perkin Elmer Model 5300 or Thermo Model 7000 series ICP, or equivalent, with background correction and computer control

6.1.2 Cetac Autosampler or ESI autosampler

6.1.3 Argon gas supply - High purity grade (99.99%). When analyses are conducted frequently, liquid argon is more economical and requires less frequent replacement of tanks than compressed argon in conventional cylinders.

6.2 Narrow-mouth storage bottles, FEP (fluorinated ethylene propylene) with screw closure, 125mL to 1L capacities

6.3 One-piece stem FEP wash bottle with screw closure, 125mL capacity

6.4 Adjustable pipettes (Eppendorf or equivalent), ranges from 2µL to 5000µL

6.5 Class A volumetric flasks for standards preparations

6.6 Polypropylene (PP) conical tubes

6.7 Peristaltic pump

7.0 REAGENTS AND STANDARDS

7.1 All reagents and standards must be recorded in the appropriate preparation log and assigned a unique number. See ENV-SOP-MTJL-0041, *Standard Logger – Tree Operation*. Additional information regarding reagent preparation can be found in the Standards Logger (Tree) digital archive system. All spiking solutions and surrogate standard solutions should be replaced at least every six (6) months or sooner if a problem is detected unless otherwise noted.

7.2 Hydrochloric acid, concentrated (sp. gr. 1.19) - HCl

7.2.1 Hydrochloric acid (1+1) - Add 500mL concentrated HCl to 400mL reagent water and dilute to 1L with reagent water.

7.3 Nitric acid, concentrated (sp. gr. 1.41) - HNO_3

7.3.1 Nitric acid (1+1) - Add 500mL concentrated HNO_3 to 400mL reagent water and dilute to 1L with reagent water.

7.4 Laboratory Reagent water

7.5 ICP Standard List

Calibration	Stock Std Cat #	Working Standard Preparation
RL Standard #1	HP7013-500	50mL of Stock LL Std, 10% rinse to volume 1000mL
0.5ppm Standard #2	HP6928-1L	125mL of 2.0ppm Std, 10% rinse to volume 500mL
1ppm Standard #3		250mL of 2.0ppm, 10% rinse to volume 500mL
2ppm Standard #4		Direct pour
10ppm Standard #5	HP6409-500	Direct pour
250ppm Standard #6	HP4526-1L	500mL of 500ppm Std, 10% rinse to volume 1000mL
500ppm Standard #7		Direct pour
La Standard #8	VHG-PLAN-100	10mL of Stock La Std, 10% rinse to volume 1000mL

Standards	Stock Std Cat #	Working Standard Preparation
ICV	ESC-8	5mL of Stock ICV Std, 10% rinse to volume 500mL
CCV	HP6929-1L	50mL of Stock CCV Std, 10% rinse to volume 1000mL
ICVLL	HP7013-500	50mL of Stock LL Std, 10% rinse to volume 1000mL
CCVLL		50mL of Stock LL Std, 10% rinse to volume 1000mL

Standards	Stock Std Cat #	Working Standard Preparation
ICSA	ICL500-6	50mL of Stock A Std, 10% rinse to volume 500mL
ICSAB	ICL500-6,HP2739-500	50mL of Stock A Std, 5ml of Stock AB Std, 10% rinse to volume 500mL
CE	HP100010-1	5mL of Stock Ce Std, 10% rinse to volume 500mL
ICSA2	varies	5 mL of Stock Std, 10% rinse to volume 500mL
LA	VHG-PLAN-100	10mL of Stock La Std, 10% rinse to volume 1000mL.
IEC / LDR As	HP10003	10mL of Stock As Std, 10% rinse to volume 1000mL
IEC / LDR Co	HP100013	10mL of Stock As Std, 10% rinse to volume 1000mL
IEC / LDR Cr	HP100012	10mL of Stock As Std, 10% rinse to volume 1000mL
IEC / LDR Cu	HP100014	10mL of Stock As Std, 10% rinse to volume 1000mL
IEC / LDR Mn	HP100032	10mL of Stock As Std, 10% rinse to volume 1000mL
IEC / LDR Si	HP100050	10mL of Stock As Std, 10% rinse to volume 1000mL
Internal Std	HP10M67-1,HP10M24-1	1mL of Stock Y, 3mL of Stock In, 10% rinse to volume 1000mL
10% Blank and Rinse	A200C-212	Fill container to 90% with DI water, add HNO3 to volume

7.6 Blanks - Three types of blanks are required for ICP-AES analysis

7.6.1 The calibration blank is used to establish the baseline for the instrument prior to the analysis of the analytical curve. The calibration blank is prepared by acidifying reagent water to the same acid concentration as used for the standards (10% HNO3).

NOTE: The calibration blank must be stored in a FEP bottle to minimize leaching from other container materials that can cause an elevation in the target analytes leached causing an inherent bias in the calibration and quantitation of field samples when baselines are established prior to calibration of the ICP-AES.

7.6.1.1 Following calibration, the Initial Calibration Blank (ICB) is analyzed prior to field sample analyses. A Continuing Calibration Blank (CCB) is analyzed following the CCV after every ten samples and at the end of the analytical sequence to verify on-going acceptable instrument conditions.

7.6.2 The method blank is used to assess possible contamination from the sample preparation procedure. The method blank must contain all the reagents in the same volumes as used in sample preparation. The method blank must be prepared in the same manner as the samples including sample digestion, when applicable.

7.6.3 The rinse blank is prepared by acidifying reagent water to the same concentrations as the acids as used in the calibration blank (10% HNO3). This solution is stored in a convenient manner. The rinse blank is used for equipment “wash out” to flush the sample delivery system and eliminate memory effects (carryover) from previous samples or standards.

7.7 Mixed Calibration Standard Solutions are used to make the following calibration solutions. All standards are prepared in Class A volumetric flasks using adjustable pipettes. The final acid concentration is matrix matched to digested field sample concentrations. See section 7.5 above for preparation of these standards.

Concentration of Target Analytes in Calibration Standards in mg/L

Analyte	STD 1	STD 2	STD 3	STD 4	STD 5	STD 6	STD 7	STD 8
Silver	0.005	0.5	1.0	2.0				
Aluminum	0.2				10	250	500	
Arsenic	0.01	0.5	1.0	2.0				
Boron	0.2		1.0	2.0				
Barium	0.005	0.5	1.0	2.0	10			
Beryllium	0.002	0.5	1.0	2.0				
Calcium	1.0		1.0	2.0	10	250	500	
Cadmium	0.002	0.5	1.0	2.0				
Cerium						10		
Cobalt	0.01	0.5	1.0	2.0				
Chromium	0.01	0.5	1.0	2.0				
Copper	0.01	0.5	1.0	2.0				
Iron	0.10	0.5	1.0	2.0	10	100	200	
Potassium	1.0			2.0	10	50	100	
Phosphorus	0.1	0.5	1.0	2.0				
Lanthanum								10
Lithium	0.015	0.5	1.0					
Magnesium	1.0				10	250	500	
Manganese	0.01	0.5	1.0	2.0				
Molybdenum	0.005	0.5	1.0	2.0				
Sodium	1.0		1.0	2.0	10	250	500	
Nickel	0.01	0.5	1.0	2.0				
Lead	0.005	0.5	1.0	2.0				
Antimony	0.01	0.5	1.0	2.0				
Selenium	0.01	0.5	1.0	2.0				
Silicon	0.2	0.5	1.0	2.0	10			
Strontium	0.01	0.5	1.0	2.0				
Sulfur	1.0		1.0	2.0	10	50	100	
Tin	0.05	0.5	1.0	2.0				
Thallium	0.01	0.5	1.0	2.0				
Vanadium	0.02	0.5	1.0	2.0				
Zinc	0.05	0.5	1.0	2.0				
Titanium	0.05	0.5	1.0	2.0				

7.8 Initial Calibration Verification (ICV) – The ICV is an analytical standard solution from a second source different from the calibration and CCV standards. The ICV is prepared at a mid-range concentration within the linear working range of the instrument. The ICV must have the same acid matrix as the Calibration Standards. See Section 7.5 above for the preparation of this standard.

All analytes are present in the mid-level ICV solution at the following concentrations (mg/L):

Analyte	Concentration
Silver	1.0
Aluminum	10.0
Arsenic	1.0
Boron	1.0
Barium	1.0
Beryllium	1.0
Calcium	10.0
Cadmium	1.0
Cobalt	1.0
Chromium	1.0
Copper	1.0
Iron	10.0
Potassium	10.0
Lithium	1.0
Magnesium	10.0
Phosphorus	1.0

Analyte	Concentration
Manganese	1.0
Molybdenum	1.0
Sodium	10.0
Nickel	1.0
Lead	1.0
Antimony	1.0
Selenium	1.0
Silicon	1.0
Strontium	0.4
Tin	1.0
Thallium	1.0
Vanadium	1.0
Zinc	1.0
Titanium	1.0
Sulfur	10.0

7.9 Continuing Calibration Verification (CCV) – The CCV is the mid-range calibration standard prepared from the same source as the initial calibration curve. The CCV is used to verify the regression of the initial calibration of the instrument and must be repeated following every ten samples and at the conclusion of the sequence. EPA Method 200.7 refers to this standard as the Instrument Performance Check (IPC) standard. See Section 7.5 above for the preparation of this standard.

All analytes are present in the mid-level CCV solution at the following concentrations (mg/L):

Analyte	Concentration
Silver	0.5
Aluminum	10.0
Arsenic	1.0
Boron	1.0
Barium	0.50
Beryllium	0.20
Calcium	50.0
Cadmium	0.50
Cobalt	1.0
Chromium	1.0
Copper	1.0
Iron	10.0
Potassium	50.0
Lithium	1.0

Analyte	Concentration
Manganese	1.0
Molybdenum	0.25
Sodium	50.0
Nickel	1.0
Lead	0.50
Antimony	0.5
Selenium	1.0
Silicon	2.0
Strontium	1.0
Tin	0.5
Thallium	1.0
Vanadium	1.0
Zinc	1.0
Titanium	1.0

Analyte	Concentration	Analyte	Concentration
Magnesium	10.0	Sulfur	5.0
Phosphorus	1.0		

7.10 Low Level Initial/Continuing Calibration Verification for EPA 6010C (ICVLL/CCVLL) –The ICVLL/CCVLL is prepared at a low concentration within the linear working range of the instrument and defines the lowest level of quantitation/reporting. The ICVLL/CCVLL must have the same acid matrix as the calibration standards. See Section 7.5 above for the preparation of this standard.

The concentration of the low-level ICVLL/CCVLL solution is listed in the table below:

Analyte	Concentration (mg/L)	Analyte	Concentration (mg/L)
Silver	0.005	Manganese	0.01
Aluminum	0.2	Molybdenum	0.005
Arsenic	0.01	Sodium	1
Boron	0.2	Nickel	0.01
Barium	0.005	Lead	0.005
Beryllium	0.002	Antimony	0.01
Calcium	1	Selenium	0.01
Cadmium	0.002	Silicon	0.2
Cobalt	0.01	Strontium	0.01
Chromium	0.01	Tin	0.05
Copper	0.01	Thallium	0.01
Iron	0.10	Vanadium	0.02
Potassium	1	Zinc	0.05
Lithium	0.015	Titanium	0.05
Magnesium	1	Sulfur	1.00
Phosphorus	0.1		

7.11 Interference Check Solutions (ICSA, ICSAB, ICSA2, LA, CE) – The ICS checks are prepared to contain known concentrations of interfering elements that provides a test of the correction factors. The ICSA, ICSA2, LA, and CE solutions contains the interfering elements at a high concentration and the ICSAB contains both the interfering analytes at a high concentration and the analytes of interest at 0.5 to 1.0mg/L. EPA Method 200.7 and 6010D refers to this standard as the Spectral Interference Check (SIC) standard. See Section 7.5 above for the preparation of these standards.

7.11.1 The ICSA solution contains 5000mg/L of each Al, Ca, Mg and 2000mg/L Fe.

7.11.2 The ICSAB solution contains all the components at the same concentrations of the ICSA and other target analytes of interest spiked. In the working ICSAB solution, silver, boron, cadmium, nickel, lead, silica, and zinc are present at 1.0mg/L. All other analytes (arsenic, barium, beryllium, cobalt, chromium, copper, manganese, molybdenum, antimony, selenium, tin, thallium, vanadium and titanium) are present at 0.5mg/L.

7.11.3 The ICSA2 solution contains interfering elements that are not in the ICSA. In the working ICSA2 solution, all analytes are present at 10mg/L.

7.11.4 The LA solution contains 10mg/L of La.

7.11.5 The CE solution contains 10mg/L of Ce.

7.12 The IEC / LDR solutions are prepared to contain known concentrations of interfering elements that are used to adjust the IECs and are used for daily LDRs for 6010D. The interfering elements are present at 10mg/L.

7.13 Internal Standards – The internal standard response is used to measure the relative responses of other method analytes in each sample. Yttrium and Indium are used as internal standards. See Section 7.5 above for the preparation of this standard.

7.14 For the preparation of Laboratory Control Samples (LCSs) and Matrix Spikes (MSs) see the applicable sample preparation SOPs.

8.0 PROCEDURE

8.1 Sample Analysis

8.1.1 **Initializing the Instrument:** Prior to daily calibration of the instrument, inspect the sample introduction system including the nebulizer, torch, injector tube for salt deposits, dirt, and debris that would restrict solution flow and affect instrument performance.

8.1.1.1 Replace the uptake tubing daily.

8.1.1.2 If any of the sample introduction parts appear soiled, first remove the part from the instrument by following the maintenance procedure in the instrument manual. Once removed, attempt to clean the part with a dilute solution of 5% nitric acid. Cleaning may be performed using a cotton swab or by submersing the part in the acid solution for no longer than five (5) minutes. If cleaning is successful, dry the part using compressed air or argon and replace it in the instrument. If cleaning does not adequately remove the residue, the part must be replaced with a new one in accordance with the manufacturer’s directions. Replacement parts are kept in the cabinet in the instrument lab.

8.1.2 **Instrument Stability:** The instrument must be allowed to become thermally stable before calibration and analyses. This usually requires at least 30 minutes of operation.

8.1.3 **Instrument Calibration:** For initial and daily operation, calibrate the instrument according to the instrument manufacturer's recommended procedures using mixed calibration standard solutions and the calibration blank. A peristaltic pump is used to introduce all solutions, samples, and the internal standard to the nebulizer. To allow adequate time for equilibrium to be reached in the plasma, aspirate all solutions for at least 30 seconds after the solution reaches the plasma before obtaining the sample analyte response.

8.1.3.1 Use the average value from three replicate analyte responses per sample to be correlated to the overall analyte concentration in the solution being sampled. Flush the system with the rinse blank for a minimum of 60 seconds between each standard.

8.1.3.2 The calibration regression is generated using first order linear regression of a calibration blank and three calibration standards where each element is present. The blank is included as a point in the calibration curve to determine the baseline correction needed for the instrument to effectively quantitate target analyte concentrations.

8.1.3.3 Calibration acceptance criteria are described in section 10.4.

8.1.4 **Internal Standard:** All standards/samples/QC etc. contain yttrium and indium as the internal standards. The instrument adds the internal standards automatically. The instrument injects a constant volume into each solution being analyzed (i.e. standard, blank, field sample, LCS/LCSD/MS/MSD/DUP) and monitors the intensity at the sample level. An internal standard is the chosen alternative to the method of standard additions (MSA). If signal variation results from the sample introduction system (samples of different viscosity, matrix constitution), all the elements are corrected in the same way by an internal standard. If variation results from a variation of the energy transfer, the internal standard most accurately corrects elements of similar energy. Internal standard acceptance criteria are described in section 10.14.

8.1.5 **Calibration Accuracy:** Verify the acceptable initial calibration of the instrument using a standard source that is either an independent lot or entirely different manufacturer to ensure calibration accuracy. After calibrating and rinsing the instrument, analyze the ICV and, if analyzing samples using EPA 6010C, analyze the ICVLL standards. These standards are prepared as directed in section 7.7 and 7.9. Acceptance criteria are described in section 10.5.

8.1.6 **On-going Calibration Stability:** Verify the acceptable on-going instrument calibration by analyzing appropriate check standards during the sequence. Instrument calibration acceptability is demonstrated after every 10 samples using the CCV and CCB and at the end of the analytical run using the CCV, CCVLL (if analyzing EPA 6010C samples), and CCB that must meet the criteria described in sections 10.6 & 10.14.

8.1.7 **Accurate Background Corrections:** The interference check standards (ICSA, ICSAB, ICSA2, LA, and CE) are used to verify the inter-element and background correction factors at the beginning of an analytical run. The ICSA and ICSAB are verified during every 8-hour work shift. The interference check standards must meet the criteria found in section 10.10.

8.1.8 An Initial Calibration Blank (Section 7.5.1) is analyzed before sample analysis is initiated to verify the cleanliness of the analytical system. Acceptance criteria are described in section 10.14.

8.1.9 **Field Sample Analysis:** After completion of the above calibration requirements, samples must be analyzed in the same operational manner used in the calibration routine with the rinse blank also being used between all sample solutions, method blanks, Laboratory Control Standards, matrix spike, matrix spike duplicates, and check solutions.

8.1.10 **Dilutions:** If a sample analyte concentration is quantitated within 90% or greater of the upper limit of the analyte's determined Linear Dynamic Range (LDR), see section 10.4.2 for further guidance.

9.0 DATA ANALYSIS AND CALCULATIONS

9.1 Sample data should be reported in units of mg/L for aqueous samples and mg/kg dry weight corrected for solid samples.

9.2 For dissolved aqueous analytes, report the data generated directly from the instrument with compensation for sample dilution. Never report analyte concentrations below the MDL and if reporting between the MDL and the routine RL, results should be qualified with the appropriate indicator for estimated target analyte concentrations.

9.3 For total recoverable aqueous analytes, multiply solution analyte concentrations by the dilution factor 0.5 when a 100mL aliquot is used to produce the 50mL final digestate volume, and report data. If a different aliquot volume other than 100mL is used for sample preparation, adjust the dilution factor accordingly. Account for any additional dilution of the prepared sample digestate required to complete the determination of any analytes exceeding 90% or greater of the LDR upper limit. Never report analyte concentrations below the MDL and if reporting between the MDL and the routine RL, results should be qualified with the appropriate indicator for estimated target analyte concentration. Routine reporting limits are adjusted for any dilution required by the sample analysis.

9.4 Results are reported to Three significant figures by the laboratory LIMS. Analyte concentrations for solids data should be rounded in a similar manner following dry weight corrections.

9.5 For total recoverable analytes in solid samples, calculate the target analyte concentration using the equation below and do not report analyte data below the estimated solids RL or an adjusted RL based on additional dilutions required to complete the analysis:

$$\text{Sample Conc. (mg/Kg)} = \frac{C \times V \times D}{W}$$
dry-weight basis

where: C = Concentration in extract (mg/L)
V = Volume of extract (L, 100mL = 0. 1L)
D = Dilution factor (undiluted = 1)
W = Weight in Kg of sample aliquot extracted (g x 0.001 = Kg)

9.6 Soil samples are routinely reported on a dry weight basis. Soil samples must be processed using the ENV-SOP-MTJL-0065, *Total Solids*. After a dry weight for each sample has been obtained, the calculations are performed automatically by the laboratory LIMS as follows:

$$\%\ \text{solids (S)} = \frac{DW}{WW} \times 100$$

where: DW = Sample weight (g) dried
WW = Sample weight (g) before drying

9.7 Hardness calculations:

$$\text{Total Hardness, mg equivalent } CaC0_3\text{/L} = 2.497\ [\text{Ca, mg/L}] + 4.118\ [\text{Mg, mg/L}]$$
$$\text{Calcium Hardness} = 2.497\ [\text{Ca, mg/L}]$$
$$\text{Magnesium Hardness} = 4.118\ [\text{Mg, mg/L}]$$

9.8 To calculate the silica concentration from silicon analysis:

$$\text{Silica (mg/L)} = 2.14*[\text{Silicon, mg/L}]$$

9.9 Formula needed to calculate dilution of stock standards of known concentration to a known final volume, using the basic chemistry formula, $C_1*V_1=C_2*V_2$:

$$V_{stock} = V_{std} * C_{std} / C_{stock}$$

where: V_{stock} = volume of stock standard required (mL)
V_{std} = final volume of diluted standard required (mL)
C_{stock} = concentration of stock standard required (µg/mL or µg/L)
C_{std} = final concentration of diluted standard required (µg/mL or µg/L)

NOTE: Be sure to maintain consistent units for both concentration and volume during the use of the calculation and keep in mind that (1µg/mL = 1mg/L=1000µg/L, 1L=1000mL=1000000µL, and 1mL=1000µL)

9.10 Percent Relative Intensity (%RI) for internal standard assessment (ISTD):

$$\%RI = \text{Intensity of ISTD}_{sample} / \text{Intensity of ISTD}_{CalBlk} * 100\%$$

9.11 Relative Standard Error (RSE – expressed as a percentage)

$$RSE = 100 \times \sqrt{\sum_{i=1}^{n}\left[\frac{x'_i - x_i}{x_i}\right]^2 \Big/ (n-p)}$$

where:
x'_i = Measured amount of analyte at the calibration level *i*, in mass or concentration units
x_i = True amount of analyte at calibration level *i*, in mass or concentration units
p = Number of terms in the fitting equation (average – 1, linear = 2, quadratic = 3)

9.12 See the current Quality Assurance Manual for other equations associated with common calculations.

10.0 QUALITY CONTROL AND METHOD PERFORMANCE

10.1 All analysts must meet the qualifications specified in ENV-SOP-MTJL-0015, *Technical Training and Personnel Qualifications,* before approval to perform this method. Analysts must complete an initial demonstration of proficiency before being approved to perform this method. Continuing proficiency must be demonstrated using proficiency testing, laboratory control sample analysis and/or MDL studies. Method performance is assessed per analyst. Updated method performance records are filed and stored in a central location within the department.

10.1.1 Prior to using Method 6010D for quantitation of samples, an initial demonstration of performance packet must be completed. This packet must document:

- The selection criteria for background correction points
- Analytical dynamic ranges including the applicable equations and upper limits of ranges

- IDLs and Method LLOQs
- The determination and verification of interelement correction equations or other routines for correcting spectral interferences. These data must be generated using the same instrument, operating conditions, and calibration routine to be used for sample analysis. The data must be kept on file and available for review by the data user or auditor.

10.2 Use Prep Data to record batch order and standards/reagents used during analysis. See ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

10.3 Batch Analyses

10.3.1 Environmental Preparation Batches: Preparation batches are defined as sets of 1-20 samples as defined in Chapter 1 of SW-846 and in section 9.3.1 of EPA 200.7. Preparation batch analysis must include the following: 1 Method Blank, 1 Laboratory Control Sample (LCS), 1 Laboratory Control Sample Duplicate (LCSD), 1 Serial Dilution, 1 Sample Post Digestion Spike, 1 Matrix Spike/Spike Duplicate (MS/MSD) pair. All batch information is maintained in Prep Data computer program.

10.3.2 Analytical Batches: Analytical batches are defined as a sequence of samples analyzed concurrently using the same calibrated instrument. Analytical batches include the QC samples produced in the Preparation Batches, in addition to: 1 Serial Dilution, 1 Sample Post Digestion Spike, 1 Initial Calibration Verification (ICV) following initial calibration, 1 Initial Calibration Verification-Low Level (ICVLL) following initial calibration (when analyzing EPA 6010C, 6010D and DOD only) 1 Initial Calibration Blank following the ICVLL, 1 Continuing Calibration Verification (CCV) following each 10 samples and at the conclusion of the sequence, 1 Continuing Calibration Verification-Low Level (CCVLL) at the conclusion of the sequence (when analyzing EPA 6010C only), 1 Continuing Calibration Blank (CCB) following each CCV, 1 Interference Check Sample A (ICSA), 1 Interference Check Sample AB (ICSAB), Interference Check Sample 2, 1 Lanthinum Interference Check Sample, and 1 Cerium Interference Check Sample following each initial calibration. A (ICSA) and 1 Interference Check Sample AB (ICSAB) at the end of the sequence or at least twice per each eight (8) hour shift. All batch information is maintained in Prep Data computer program.

10.4 Supporting Analytical Studies

10.4.1 Instrument Detection Limits (IDL) Studies - IDLs in µg/L can be determined as the mean of the calibration blank results plus three times the standard deviation of 10 replicate analyses of the solution. Use zero for the mean if the mean is determined to be a negative value.

IDLs must be verified quarterly[14.13] or when major instrumentation change occurs.

10.4.2 Linear Dynamic Range (LDR) Studies – Linear dynamic ranges are established for each instrument to allow for quantitation above the highest level of calibration without qualification. ICP instruments are known to remain linear at high levels, but each upper limit of linearity is based on the target analyte being measured and the routine instrument operating conditions.

To perform a linear dynamic range study, the instrument must be calibrated normally as used with client field samples. The LDR is determined by the analysis of a minimum of three, but preferably five, different increasing concentrations of standards containing each target analyte across a range. One concentration should be near the expected upper linear range for each analyte. The highest concentration, where the instrument calibration remains linear, is determined when the observed concentration of the increasing standards is no more than 10% below the expected concentration of the analyte. If more than a 10% deviation exists, the instrument is proven to no longer be linear at that value for that analyte. The upper linear range is therefore the next lower concentration of standards used in the determination. Samples quantitated above that upper determined LDR require dilution to quantitate within the proven linear range of the instrument.

LDR studies must be verified semi-annually[14.1] or when major instrumentation change occurs.

Method 6010D - LDR standards must be ran daily within ten percent of true value, or dilute all samples above the high standard in the curve.

STATE NOTE: For work performed in support of the NC Department of Natural Resources (15A NCAC 02H.0805(a)(7)(I)) for target analytes quantitated by ICP or ICPMS, a series of at least three standards must be analyzed along with each group of samples. The concentrations of these standards must bracket the concentration of the analytes in the field samples analyzed. Samples with target analyte concentrations above the highest level of calibration must be diluted to quantitate analytes within the calibration range. The use of the dynamic linear range studies to validate analyte/instrument calibration linearity must not be used for NC sample analysis.

10.4.3 Method Detection Limits – See also ENV-SOP-MTJL-0016, *Method Detection Limits (MDL), Limits of Detection (LOD) and Limits of Quantitation (LOQ)*.

MDL studies are required annually or when instrumentation change occurs. Method detection limit studies are performed on blank matrices most closely matching field sample matrices.

10.4.4 Inter-element Correction Factors – All inter-element spectral correction factors must be verified and updated every six months or when major instrumentation change occurs.[14.1,14.5,].

Criteria for determining an inter-element spectral interference is an apparent positive or negative concentration of an analyte that is outside the 3-sigma control limits of the calibration blank for the analyte. See Attachment II for a listing of potential interfering analytes and their contributions from SW-846 method EPA 6010B. Testing is performed using 100mg/L single element solutions; however, for analytes such as iron that may be found at high concentration, a more appropriate test would be to use a concentration near the upper analytical range limit.

Suggested analytes that are known to commonly interfere include: Ag, Al, As, B, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Si, Sn, Sr, Ti, Tl, V, and Zn.

10.4.5 Proficiency Testing (PT) – See also ENV-SOP-MTJL-0022, *Proficiency Testing Program*. Proficiency testing is performed in the metals department in support of both environmental and industrial hygiene analyses. Environmental PTs are performed semi-annually for Water Supply (Safe Drinking Water Act), Water Pollution (Clean Water Act), and soils (RCRA) testing.

10.5 Initial Calibration - Run a calibration curve on a daily basis that employs a minimum of a calibration blank and three standards for each target analyte. If the correlation coefficient does not meet the acceptance criteria, see the corrective action guidance listed in Section 11.1.

NOTE: For EPA Methods 200.7 & 6010B/D, the linear regression correlation coefficient for the each analyte in the calibration curve lines must be >0.995.

NOTE: For Method 6010D - If a multipoint calibration is used the low standard must be at or below the LLOQ.

NOTE: For EPA Method 6010C, the regression correlation coefficient must be >0.998.

10.6 Initial Calibration Verification (ICV/ICVLL) - Verify the accuracy of the initial instrument standardization by analyzing appropriate check standards following calibration. The routine mid-level ICV must be prepared from a source that is independent of the stock standard used for the preparation of the initial calibration curve. For EPA Method 6010C, a low-level ICV (ICVLL) is also performed as required; however the low level ICV is not required to be from a second source. It may be made from the same stock standard as the calibration standards as long as the initial calibration is verified by a second source in the mid-level ICV.

10.6.1 **EPA Method 6010B/D** - The routine ICV standard recovery results must be ±10% of the true value for EPA method 6010B/D. The RSD must be <5% for the triplicate passes of the spectrometer. If the RSD exceeds 5% and/or the recovery exceeds 10%, locate and correct the cause of the problem and do not proceed until this criterion is met. Corrective actions for failures can be found in section 11.2.

10.6.2 **EPA Method 200.7** - The routine ICV standard recovery results must be ± 5% of the true value for EPA method 200.7. The RSD must be within 3% for the four replicate passes of the spectrometer. If the RSD exceeds 3% and/or the recovery exceeds 5%, locate and correct the cause of the problem and do not proceed until this criterion is met. Corrective actions for failures can be found in section 11.2.

10.6.3 **EPA Method 6010C -** The routine ICV standard recovery results must be ±10% of the true value for EPA methods 6010C. The RSD must be <5% for the triplicate passes of the spectrometer. The ICVLL standard recovery results should be within 70-130%. If the recovery does not meet the criteria for either level of ICV and/or the %RSD is exceeded, locate and correct the cause of the problem and do not proceed until this criterion is met. Corrective actions for failures can be found in section 11.2.

10.6.4 **EPA Method 6010D** Low-level Readback or Verification - For a multi-point calibration, the low level standard should quantitate to within 80-120% of the true value. For a single point calibration, a standard from the same source as the calibration standard and at the LLOQ is analyzed and should recover within 80-120% of the true value.

10.6.5 **EPA Method 6010D** Mid-level Readback or Verification - For a multi-point calibration, the midlevel standard should quantitate to within 90-110% of the true value. For a single point calibration, a standard from the same source as the calibration standard and at the midpoint of the linear range is analyzed and should recover within 90-110% of the true value.

10.7 Continuing Calibration Verification (CCV/CCVLL) - Verify the on-going instrument standardization by analyzing appropriate check standards during the sequence. Verification is achieved by analyzing both a CCV standard and a CCB (instrument blank). Continuing calibration verification standards can be created from either primary or secondary source standards from those used in instrument calibration. Continuing instrument calibration acceptability is demonstrated after every 10 samples and at the end of the analytical run using the CCV that must meet the following criteria per the method being analyzed:

10.7.1 **For SW-846 Method 6010B/D** – Continuing calibration verification (CCV) analyzed after every 10 samples and at the conclusion of the sequence must have a recovery within ±10%. The RSD must be within 5% for the triplicate passes of the spectrometer. The CCVLL recovery should be within ±50%.

10.7.2 **For EPA Method 200.7 -** Continuing calibration verification (CCV) analyzed after every 10 samples and at the conclusion of the sequence must have a recovery within ±10%. The RSD must be within 3% for the triplicate passes of the spectrometer.

10.7.3 **For SW-846 Method 6010C** - Continuing calibration verification (CCV) analyzed after every 10 samples and at the conclusion of the sequence must have a recovery within ±10%. The RSD must be within 5% for the triplicate passes of the spectrometer. The CCVLL recovery should be within ±30%. ICVLL are analyzed at the beginning of the analytical run and CCVLL are analyzed at the end of the analytical run for 6010C.

10.8 Method/Calibration/Rinse Blanks

10.8.1 Method Blank

10.8.1.1 A method blank is generated for each analytical batch during sample preparation to determine if any contamination is introduced during sample processing. A method blank is routinely a volume of reagent water that is carried through the entire digestion and analysis procedure with the samples.

10.8.1.2 The method blank must not contain analytes >MDL or, in the case of common laboratory contaminants, the concentrations should not exceed the RL. Common laboratory contaminants include: Calcium, Potassium, Magnesium, Zinc, Iron and Sodium. If target analytes are present in the method blank, corrective action must be taken. See section 11.5 for corrective actions.

NOTE: Per DoD QSM, version 5.0, Section 1.7.4.1, DoD/DOE require that method blanks be evaluated to ½ RL (LOQ) for target analytes and RL (LOQ) for common laboratory contaminants. If contaminants are present in the blank above this level, samples must be re-prepared and re-analyzed or reported with appropriate qualification.

NOTE: Method 6010D – The method blank is considered to be acceptable if target analyte concentrations are less than ½ the LLOQ or are less than project-specific requirements.

State Note: For Wisconsin samples, the method blank must not contain analytes more negative than the MDL value. If target analytes are more negative than the MDL, the instrument must be recalibrated or a new LOD study performed.

State Note: For West Virginia samples analyzed by Method 6010D, blanks are generally considered to be acceptable if target analyte concentrations are less than ½ the lower limit of quantitation (LLOQ) or are less than project-specific requirements. Blanks may contain analyte concentrations greater than acceptance limits if the associated samples in the batch are unaffected (i.e., targets are not present in samples or sample concentrations are ≥10X the blank). Other criteria may be used depending on the needs of the project.
For West Virginia samples analyzed by Method 200.7, blank values that exceed the MDL indicate laboratory or reagent contamination should be suspected.

10.8.2 Calibration Blank

10.8.2.1 An initial calibration blank is generated for each analytical sequence using acidified reagent water. The CALBLK analyzed prior to the initial calibration standards is used to establish a baseline for the instrument prior to calibration. Great care is required during this analysis to ensure that the baseline is correctly established prior to the calibration of the instrument and the analysis of field samples. Inaccurate baselines established with contaminated calibration blanks degrade precision and accuracy of the analyses performed by creating biases in target analyte calibration.

If the initial calibration blank is grossly negative for a target analyte, then the quantitation of that target analyte in the calibration standards will be biased high due to over compensation by the instrument. This will lead to low recovery issues with the CCV, ICV, field samples, and batch QC samples. If target analytes are present in the CALBLK leading the instrument to make an over correction of the baseline for these targets, then the calibration curve will be biased high yielding a low bias for those target analytes in the CCV, ICV, field samples, and batch QC.

10.8.2.2 Continuing calibration blank (ICB/CCB) is also analyzed following each initial and continuing calibration verification standard within an instrument sequence to verify instrument stability and system cleanliness. This does not baseline correct the instrument for possible contaminants in the background and must be evaluated to ensure that background corrections are appropriate and consistently applied throughout the sequence.

The ICB must not contain analytes > ½ RL, for CCB must not contain analytes >RL for all 6010 methods or, in the case of common laboratory contaminants, the concentrations should not exceed the RL. Common laboratory contaminants include: Calcium, Potassium, Magnesium, Zinc, Iron and Sodium.

NOTE: West Virginia requires all blank results to be less than the MDL. If the concentration of the target analyte is above the MDL, then corrective action and reanalysis is required, or the data must be qualified as including a potential high bias.

10.8.3 Rinse Blank

10.8.3.1 A rinse blank is utilized by the ICP to cleanse the system following the intake of each digestate analyzed. No data is obtained during this rinse and no applicable controls are required for this type of blank. This is merely cleansing the lines throughout the analytical system.

10.9 Matrix Spike/Matrix Spike Duplicate (MS/MSD) - A matrix/matrix spike duplicate must be prepared for each matrix for each batch of 10 samples for method 200.7 or 20 samples for method 6010B/C/D, where sufficient sample volume was submitted by the client. Matrix spike and matrix spike duplicate are prepared from a sample aliquot spiked with the known concentration of analytes.

The matrix spike recoveries must meet the criteria in the table below unless the analyte concentration in the sample is at least four (4) times greater than the spike concentration.

Method	Acceptance Criteria	
	Water	Soil
6010B, C, and D	75 – 125%	75 – 125%
200.7	70-130%	NA

Assess that the matrix spike duplicate precision (%RPD) results meet project-established goals acceptance criteria. If no project goals are specified, then results for the RPD must be less than 20%.

10.10 Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD) - An LCS/LCSD pair must be digested and analyzed with each batch of 20 samples.

10.10.1 **For SW-846 Method 6010B, 6010C, and 6010D** – The LCS recovery must be 80-120%. The RPD must be less than 20%. When using a certified solid reference material for paint chip analysis, the manufacturer's established limits are used for control limits

10.10.2 **For EPA Method 200.7** – The LCS recovery must be 85-115%. The RPD must be less than 20%.

10.11 Interference Check Standards (ICSA/ICSAB/ICSA2/LA/CE) – The ICSA2, LA and CE must be analyzed at the beginning of each analytical run. The ICSA and ICSAB must be analyzed at the beginning and ending of each sequence or twice within each eight (8) hour shift, whichever is more frequent. The recovery of the ICSA and ICSAB elements must be

80-120%. If the results are unsatisfactory, see section 11.10 for further guidance. Do not proceed until this criterion is met.

NOTE: The unspiked elements in the ICSA, ICSA2, LA, and CE are not evaluated by the data capture software. The instrument analyst evaluates whether the unspiked elements are ±LLOQ for the ICSA, ICSA2, LA, and CE.

10.11.1 For Method 6010D two types of SIC checks are used. Individual element SIC checks are performed when the instrument is initially setup, and periodically (at least once every six (6) months) thereafter. The mixed element SIC solution is used daily to check that the instrument is free from interference from elements typically observed in high concentration and to check that and interference corrections applied are still valid.

10.11.1.1 Single element interference checks - At a minimum, single element SIC checks must be performed for the following elements: Aluminum 500mg/L; Boron 50mg/L, Barium, 50mg/L, Calcium 500mg/L; Copper 20mg/L; Iron 200mg/L; Magnesium 500mg/L; Manganese 10mg/L; Molybdenum 20mg/L; Sodium 1000mg/L; Nickel 20mg/L; Selenium 20mg/L; Silicon 100mg/L; Tin 20mg/L; Vanadium 20mg/L; Zinc 10mg/L.

The absolute value of the concentration observed for any unspiked analyte in the single element SIC checks must be ±LLOQ. The concentration of the SIC checks are suggested, but become the highest concentration allowed in a sample analysis, and cannot be higher than the highest established linear range. Samples with concentrations of elements higher than the SIC check must be diluted until the concentration is less than the SIC check solution. Note that reanalysis of a diluted sample is required even if the high concentration element is not required to be reported for the specific sample, since the function of the SIC check is to evaluate spectral interferences on other elements.

The single element SIC checks are performed when the instrument is setup and periodically (at least once every six months) thereafter.

10.11.1.2 Mixed element interference check - The mixed element SIC solution (see section 7.10.3.2) is analyzed at least once per day, immediately after the initial calibration. The concentration measured for any target analytes must be less than ±LLOQ. If this criterion is not met then sample analysis may not proceed until the problem is corrected, or alternatively the LLOQ may be raised to the concentration observed in the SIC solution. The only exceptions are those elements that have been demonstrated to be contaminants in the SIC solutions (see Section 7.10.3.1). These may be present up to the concentration documented plus the LLOQ.

10.12 Serial Dilution (SD) - If the analyte concentration is sufficiently high (minimally 10X the IDL), an analysis of a 1:4 dilution must agree within 10% of the original determination. If not, see section 11.11 for further guidance.

For Method 6010D - If the analyte concentration is within the linear range of the instrument and sufficiently high (minimally, a factor of 25 times greater than the LLOQ), an analysis of a 1:5 dilution should agree to within ±20% of the original determination.

10.13 Post digestion Spike (PS) - An analyte spike added to a portion of a prepared sample, or its dilution and must be recovered to within 75% to 125% of the known value. The spike addition should produce a minimum level of 10 times and a maximum of 100 times the IDL. If the spike is not recovered within the specified limits, see section 11.11 for further guidance.

For Methods 6010C and 6010D – The Post Digestion Spike must recover within ±20% of the known value.

10.14 Internal Standard (ISTD) – Verify the internal standard responses. The intensity of the internal standard response in a sample is monitored and compared to the intensity of the response for that internal standard in the calibration blank. The Percent Relative Intensity (%RI) in the sample must fall within 60-140% of the response in the calibration blank. If the %RI of the response in the sample falls outside of these limits, see sections 9.15 & 11.9 for further guidance.

10.15 Sample Dilution - If a sample analyte concentration is quantitated within 90% or greater of the upper limit of the analyte Linear Dynamic Range (LDR), the sample must be diluted with acidified reagent water and re-analyzed.

10.16 Lower Limit of Quantitation (LLOQ) – When analyzing samples according to Method 6010D, the LLOQ is initially verified by the analysis of at least seven (7) replicate samples, spiked at the LLOQ and processed through all preparation and analysis steps of the method. The mean recovery and relative standard deviation of these samples provide an initial statement of precision and accuracy at the LLOQ. In most cases the mean recovery should be +/- 35% of the true value and RSD should be < 20%. In-house limits may be calculated when sufficient data points exist. Monitoring recovery of LLOQ over time is useful for assessing precision and bias.

10.16.1 Ongoing LLOQ verification, at a minimum, is on a quarterly basis to validate quantitation capability at low analyte concentration levels. This verification may be accomplished either with clean control material (e.g., reagent water, method blanks, Ottawa sand, diatomaceous earth, etc.) or a representative sample matrix (free of target compounds). Optimally, the LLOQ should be less than the desired regulatory action levels based on the stated project-specific requirements.

11.0 DATA VALIDATION AND CORRECTIVE ACTION

11.1 All data must undergo a primary review by the analyst. The analyst must check the performance of the initial calibration, mid-point check standard and continuing calibrations to ensure that they meet the criteria of the method. The analyst should review any sample that has quantifiable compounds and make sure that they have been confirmed, if needed. The analyst must also verify that reported results are derived from quantitation between the RL and the highest standard of the initial calibration curve. All calculations must be checked (any dilutions, %solids, etc.). Data must be checked for the presence or absence of appropriate flags. Comments should be noted when data is flagged.

11.2 All data must then undergo a second analyst review. This review must be performed according to ENV-SOP-MTJL-0014, *Data Handling and Reporting* and ENV-SOP-MTJL-0038*, Data Review*.

11.3 Initial Calibration – After analyzing the calibration standards, the curve is reviewed to ensure the acceptance criteria described in section 10.5 are met. If analytes do not meet this requirement, corrective action must be taken. Corrective actions may include re-calibrating the instrument, replacing the tubing on the peristaltic pump, examining blanks and standards for degradation/contamination, or performing instrument maintenance. If the internal standard responses in the calibration standards do not meet the criteria in section 10.14, re-calibrate the instrument.

11.4 Initial Calibration Verification (ICV) – If the criteria described in section 10.6 are not met for a target analyte, re-analyze the ICV/ICVLL. If this fails a second time, corrective action must be taken. Re-calibrate and re-analyze the ICV/ICVLL using the same standard. If acceptance criteria are still not met, re-check standard curve and ICV/ICVLL preparation and/or perform routine instrument maintenance. If still not acceptable, refer to manufacturer's instruction or call service representative.

11.5 Continuing Calibration Verification (CCV) – The continuing calibration verification standard must agree with the criteria in section 10.7 or the CCV must be re-analyzed. If the recovery fails a second time, corrective action must be taken. The corrective action may require re-calibrate the instrument and re-analyze the last 10 samples, using the same CCV standard. If acceptance criteria are still not met, re-check the standard curve and CCV preparation and/or perform instrument maintenance. If the CCV still does not pass, refer to the manufacturer's instruction or call a service representative.

11.6 Blanks – Evaluate the blanks. The analyst must confirm that both the method blanks and the continuing calibration blanks were analyzed at the required frequency. Other items to check are as follows:

11.6.1 The instrument blank or continuing calibration blank (ICB/CCB) must meet the criteria in section 10.8. Corrective actions for method blank contamination include re-prepping the entire batch of samples, or if the site-specific requirements can be met, an elevated detection limit may be used, or the sample data qualified with a “B” qualifier and footnoted.

State Note: For West Virginia samples analyzed by Method 6010D, if the method blank fails to meet the necessary acceptance criteria, it should be re-analyzed once. If still unacceptable, then all samples associated with the method blank must be re-prepared and re-analyzed, along with all other appropriate analysis batch QC samples. If the method blank results do not meet the acceptance criteria and reanalysis is not practical, then the laboratory should report the sample results along with the method blank results and provide a discussion of the potential impact of the contamination on the sample results. However, if an analyte of interest is found in a sample in the batch near its concentration confirmed in the blank, the presence and/or concentration of that analyte should be considered suspect and may require qualification
For West Virginia samples analyzed by Method 200.7, when blank values constitute 10% or more of the analyte level determined for a sample or is 2.2 times the analyte MDL whichever is greater, fresh aliquots of the samples must be prepared and analyzed again for the affected analytes after the source of

contamination has been corrected and acceptable LRB values have been obtained.

NOTE: Method 6010D - If the method blank fails to meet the necessary acceptance criteria, it should be reanalyzed once. If still unacceptable, then all samples associated with the method blank must be re-prepared and re-analyzed along with all other appropriate analysis batch QC samples. If the method blank results do not meet the acceptance criteria and reanalysis is not practical, then the laboratory should report the sample results along with the method blank results and provide a discussion of the potential impact of the contamination on the sample results. However, if an analyte of interest is found in a sample in the batch near its concentration confirmed in the blank, the presence and/or concentration of that analyte should be considered suspect and may require qualification.

11.7 Laboratory Control Sample (LCS)/Laboratory Control Sample Duplicate (LCSD) – Assess that LCS pairs were prepared at the required frequency. If all target analyte recoveries are not within the criteria described in section 10.10, rinse the instrument and re-analyze. If the LCS/LCSD fails for a second time, re-prepared all samples prepared in conjunction with the failing LCS. The affected samples must be re-digested and re-analyzed along with a new LCS. If there is insufficient volume submitted to re-prepare the field samples, notify the project manager to contact the client for further instruction. Reporting with a qualifier may be performed if acceptable to the client.

11.8 Matrix Spike (MS)/Matrix Spike Duplicate (MSD) – Assess that MS pairs were prepared at the required frequency. If all target analyte recoveries are not within the criteria described in section 10.9, review the post digestion spike results for similar failures. Review the data to see if similar results are also present in the LCS/LCSD. If the LCS/LCSD are acceptable, the MS/MSD failures can be attributed to matrix interferences and the data can be qualified with a J4 and reported. If similar results are seen in the LCS, then re-prepared all samples prepared in conjunction with the failing MS/MSD. In this case, the affected samples must be re-digested and re-analyzed along with a new MS/MSD pair. If there is insufficient volume submitted to re-prepare the field samples, notify the project manager to contact the client for further instruction. Reporting with a qualifier may be performed if acceptable to the client. If insufficient field sample remains for re-analysis, report results with a J3 and an L3.

NOTE: If the sample concentration for an analyte is greater than four times (4x) the spike concentration, a “V” qualifier is used. The “V” qualifier indicates that the high concentration of analyte in the sample interfered with the ability to make an accurate spike recovery determination.

11.9 ISTD – The intensity of the Yttrium internal standard response in each sample is monitored and compared to the intensity of the response for that internal standard in the calibration blank. The Percent Relative Intensity (%RI) in each sample must meet the criteria in section 10.14. If the %RI of the response in the sample falls outside of these limits, the laboratory must immediately re-analyze the calibration blank and monitor the internal standard intensities. If the %RI for that calibration blank is within the limits, the laboratory must re-analyze the original sample at a two-fold dilution due to a possible interference from the matrix on the ISTD. If the %RI for the re-analyzed calibration blank is outside the limits, the analysis must be terminated, the problem corrected, the instrument recalibrated, the new calibration verified, and the samples reanalyzed.

11.10 Interference Check Standards (ICSA/ICSAB/ICSA2/LA/CE) - Evaluate the ICSA, ICSAB, ICSA2, LA, and CE. The analyst must verify that the ICS checks have been analyzed at the required frequency. If the criteria in section 10.11 are not met, check the background correction protocols currently in place for appropriateness. If these are the initial ICS checks run after daily calibration, re-analyze the CALBLANK and re-calibrate the instrument. If the ICSA and/or ICSAB did not agree at the end of an 8-hour shift, re-analyze the ICSA and ICSAB. If failure persists, perform instrument maintenance as needed, recalibrate and re-analyze any samples in the previous run that may have been affected.

11.11 Serial Dilution/Post-digestion Spike – The analyst must verify that the SD and PS have been analyzed at the required frequency. If either of these tests fails to meet the required criteria in sections 10.12 & 10.13, the possibility of a matrix interferent should be suspected. An O1 qualifier is used when either sample type fails due to matrix interferences.

11.11.1 Serial Dilution - An analysis of a 1:4 dilution must agree within 10% of the original determination. If not, a chemical or physical interference effect is suspected.

11.11.2 Post-digestion Spike - The spike addition should produce a minimum level of 10 times and a maximum of 100 times the instrumental detection limit. If the spike is not recovered within the specified limits, a matrix effect is suspected.

CAUTION: If spectral overlap is suspected, use of computerized compensation, an alternate wavelength, or comparison with an alternate method is recommended.

11.12 Data that does not meet acceptable QC criteria may be acceptable for use in certain circumstances.

11.12.1 If a method blank contains an amount of target analyte, but all samples are non-detected, the data may be reported with a “B3” flag. If a method blank contains an amount of target analyte, but the samples contain analyte at a level that is 10 times the level present in the method blanks, the data may be reported with a “B” flag.

11.12.2 If the MS/MSD fails (recovery less than 30% or greater than 150% and/or RPD greater than 30%) in an initial analysis and again upon re-analysis, the data is released with an appropriate qualifier as the failure is accepted as matrix related.

11.12.3 If a calibration verification standard is above the acceptable QC criteria and all samples being bracketed are below the reporting limit, the data is acceptable based on a high calibration bias with undetectable levels in the field samples. Any positive samples require re-analysis.

11.12.4 If the target analyte spiked in the quality control samples (LCS, LCSD, MS, MSD) exhibits high recovery and the target analytes in the field samples are below the reporting limit, the data may be released with a J+ qualifier indicating the high bias with no impact on the field sample analysis due to the bias present.

11.12.5 If the target analyte spiked into the QC pair (LCS/LCSD, MS/MSD) exhibit acceptable recoveries, but high calculated RPD values for precision, and the target analytes in the field sample are flagged with a J3 for the precision beyond acceptable quality control limits.

11.12.6 Sample results can be qualified and possible bias is narrated per the ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

11.12.7 Samples with multiple elements above the LDR must be diluted to verify interferences are not present

STATE NOTE: Drinking water samples analyzed using this procedure for compliance cannot be qualified.

12.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

12.1 The EPA requires that a laboratory waste management practice be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner. See ENV-SOP-MTJL-0051*, Waste Management Plan.*

12.2 See ENV-SOP-MTJL-0046, *Environmental Sustainability & Pollution Prevention*.

13.0 METHOD MODIFICATIONS/CLARIFICATIONS

13.1 Adjustments to the concentrations of standards/spiking solutions, standards providers, and quality control are subject to change to better meet client/project/regulatory needs or to improve laboratory method performance.

13.2 Modifications to this method are noted in the body of the text as state notes. Compliance analyses performed in conjunction with specific state requirements must be performed as noted within the specific state(s) note listed.

13.3 Superscripts are provided where necessary to indicate the reference in Section 14.0 where the requirement/information can be found. Subscripts noted identify the most frequent/restrictive cases, but requirements may also be included at different frequencies/conditions in other references noted in section 14.0.

13.4 In the May 2012 Methods Update Rule, the EPA revised the previous interpretation of EPA 200.7 to include the use of axial torch orientation in the published method. Either axial or radial orientation is acceptable.

14.0 REFERENCES

14.1 *Inductively Coupled Plasma-Atomic Emission Spectrometry*, SW-846 Method 6010B, Revision 2, December 1996.

14.2 *Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry*, EPA Method 200.7, Revision 4.4, May 1994.

14.3 *Identification of Test Procedures*, 40 CFR §136.3.

14.4 *Inorganic Chemical Sampling and Analytical Requirements*, 40 CFR §141.23.

14.5 *Inductively Coupled Plasma-Atomic Emission Spectrometry*, SW-846 Method 6010C, Revision 3, February, 2007.

14.6 *Hardness by Calculation*, Standard Methods 2340B, 20th Edition.

14.7 *Hardness by Calculation*, Standard Methods 2340B, 2011.

14.8 *Hardness by Calculation*, Standard Methods 2340B, 1997.

14.9 *Inorganic Analytes*, SW-846 Chapter 3, Revision 4, February, 2007.

Attachment I: Revision History

Current Version (Pace National):

Date	Description of Revisions
8/13/2020	Technical and quality review and update. Revised header. Revised sections 2.7, 7.5, 7.11, 8.1.7, 10.3.2, 10.11, 11.8 and 11.10. Added sections 2.7.3, 2.7.4, 2.7.5, 7.11.3, 7.11.4, 7.11.5 and 7.12 and renumbered as necessary. Revised all subsections of 3.0.

Superseded Versions (ESC Lab Sciences SOP#340386):

Version	Date	Description of Revisions
0	5/1/95	Origination
1	7/25/95	
2	3/11/97	
3	8/18/99	
4	2/11/00	
5	8/21/00	
6	3/28/01	
7	12/14/01	
8	4/11/03	
9	1/26/04	
10	8/2/04	
11	10/15/05	Corrected CCV criteria for EPA 200.7
12	10/29/08	Technical and Quality Review and update. Corrected acceptance criteria in Section 10.6. Updated format and re-organized sections 8.0, 10.0 and 11.0 based on new format.
13	1/23/09	Technical and Quality Review and update.
14	2/2/09	Technical and Quality Review and update. Clarification of holding times, Inclusion of cross-references. Inclusion of section 13.1 and section 7.1.
15	4/15/11	Technical and Quality Review and update. Added state notes where applicable; Added Tables 1.2b & 1.2c; Revised Table 1.2a and Sections 1.1, 1.3, 1.6, 1.11, 2.18, 2.22, 5.6, 7.1, 7.6.2, 7.9, 8.1.3, 8.1.5, through 8.1.10, 9.1, 9.7 through 9.12, 10.3, 10.0 & 11.0, 12.1; Added Sections 2.13.1, 2.14.1, 2.31 through 2.35, 3.1.1, 4.1, 4.7, 7.17, 13.2, 13.3, 14.5 through 14.10.
16	6/27/14	Complete Rewrite and update.
17	12/7/2015	Technical and quality review and update. Header and signature block re-formatting. Revised Sections 1.13.1, 2.13.1, 2.23, 5.1.3, 6.1.1, 6.1.2, 7.1, 7.6, 7.7, 7.8, 7.9, 7.10.1, 7.10.2, 7.11, 7.12, 7.13, 7.14, 7.16, 8.1.3, 8.1.5, 8.1.11, 9.4, 10.2, 10.3.1, 10.3.2, 10.4.2, 10.4.4, 10.9, 10.10, 10.14, 11.12.6, and 12.2. Revised Tables 1.2a, and 1.10, Deleted Sections 2.22 and 7.12. Added Attachment III.

STANDARD OPERATING PROCEDURE

TITLE: Determination Metals and Trace Elements in Various Matrices by ICP-AES (EPA Methods 6010B, 6010C, 6010D [ICP-OES], and 200.7) Including Hardness (EPA Methods 200.7 and 6010B/C/D and SM 2340B)

ISSUER: Pace National – Mt. Juliet, Tennessee

Version	Date	Description of Revisions
18	10/28/2016	Technical and quality review and update. Update per South Carolina DHEC correspondence of 6/24/16. Header and signature block re-formatting. Revised SOP title. Revised Sections 1.1, Table 1.2a, 1.3, 1.6, 1.10, 2.12, 2.15, 5.6, 7.5.2, 7.10.1, 9.1, 10.2, 10.3.1, 10.4.2, 10.4.3, 10.4.5, 10.5, 10.6.1, 10.6.2, 10.7.1, 10.8.1.2, 10.8.2.2, 10.10.1, 10.16, and Attachment III Table 2. Deleted Table 1.2b. Deleted Sections 2.2, 2.12, 2.13, 2.14, 2.15, 2.17, 2.20, through 2.33, 3.5, 4.8, 7.14, 7.16, 8.1.3, 9.7 through 9.10, 9.13, 10.4.5.1, 10.4.5.2, 10.4.5.3, 10.10.3, 13.5, 14.7, 14.8, 14.9, and 14.10. Added Sections 2.14, 7.10.3 and all subsections, 9.11, 9.12, 10.1.1, 10.6.4, 10.6.5, 10.8.1.2, 10.9.1 and all subsections, 10.11.1 and all subsections, and 11.6.1.
19	11/30/2017	Update in response to A2LA audit finding CAR2872. Changed ESC logo. Updated Sections 1.5, 3.1, 7.9, 10.11, 14.1, 14.2, 14.3, 14.4, 14.5, 14.6, 14.7, 14.8, 14.9, and Attachment III Table 5.
20	7/27/18	Update in response to WI and AZ audit findings. Changed logo and references to “ESC” to “Pace National”. Revised Section 7.14, 10.4.4, and 10.7.3. Added State Note to Sections 10.8.1.2 and 10.11. Also added 6010C note to Section 10.13
21	9/10/18	Update in response AZ audit finding CAR3296. Revised Post-Spike acceptance criteria to ±20% in Section 10.9.1.2

Superseded Versions (Pace National):

Date	Description of Revisions
1/27/2019	Technical and quality review and update. Deleted header, footer and signature. Revised sections 1.0, 1.3, 1.5, 1.6, 1.7, 1.13, 1.13.1, 2.8.1(2.7.1), 2.8.2(2.7.1), 4.2, 4.4, 4.7, 6.2, 6.3, 6.4, 6.5, 6.6, 7.1, 7.2, 7.3, 7.4, 7.5.1, 7.5.3, 7.6, 7.7, 7.8, 7.9, 7.10, 7.10.1, 7.10.2, 7.13, 9.5, 9.6, 9.9, 10.1, 10.2, 10.3, 10.4, 10.4.3, 10.4.5, 10.5, 10.6.3, 10.6.4, 10.6.5, 10.7.3, 10.8, 10.8.1, 10.8.1.2, 10.8.2, 10.8.3, 10.10.1, 10.11, 10.11.1.2, 10.12, 10.13, 10.16, 11.1, 11.2, 11.12.6, 12.1, 12.2, 14.2, 14.6, 14.7 and 14.8. Revised Table 1.10. Added section 7.5 and renumbered as necessary. Deleted sections 7.10.3, 7.10.3.1, 7.10.3.2, 7.11, 7.12, 7.14, 10.9.1, 10.9.1.1 and 10.9.1.2. Revised Attachment I. Revised Attachment II sections 4.10, 4.17 and 4.18.
5/7/2019	Technical and quality review and update. Revised sections 1.1, 1.2, 2.14, 8.1.1.2, 10.3.2, 10.9, 10.11, 10.11.1, 10.11.1.1, 10.11.1.2, 11.8, 11.12.6 and 12.1. Correctly numbered section 7.6.1.1.
6/19/2019	Added corporate header and footer. Revised based on LA DW Auditor’s comments. Revised Sections 8.1.6, 10.3.2, and Attachment I.
10/16/2019	Revised section 1.2 and 10.7.1. Added section 11.12.7.
2/4/2020	West Virginia audit response. Revised Section 10.8.2.2.
4/8/2020	Revision in response to West Virginia audit deficiency. Revised Sections 10.8.1.2 and 11.6.1.

Attachment II: Potential ICP interferences arising from analytes present in field samples at concentrations of 100mg/L

		Interferant[a,b]									
Analyte	Wavelength (nm)	Al	Ca	Cr	Cu	Fe	Mg	Mn	Ni	Ti	V
Aluminum	308.215	--	--	--	--	--	--	0.21	--	--	1.4
Antimony	206.833	0.47	--	2.9	--	0.08	--	--	--	0.25	0.45
Arsenic	193.696	1.3	--	0.44	--	--	--	--	--	--	1.1
Barium	455.403	--	--	--	--	--	--	--	--	--	--
Beryllium	313.042	--	--	--	--	--	--	--	--	0.04	0.05
Cadmium	226.502	--	--	--	--	0.03	--	--	0.02	--	--
Calcium	317.933	--	--	0.08	--	0.01	0.01	0.04	--	0.03	0.03
Chromium	267.716	--	--	--	--	0.003	--	0.04	--	--	0.04
Cobalt	228.616	--	--	0.03	--	0.005	--	--	0.03	0.15	--
Copper	324.754	--	--	--	--	0.003	--	--	--	0.05	0.02
Iron	259.940	--	--	--	--	--	--	0.12	--	--	--
Lead	220.353	0.17	--	--	--	--	--	--	--	--	--
Magnesium	279.079	--	0.02	0.11	--	0.13	--	0.25	--	0.07	0.12
Manganese	257.610	0.005	--	0.01	--	0.002	0.002	--	--	--	--
Molybdenum	202.030	0.05	--	--	--	0.03	--	--	--	--	--
Nickel	231.604	--	--	--	--	--	--	--	--	--	--
Selenium	196.026	0.23	--	--	--	0.09	--	--	--	--	--
Sodium	588.995	--	--	--	--	--	--	--	--	0.08	--
Thallium	190.864	0.30	--	--	--	--	--	--	--	--	--
Vanadium	292.402	--	--	0.05	--	0.005	--	--	--	0.02	--
Zinc	213.856	--	--	--	0.14	--	--	--	0.29	--	--

[a] Dashes indicate that no interference was observed even when interferents were introduced at the following levels:

Al -	1000 mg/L	Mg -	1000 mg/L
Ca -	1000 mg/L	Mn -	200 mg/L
Cr -	200 mg/L	Tl -	200 mg/L
Cu -	200 mg/L	V -	200 mg/L
Fe -	1000 mg/L		

[b] The figures recorded as analyte concentrations are not the actual observed concentrations; to obtain those figures, add the listed concentration to the interferant figure.

[c] Interferences will be affected by background choice and other interferences may be present.

NOTE: Using the above table, if analyzing for Lead in a sample containing 1000mg/L Aluminum, the lead results could demonstrate a high bias of 0.17mg/L. (If the sample contained 10000mg/L of Al, the bias in lead could be 1.7mg/L), if background corrections are not accurately applied by the instrument.

Attachment III: DoD Requirements

1.0 Equipment/Instrument Maintenance

Instrument maintenance must be performed routinely to optimize instrument performance and improve chromatography. Commonly performed maintenance includes changing pump tubing, replacing the torch, cleaning the nebulizer, etc. A new calibration curve must be analyzed following any major maintenance performed on the analytical system.

2.0 Computer Hardware and Software

QTegra, Version 2.4

3.0 Troubleshooting

Table 1. GC Troubleshooting Guide

Problem	Cause	Treatment
Poor Precision	Nebulizer Pressure	Pressure should be about 0.15 mPa for aqueous solutions. If pressure is substantially higher, clean the nebulizer orifice or replace it entirely.
	Pooling in Spray Chamber	Usually caused by an oily film in the spray chamber. Aspirate 0.1% HF solution for about 20 seconds or 0.01% Triton X-100 solution.
	Center Tube	Replace the tube.
	Capillary Tubing	Air bubble migration through tubing should be smooth and consistent. Replace kinked/ pinched tubing.
	Peristaltic Pump	Adjust platen pressure. Check for leaks. Replace damaged pump.
Poor Accuracy	Pump Rate	Ensure the flush pump rate is the same as the analysis pump rate.
	Flush Time	Ensure proper time set for adequate rinse (typically 30 seconds).
Poor Detection Limits	Dirty Window or Mirror	Clean or replace dirty components.

4.0 Other Requirements

4.1 All hardcopy laboratory notebooks must be reviewed by the Supervisor, or their designee, on a monthly basis.

4.2 If not self-explanatory (e.g., a typo or transposed number), corrections to technical and quality records shall also include a justification for the change.

4.3 A person performing a manual integration must sign and date each manually integrated chromatogram and record the rationale for performing manual integration. Electronic signatures are acceptable.

4.4 The results of calibration and verification of support equipment must be within the specifications required of the application for which this equipment is used or the equipment must be removed from service until repaired. Calibration and verification records, including those of established correction factors, must be maintained. In the absence of method-specific requirements, the minimum requirements are as follows:

Table 2. Support Equipment Checks

Performance Check	**Frequency**	**Acceptance Criteria**
Balance calibration check [Using two standard weights that bracket the expected mass]	Daily prior to use	Top-loading balance: ±2% or ±0.02g, whichever is greater Analytical balance: ±0.1% or ±0.5 mg, whichever is greater
Verification of standard mass [Using weights traceable to the International System of Units (SI) through a NMI	Every 5 years	Certificate of Calibration from ISO/IEC 17025 accredited calibration laboratory
Monitoring of refrigerator/freezer temperatures	Daily (i.e. 7 days per week) [use MIN/MAX thermometers or data loggers equipped with notification of out of control event capabilities if personnel not available to record daily]	Refrigerators: 0˚C to 6˚C Freezers: ≤-10˚C
Thermometer verification check [Using a thermometer traceable to the SI through an NMI] [Performed at two temperatures that bracket the target temperature(s). Assume linearity between the two bracketing temperatures.] [If only a single temperature is used, at the temperature of use]	Liquid in glass: Before first use and annually Electronic: Before first use and quarterly	Apply correction factors or replace thermometer
Volumetric labware	Class B: By lot before first use Class A and B: Upon evidence of deterioration	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on 10 replicate measurements)
Non-volumetric labware [Applicable only when used for measuring initial sample volume and final extract/ digestates volume]	By lot before first use or upon evidence of deterioration	Bias: Mean within ±3% of nominal volume Precision: RSD ≤3% of nominal volume (based on 10 replicate measurements)
Mechanical volumetric pipette	Quarterly	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on minimum of 3 replicate measurements) [Note: for variable volume pipettes, the nominal volume is the volume of use]
Glass microliter syringe	Upon receipt and upon evidence of deterioration	General Certificate of Bias & Precision upon receipt Replace if deterioration is evident
Drying oven temperature check	Daily prior to and after use	Within ±5% of set temperature

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Water purification system	Daily prior to use	See method blank criteria given in Section 4.20 of this addendum

4.5 The expiration date of the prepared standard shall not exceed the expiration date of the primary standard. All containers must bear a preparation date.

4.6 To avoid preparing non-representative samples, the laboratory shall not “target” within a relatively small mass range (e.g., 1.00 ± 0.01g) because such targeting will produce non-representative subsamples if the sample has high heterogeneity. The laboratory shall not manipulate the sample material so the sample aliquot weighs exactly 1.00g ± 0.01g, as an example.

4.7 In the absence of project-specific requirements, the minimum standard data qualifiers to be used are:

U	Analyte was not detected and is reported as less than the LOD or as defined by the customer. The LOD has been adjusted for any dilution or concentration of the sample.
J	The reported result is an estimated value (e.g., matrix interference was observed or the analyte was detected at a concentration outside the quantitation range).
B	Blank contamination. The recorded result is associated with a contaminated blank.
N	Non-target analyte. The analyte is a tentatively identified compound using mass spectrometry or any non-customer requested compounds that are tentatively identified.
Q	One or more quality control criteria failed (e.g., LCS recovery, surrogate spike recovery, or CCV recovery).

Additional data qualifiers may be used, or different letters or symbols to denote the qualifiers listed above, as long as they are appropriately defined and their use is consistent with project-specific requirements (e.g., QSM 5.0, the contract, and project-planning documents).

4.8 If the time of the sample collection is not provided, assume the most conservative time of day. For the purpose of batch processing, the start and stop dates and times of the batch preparation shall be recorded.

4.9 Each preparation method listed on the scope of accreditation must have quarterly LOD/LOQ verifications. However, not all possible combinations of preparation and cleanup techniques are required to have LOD/LOQ verifications. If LOD/LOQ verifications are not performed on all combinations, the laboratory must base the LOD/LOQ verifications on the worst case basis (preparation method with all applicable cleanup steps).

4.10 After each MDL determination, the laboratory must establish the LOD by spiking a quality system matrix at a concentration of at least 2 times but no greater than four times the MDL. This spike concentration establishes the LOD and the concentration at which the LOD shall be verified. It is specific to each suite of analyte, matrix, and method (including sample preparation). The following requirements apply to the initial LOD establishment and to the LOD verifications:

- The apparent signal to noise (S/N) ratio at the LOD must be at least three and the results must meet all method requirements for analyte identification (e.g., ion abundance, second column confirmation, or pattern recognition). For data systems that do not provide a measure of noise, the signal produced by the verification sample must produce a result that is at least three standard deviations greater than the mean method blank concentration. This is initially estimated based on a minimum of four method blank analyses and later established with a minimum of 20 method blank results.

- If the LOD verification fails, then the laboratory must repeat the MDL determination and LOD verification or perform and pass two consecutive LOD verifications at a higher spike concentration and set the LOD at the higher concentration.
- The laboratory shall maintain documentation for all MDL determinations and LOD verifications.
- The DL and LOD must be reported for all analyte-matrix-methods suites, unless it is not applicable to the test or specifically excluded by project requirements.

4.11 The LOD shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOD verifications on a one per batch basis. All verification data will be in compliance, reported, and available for review.

4.12 For DoD, at a minimum, the LOQ shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOQ verifications on a one per batch basis.

4.13 All initial instrument calibrations must be verified with a standard obtained from a second manufacturer prior to analyzing any samples. The use of a standard from a second lot obtained from the same manufacturer (independently prepared from different source materials) is acceptable for use as a second source standard. The concentration of the second source standard shall be at or near the midpoint of the calibration range. The acceptance criteria for the initial calibration verification must be at least as stringent as those for the continuing calibration verification.

4.14 Exclusion of calibration points without documented scientifically valid technical justification is not permitted.

4.15 The concentration of the CCV standard shall be greater than the low calibration standard and less than or equal to the midpoint of the calibration range.

4.16 All CCVs analyzed must be evaluated and reported. If a CCV fails, reanalysis or corrective actions must be taken.

- If a CCV fails, the laboratory can immediately analyze two additional consecutive CCVs (immediately is defined as starting a consecutive pair within one hour; no samples can be run between the failed CCV and the two additional CCVs). This approach allows for spurious failures of analytes to be reported without reanalysis of samples. Any corrective actions that change the dynamics of the system (e.g., clip column, clean injection port, run blanks) requires that all samples since the last acceptable CCV be reanalyzed.
- Both of these CCVs must meet acceptance criteria in order for the samples to be reported without reanalysis.
- If either of these two CCVs fail or if the laboratory cannot immediately analyze two CCVs, the associated samples cannot be reported and must be reanalyzed.
- Corrective action(s) and recalibration must occur if the above scenario fails. All affected samples since the last acceptable CCV must be reanalyzed.

- Flagging of data for a failed CCV is only appropriate when the affected samples cannot be reanalyzed. The laboratory must notify the client prior to reporting data associated with a failed CCV.

4.17 The results of all MS/MSDs must be evaluated using the same acceptance criteria used for the DoD LCS limits (see Addendum Tables 3 and 4) or project limits, if specified. If the specific analyte(s) are not available in the Addendum Tables 3 and 4, the laboratory shall use their LCS in-house limits (see the LIMS) as a means of evaluating MS/MSDs. The MS and MSD must be spiked with all reported analytes.

4.18 Surrogate spike results shall be compared with DoD LCS limits (see Addendum Tables 3 and 4) or acceptance criteria specified by the client. If these criteria are not available, the laboratory shall compare the results with its in-house statistically established LCS criteria (see the LIMS).

4.19 The method blank shall be considered to be contaminated if:

- The concentration of any target analyte (chemical of concern) in the blank exceeds 1/2 the LOQ and is greater than 1/10th the amount measured in any associated sample, or 1/0th the regulatory limit, whichever is greater;
- The concentration of any common laboratory contaminant in the blank exceeds the LOQ;
- If a method blank is contaminated as described above, then the laboratory shall reprocess affected samples in a subsequent preparation batch, except when sample results are below the LOD. If insufficient sample volume remains for reprocessing, the results shall be reported with appropriate data qualifiers.

4.20 Sporadic Marginal Exceedances are not allowed for target analytes (chemicals of concern as identified by a project) without project-specific approval. Target analytes are considered those few analytes that are critical for the success of a project (such as risk drivers) where sporadic marginal exceedances cannot be allowed. Laboratories should consult with clients whenever long lists of analytes are requested for analysis to determine if marginal exceedances will not be allowed.

4.21 DoD considers the same analyte exceeding the LCS control limit two (2) out of three (3) consecutive LCS to be indicative of non-random behavior, which requires corrective action and reanalysis of the LCS.

Table 3. LCS Control Limits – Method 6010 Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
7429-90-5	Aluminum	6258	96.7	7.5	74	119
7440-36-0	Antimony	5997	96.4	5.7	79	114
7440-38-2	Arsenic	9530	96.2	4.9	82	111
7440-39-3	Barium	9236	98.3	5	83	113
7440-41-7	Beryllium	6799	97.8	5.1	83	113
7440-42-8	Boron	2312	93	7.1	72	114
7440-43-9	Cadmium	9466	97.5	5.3	82	113
7440-70-2	Calcium	6347	98.1	5.8	81	116
7440-47-3	Chromium	9598	98.9	4.6	85	113
7440-48-4	Cobalt	6725	98.7	4.5	85	112
7440-50-8	Copper	7839	99.1	6	81	117
7439-89-6	Iron	5746	99.7	6.1	81	118
7439-92-1	Lead	10160	96.8	5.1	81	112
7439-93-2	Lithium	551	98.8	4.5	85	112
7439-95-4	Magnesium	6283	96.1	6.1	78	115
7439-96-5	Manganese	6732	99.1	4.9	84	114
7439-98-7	Molybdenum	4424	98.7	5.7	82	116
7440-02-0	Nickel	7412	98.1	4.9	83	113
7723-14-0	Phosphorus	189	103.1	3.8	92	114
7440-09-7	Potassium	6574	98.3	5.8	81	116
7782-49-2	Selenium	8862	94.5	5.6	78	111
7440-22-4	Silver	9105	97.3	5	82	112
7440-23-5	Sodium	5825	100.1	5.8	83	118
7440-24-6	Strontium	2573	98.5	5	83	114
7440-28-0	Thallium	6416	96.8	4.6	83	111
7440-31-5	Tin	2780	100.1	6.6	80	120
7440-32-6	Titanium	2107	98.2	5.2	83	114
7440-61-1	Uranium	109	97.4	5.2	82	113
7440-62-2	Vanadium	6934	98.3	5.4	82	114
7440-66-6	Zinc	7882	97.4	5	82	113

Table 4. LCS Control Limits – Method 6010 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
7429-90-5	Aluminum	11532	100	4.8	86	115
7440-36-0	Antimony	10737	100.2	4.2	88	113
7440-38-2	Arsenic	14123	99.9	4.3	87	113
7440-39-3	Barium	14476	100.3	4.1	88	113
7440-41-7	Beryllium	11552	100.4	4	89	112
7440-69-9	Bismuth	147	95.8	3.2	86	105
7440-42-8	Boron	3871	98.8	4.8	85	113
7440-43-9	Cadmium	13922	100.8	4.1	88	113
7440-70-2	Calcium	11382	100	4.2	87	113
7440-47-3	Chromium	15027	101.1	3.9	90	113
7440-48-4	Cobalt	11824	101.2	4.2	89	114
7440-50-8	Copper	12910	100.2	4.6	86	114
7439-89-6	Iron	13797	100.7	4.7	87	115
7439-92-1	Lead	14391	99.3	4.4	86	113
7439-93-2	Lithium	938	100.7	5.3	85	117
7439-95-4	Magnesium	11423	98.8	4.8	85	113
7439-96-5	Manganese	12767	101.9	4.1	90	114
7439-98-7	Molybdenum	8251	101.1	4	89	113
7440-02-0	Nickel	12699	100.5	4.1	88	113
7440-05-3	Palladium	492	99.8	4	88	112
7723-14-0	Phosphorus	203	100.5	4.2	88	113
7440-09-7	Potassium	11006	99.9	4.7	86	114
7782-49-2	Selenium	13264	98.5	5.2	83	114
7440-21-3	Silicon	1525	100.6	6.1	82	119
7440-22-4	Silver	13770	99.1	5.1	84	115
7440-23-5	Sodium	10893	100.9	4.7	87	115
7440-24-6	Strontium	3782	101.3	3.8	90	113
7704-34-9	Sulfur	145	100.7	3.9	89	112
7440-28-0	Thallium	10063	99.5	4.7	85	114
7440-31-5	Tin	4502	101.3	4.4	88	115
7440-32-6	Titanium	5625	101.1	3.4	91	111
7440-61-1	Uranium	223	101.3	5.8	84	119
7440-62-2	Vanadium	12032	100.2	3.6	90	111
7440-66-6	Zinc	13549	100.6	4.6	87	115

Table 5. Quality Control Requirements – Inorganic Analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP/AES)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Linear Dynamic Range (LDR) or high-level check standard	At initial set up and checked every 6 months with a high standard at the upper limit of the range.	Within ± 10% of true value.	Dilute samples within the calibration range, or re-establish/ verify the LDR.	Flagging is not appropriate.	Data cannot be reported above the high calibration range without an established/passing high-level check standard.
Initial Calibration (ICAL) for all analytes	Daily ICAL prior to sample analysis.	If more than one calibration standard is used, r2 ≥ 0.99.	Correct problem, then repeat ICAL.	Flagging is not appropriate.	Minimum one high standard and a calibration blank. No samples shall be analyzed until ICAL has passed.
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis.	All reported analytes within ± 10% of true value.	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.

Table 5. Quality Control Requirements – Inorganic Analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP/AES)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Continuing Calibration Verification (CCV)	After every 10 field samples, and at the end of the analysis sequence.	All reported analytes within ± 10% of the true value.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since the last successful CCV. Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since the last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Table 5. Quality Control Requirements – Inorganic Analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP/AES)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Low-Level Calibration Check Standard (LLCCV)	Daily	All reported analytes within ± 20% of true value.	Correct problem and repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed without a valid low-level calibration check standard (LLCCV). Low-level calibration check standard should be less than or equal to the LOQ. If the concentration of the lowest calibration standard is less than or equal to the LOQ, the lowest standard may be re-quantified against the calibration curve as a LLCCV. Otherwise, a separate standard must be analyzed as LLCCV prior to the analysis of any samples.

Table 5. Quality Control Requirements – Inorganic Analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP/AES)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Method Blank (MB)	One per preparatory batch.	The absolute values of all analytes must be < ½ LOQ or < 1/10th the amount measured in any sample or 1/10 the regulatory limit, whichever is greater.	Correct problem. If required, reprep and reanalyze MB and all QC and field samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid method blank. Non-detects associated with positive blank infractions may be reported. Sample results >10X the LOQ associated with negative blanks may be reported. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Initial and Continuing Calibration Blank (ICB/CCB)	Immediately after the ICV and immediately after every CCV.	The absolute values of all analytes must be < ½ LOQ or < 1/10th the amount measured in any sample.	ICB: Correct problem and repeat ICV/ICB analysis. If that fails, rerun ICAL. All samples following the last acceptable Calibration Blank must be reanalyzed. CCBs may not be reanalyzed without reanalysis of the associated samples and CCV(s).	Flagging is not appropriate.	Results may not be reported without a valid calibration blank. Non-detects associated with positive blank infractions may be reported. Sample results >10X the LOQ associated with negative blanks may be reported. For CCB, failures due to carryover may not require an ICAL.

Table 5. Quality Control Requirements – Inorganic Analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP/AES)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Interference Check Solutions (ICS) (also called Spectral Interference Checks)	After ICAL and prior to sample analysis.	ICS-A: Absolute value of concentration for all non-spiked project analytes <1/2 LOQ (unless they are a verified trace impurity from one of the spiked analytes); ICS-AB: Within ± 20% of true value.	Terminate analysis; locate and correct problem; reanalyze ICS, reanalyze all samples.	If corrective action fails, apply Q-flag to all results for specific analyte(s) in all samples associated with the failed ICS.	All analytes must be within the LDR. ICS-AB is not needed if instrument can read negative responses.
Laboratory Control Sample (LCS)	One per preparatory batch.	A laboratory must use Table 3 and 4 limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Must contain all reported analytes. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Matrix Spike (MS)	One per preparatory batch.	A laboratory must use Table 3 and 4 limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J flag if acceptance criteria are not met and explain in the case narrative.	For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to the source(s) of difference (i.e., matrix effect or analytical error).

Table 5. Quality Control Requirements – Inorganic Analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP/AES)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Matrix Spike Duplicate (MSD) or Matrix Duplicate (MD)	One per preparatory batch.	A laboratory must use Table 3 and 4 limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified. MSD or MD: RPD of all analytes ≤ 20% (between MS and MSD or sample and MD).	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J flag if acceptance criteria are not met and explain in the case narrative.	The data shall be evaluated to determine the source of difference. For Sample/MD: RPD criteria only apply to analytes whose concentration in the sample is greater than or equal to the LOQ.
Dilution Test	One per preparatory batch if MS or MSD fails.	Five-fold dilution must agree within ± 10% of the original measurement.	No specific CA, unless required by the project.	For the specific analyte(s) in the parent sample, apply J flag if acceptance criteria are not met and explain in the case narrative.	Only applicable for samples with concentrations > 50 x LOQ (prior to dilution). Use along with MS/MSD and PDS data to confirm matrix effects.
Post-Digestion Spike (PDS) Addition (ICP only)	Perform if MS/MSD fails. One per preparatory batch (using the same sample as used for the MS/MSD if possible).	Recovery within 80-120%.	No specific CA, unless required by the project.	For the specific analyte(s) in the parent sample, apply J flag if acceptance criteria are not met and explain in the case narrative.	Criteria applies for samples with concentrations <50 X LOQ prior to dilution.

Table 5. Quality Control Requirements – Inorganic Analysis by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP/AES)

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Method of Standard Additions (MSA)	When dilution test or post digestion spike fails and if required by project.	NA	NA	NA	Document use of MSA in the case narrative.

Document Information

Document Number: ENV-SOP-MTJL-0155	**Revision:** 07
Document Title: Determination of Elements in Water and Solids by Ion Chromatography (EPA Methods 300.0, 300.1, 9056, 9056A, and SM 4110B)	
Department(s): Wet Chemistry	

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Notes

Document Notes:

All Dates and Times are listed in: Central Time Zone

Signature Manifest

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ENV-SOP-MTJL-0155

QM Approval

Name/Signature	Title	Date	Meaning/Reason
Pamela Langford (006563)	Quality Analyst 2	02 Dec 2021, 08:22:47 AM	Approved

Management Approval

Name/Signature	Title	Date	Meaning/Reason
James Burns (006456)	Manager - EHS	01 Nov 2021, 12:45:24 PM	Approved
Keith Blanchard (004545)	Manager	01 Nov 2021, 12:45:47 PM	Approved

ENV-SOP-MTJL-0155

STANDARD OPERATING PROCEDURE
TITLE: Determination of Elements in Water and Solids by Ion Chromatography
(EPA Methods 300.0, 9056, 9056A, and SM 4110B)
ISSUER: Pace National – Mt. Juliet, Tennessee

1.0 SCOPE AND APPLICATION

1.1 This procedure is used for the determination of Nitrogen as Nitrite, Fluoride, Sulfate, Chloride, Nitrogen as Nitrate, Chlorate, Chlorite, and Bromide in aqueous matrices (drinking, surface, ground, effluent and influent water), soil extracts and combustates.

1.2 Typical reporting Limits are as follows (see LIMS for current active limits):

Analyte	Water*	Solid
Bromide	1mg/L	10 mg/kg
Chloride	1mg/L	10 mg/kg
Fluoride	0.1mg/L	1 mg/kg
Nitrate (N)	0.1mg/L	1 mg/kg
Nitrite (N)	0.1mg/L	1 mg/kg
Orthophosphate	0.1mg/L	1.0mg/kg
Sulfate	5mg/L	50 mg/kg
Chlorate	0.05mg/L	--
Chlorite	0.05mg/L	--

** See section 13.5*

1.3 An MDL study must be completed every six months or more frequently if major instrumentation changes occur. Method Detection Limits (MDLs) are performed based on ENV-SOP-MTJL-0016. Updated MDL records are filed and stored in a central location within the department.

1.3.1 Limit of Detection (LOD) and Limit of Quantitation (LOQ) studies are completed at the frequency required by the TNI standard per the procedure identified in the ENV-SOP-MTJL-0016, *Method Detection Limits (MDL), Limits of Detection (LOD) and Limits of Quantitation (LOQ).* Should the procedure be utilized for DOD support; then the frequency of these studies must meet the requirements of the current DOD QSM (see Attachment III).

2.0 METHOD SUMMARY AND DEFINITIONS

2.1 Aqueous samples, soil extracts and bomb combustates are injected into the Ion Chromatograph (IC) and separated on an analytical column equipped with a guard column. A Potassium Hydroxide or Carbonate/Bicarbonate solution serves as the eluent (mobile phase). Once separated, the anions pass through an anion suppressor where they are converted to their highly conductive forms. The separated anions are measured by conductivity and are identified by retention time as compared to known targets.

2.2 Ion Chromatography eliminates the need to use hazardous reagents and it effectively distinguishes among the halides (Br^-, Cl^-, F^-) and the oxy-anions (SO_3^-/SO_4^-, NO_2^-/NO_3^-, ClO_2/ ClO_3^-, PO_4^{-3}).

2.3 See the current Quality Assurance Manual for other definitions associated with terms found in this document.

3.0 HEALTH AND SAFETY

3.1 The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

3.2 The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets (SDS) for all hazardous chemicals are available to all personnel. Employees must abide by the environmental, health, and safety (EHS) policies and procedures specified in this SOP and in the Pace National Chemical Hygiene / Safety Manual.

3.3 Personal protective equipment (PPE) such as safety glasses and/or side shields, gloves, a laboratory coat, and shoes that are not cloth, canvas, and/or perforated must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure. When handling glass, needles, knives, or any material with a potential sharp edge, employees must use cut-resistant gloves.

3.4 Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids, bases, or oxidizers in a fume hood whenever possible with the appropriate PPE designed for handing these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

CAUTION: Be careful when diluting and mixing acids. ALWAYS pour acid into water when mixing. Gently heat acid mixtures (NEVER HEAT RAPIDLY) to prevent splatter from extremely exothermic reactions typical of acid/water mixtures, etc.

3.5 Universal precautions should be observed when performing any tests or procedures. Hard surfaces, instrument surfaces may be contaminated and should be handled according to good laboratory practices.

3.6 Contact your supervisor or local EHS coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure. Any accidents involving personnel or sample supplies are to be reported immediately to either the Service Center Operations Manager and/or to the Safety Officer.

4.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

4.1 All samples must have been collected using a sampling plan that addresses the considerations of this method.

4.2 Samples must be collected in plastic or glass bottles. Volume collected must be sufficient to ensure a representative sample, allow for replicate analysis, if required, and minimize waste disposal. Samples for Chlorite and recommended for Chlorate must be protected from light i.e. containers must be opaque or covered.

4.3 The preservation and the holding times for samples analyzed by this procedure is determined by the anion(s) of interest. In a given sample, the anion that requires the preservation treatment and the shortest holding time will determine the preservation treatment utilized within the laboratory.

4.4 The holding time for aqueous samples begins at collection and ends with analysis. The holding time for leachates/combustates of solid samples begins with extraction or bombing and ends with analysis.

Analyte	Preservation	Holding Time
Bromide	None required	28 days
Chloride	None required	28 days
Fluoride	None required	28 days
Nitrate*	Cool to ≤6°C (not frozen)	48 hours*
Nitrite	Cool to ≤6°C (not frozen)	48 hours
Orthophosphate	Cool to ≤6°C (not frozen)	48 hours
Sulfate	Cool to ≤6°C (not frozen)	28 days
Chlorate	None required 300, EDA if 300.1	28 days
Chlorite**	Cool to 4°C (50 ppm EDA)	14 days

*For chlorinated drinking water samples, the holding time for Nitrate is extended to 14 days if kept at ≤6°C (not frozen).

**Since the sample cannot be analyzed for Chlorite within 10 minutes, the sample must be preserved by adding 1 mL of the Ethylenediamine (EDA) preservation solution to 1 L of sample or equivalent.

4.5 Samples submitted for analysis that do not meet the requirements contained within this section must be addressed before performing the logging process within the laboratory. In some cases, exceeding the appropriate preservation and storage criteria can cause significant bias in the resulting data. Clients may need to resubmit samples where the conditions during shipment cause uncertainty regarding sample integrity. If samples do not meet the requirements for preservation, sampling, shipment and storage and the client approves the completion of the analytical process, sample results can be qualified per the ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

5.0 INTERFERENCES

5.1 Any species with a retention time similar to that of the desired ion will interfere. Large quantities of ions eluting near the ion of interest will also result in interference.

5.1.1 Separation may be improved by adjusting the eluent concentration and/or flow rate.

5.1.2 Sample dilution and/or the use of the method of standard additions can also be used. For example, high levels of organic acids may be present in industrial wastes, which may interfere with inorganic anion analysis. Two common species, Formate and Acetate, may elute between Fluoride and Chloride depending on the column and eluent used.

5.2 Interferences may be caused by contaminants in the reagent water, reagents, glassware, and other sample processing apparatus that lead to artifacts or elevated baselines.

5.3 Targets, by definition, are “dissolved”. Samples may be filtered using either 0.45/0.2 um pore filters/frits.

6.0 EQUIPMENT AND SUPPLIES

6.1 Ion Chromatograph: Dionex ICS 2100, or equivalent.

6.2 Detector: Dionex ED40, CD20 or equivalent.

6.3 Automated sampler: Dionex AS-DV, or equivalent.

6.4 Eluent Pump: Dionex GP40, GP50 or equivalent.

6.5 Column: AS-18 (Dionex P/N 060549), or equivalent.

6.6 Guard column: AG-18 (Dionex P/N 060551), or equivalent.

6.7 Automatic Self-Regenerating Suppressor: ASRS 500 (Dionex P/N 082540), or equivalent.

6.8 Balance – Analytical, capable of accurately weighing to the nearest 0.0001 grams: Mettler AG204 Delta Range or equivalent.

6.9 5.0mL autosampler vials with filter caps: Environmental Express K1250 or equivalent.

6.10 0.20µm or 0.45 um pore filters (Acrodisc and Gelman): Fisher SLGN033NK, or equivalent.

6.11 10mL syringes (sterile polypropylene or glass): Fisher 1482316E or equivalent.

6.12 Software package for control of instrument operations and conditions and for data evaluation and reporting: Chromeleon™, or equivalent.

6.13 Eluent generator: Dionex EG50 or equivalent. Manual eluent preparation may be used.

6.14 Eluent generator cartridge (if eluent generation is used): Dionex EGCIIKOH.

6.15 Sulfate test strips: EMD 10019-1, or equivalent.

6.16 Nitrate/Nitrite test strips: HACH 27454-25, or equivalent.

6.17 Chloride test strips: HACH 27513-40, or equivalent.

6.18 Serological Pipettes for Dilutions: VWR™ Part #89130 or equivalent. Volumes will vary. Each lot must be verified for accuracy. Pipettes used for dilution must be replaced daily.

6.19 Pretreatment cartridge(s) for removal of interferences.

7.0 REAGENTS AND STANDARDS

7.1 All reagents and standards must be recorded in the appropriate preparation log and assigned a unique number. See ENV-SOP-MTJL-0041, *Standards Logger – Tree Operation*. Additional information regarding reagent preparation can be found in the Standards Logger (Tree) digital archive system. All spiking solutions and surrogate standard solutions should be replaced at least every six (6) months or sooner if a problem is detected unless otherwise noted.

7.2 Stock Standards: Stock standard solutions are purchased as certified solutions (Inorganic Ventures ESC-IC-2A) with Fluoride, Nitrite (N) and Nitrate (N) at 100µg/mL and Chloride, Bromide, and Sulfate at 1000µg/mL. A 50mg/mL phosphate as P may be purchased as a certified standard (RICCA 5830-16). ISO 34, if available.

NOTE: The manufacturer provides an expiration date of the stock standards, and stock standards are stored according to manufacturer's recommendations. The Primary and Secondary Source Standards must be from the different vendors or lot numbers. Dilute working standards are prepared fresh weekly, except those that contain Nitrite, which must be prepared fresh daily or sooner if a problem is detected.

7.2.1 Sodium Chloride ACS Grade (VWR™ 200004-248 or equivalent) – Used for the Primary Source Stock Standard in the Fast Chloride Method for Soil. Dry at 105°C for at least 30 minutes.

7.2.2 Fast Chloride Primary Source Stock Standard: Prepare a solution containing Chloride at an appropriate concentration such that the solution may be diluted to create a range of calibration standards. An appropriate example follows. Dissolve the following amounts in reagent water and dilute to 1000mL. This stock standard is stable for one month. Use of commercial standard is acceptable.

Anion	Salt	Amount (g)	Final conc. (mg/L)
Chloride	Sodium Chloride	1.6485	1000

7.2.3 Chlorate Stock primary standard (1000mg/L): Inorganic Ventures ICCLO31 Exp.: 1year from time of opening or the manufactures expiration whichever is sooner. ISO 34, if available.

7.2.4 100mg/L Chlorate primary intermediate standard: 10mL of 1000mg/L Chlorate primary Stock to 100mL. Exp.: 6months

7.2.5 Chlorite Stock Primary Standard (1000mg/L): Inorganic Ventures 1CCL021 Exp.: 1 year from time of opening or the manufactures expiration whichever is sooner. ISO 34, if available.

7.2.6 100mg/L Chlorite Primary Intermediate Standard: 10mL of 1000mg/L Chlorite Primary Stock to 100mL. Exp.: 6months

7.3 Combined Working Standards: Prepare serial dilutions of the Primary Source Stock Standard Solution(s) to create calibration standards over a range of concentration values with the lowest level of the curve being at or below the reporting limit. Use volumetric flasks and Class A pipettes for all dilutions. Examples of appropriate sets of calibration standards for water and soil samples follow. Concentrations may be adjusted as needed to meet expected sample ranges or as instrument conditions change. Cal Std #1 as listed in the water calibration standards is also used for the RL 1 standard for drinking water analysis.

Water Calibration Standards:

Cal Std #	Chlorite Intermediate (mL)	Anion Stock Std (mL)*	Final Volume (mL)*	Final Concentration (µg/mL)*
Zero	0.00	0.0	100	0.00
STD 1 (RL 1)	0.05	0.1	100	0.05 / 0.1 / 1.0
STD 2	0.25	0.5	100	0.25 / 0.5 / 5.0

Cal Std #	Chlorite Intermediate (mL)	Anion Stock Std (mL)*	Final Volume (mL)*	Final Concentration (µg/mL)*
Zero	0.00	0.0	100	0.00
STD 3	0.5	1.0	100	0.5 / 1.0 / 10.0
STD 4	1.0	2.5	100	1.0 / 2.5 / 25.0
STD 5	2.5	5.0	100	2.5 / 5.0 / 50.0
STD 6	10	10	100	10 / 10.0 / 100

** Spiking volumes/concentrations and final volumes may be revised to better meet client/project/regulatory needs or to improve laboratory method performance. First value is Chlorate concentration. Second value is Nitrate, Nitrite, and Fluoride concentration. Third value is Bromide, Chloride, and Sulfate concentration.*

Soil Calibration Standards:

Cal Std #	**Anion Stock Std (mL)***	**Chlorate/Chlorite Intermediate (mL)**	**Final Volume (mL)***	**Final Conc. (µg/mL)***
Zero	0.00	0.0	100	0.00
STD 1 (RL1)	0.1	0.05	100	0.05 / 0.1 / 1.0
STD 2	0.5	0.25	100	0.25 / 0.5 / 5.0
STD 3	1.0	0.5	100	0.5 / 1.0 / 10.0
STD 4	2.5	1.0	100	1.0 / 2.5 / 25.0
STD 5	5.0	2.5	100	2.5 / 5.0 / 50.0
STD 6	10	10	100	10 / 10.0 / 100

** Spiking volumes/concentrations and final volumes may be revised to better meet client, project, and regulatory needs or to improve laboratory method performance. First value is Chlorate concentration. Second value is Nitrate, Nitrite, and Fluoride concentration. Third value is Bromide, Chloride, and Sulfate concentration.*

NOTE: Dilute working standards are prepared fresh daily.

NOTE: If EDA used as preservative, add to calibration for Chlorite/Chlorate.

NOTE: Concentrations may vary but one must be at or below the RL.

NOTE: when used, add constant amount of surrogate to all calibration standards for 1.0 ug/ml concentration.

NOTE: Limit calibration range to two (2) orders of magnitude.

Low Level Bromide Water Calibration Standards:

Make a 10mg/L Br Standard using 1mL 1000ppm ICV Standard to 100mL.

Cal Std #	Anion Stock Std (mL)*	Final Volume (mL)*	Final Concentration (µg/mL)*
Zero	0.00	100	0.00
STD 1 (RL 1)	0.5	100	0.05
STD 2	1.0	100	0.1
STD 3	2.5	100	0.25

STD 4	5.0	100	0.5
STD 5	10	100	1.0

** Spiking volumes/concentrations and final volumes may be revised to better meet client/project/regulatory needs or to improve laboratory method performance.*

7.4 Laboratory Control Sample (LCS) - secondary source.

7.4.1 Water LCS: This solution is purchased as a certified solution (NSI Q-3440), with Fluoride, Nitrite (N) and Nitrate (N) at 40µg/mL and Chloride, Bromide, and Sulfate at 200µg/mL.

7.4.2 Chlorate and Chlorite Stock Secondary 1000mg/L.: Manufacture's expiration date.

7.4.3 100mg/L Secondary Chlorate/Chlorite intermediate: 10mL of 1000mg/L Chlorate Secondary Stock to 100mL Exp.: 2 weeks

7.4.4 Working LCS: 20mL Anions water LCS + 5mL 100mg/L Secondary Chlorate intermediate + 5mL 100mg/L Chlorite Secondary Intermediate Standard + 0.1mL EDA to 100mL.

- Concentrations are: F, NO2, NO3 8mg/L, Cl, Br, SO4: 40mg/L; ClO3/ ClO_2: 5mg/L
- Solution MUST be obtained from different source than the Calibration standard solution.
- This standard is made daily.

- NOTE: concentration may vary but should be near mid-level.

7.4.5 Ethylenediamine (EDA) 99 %: Dilute 10 ml EDA to 200 ml reagent water. Use 1 ml per 1000 ml sample.

7.4.6 Ottawa Sand or equivalent.

7.4.7 Surrogate, Dichloroacetate as Potassium salt, commercial, various. Prepare 500 ug/ml solution by dissolving 0.065 g to 100 ml reagent water.

8.0 PROCEDURE

8.1 Initial Calibration

8.1.1 Continuing calibration verification is used to verify on-going calibration stability. Calibration is required when initial QC fails or if major changes are made to the instrument.

8.1.2 Prepare at least six calibration standards (as described in 7.3). The calibration model is not forced through zero.

- If the working range exceeds the linear range of the system, a sufficient number of standards must be analyzed to allow an accurate calibration curve to be established.
- One of the standards must be representative of a concentration at or below the reporting limit.

- The other standards should correspond to the range of concentrations expected in the sample or should define the working range of the detector.

STATE NOTE: When analyzing samples in conjunction with TN Drinking Water, and South Carolina programs, the calibration model must be linear. Quadratic curve modeling is not permitted.

8.1.3 Begin to inject standards starting with the lowest concentration standard and increasing in concentration.

8.1.4 Inject 25µL (determined by injection loop volume) of each calibration standard, and tabulate area response against concentration. Use results to prepare a calibration curve for each analyte. Record retention times as well. Loop may vary but must be held constant for ICAL and subsequent samples.

8.1.5 Evaluate the initial standard curve.

- The calibration correlation coefficient, r, should be 0.995 or better or if r^2 at least 0.990. Use of average RF is recommended with </= RSD of 15. When appropriate, select calibration model that minimizes residuals and intercept.
- Compare these values with those obtained in the past. If they are significantly different, stop the analysis and look for the cause.
- Nonlinear response can result when the separator column capacity is exceeded (overloading). Maximum column loading (all anions) should not typically exceed about 400 ug/ml.

8.2 Continuing Calibration (ICV/CCV)

8.2.1 Daily, in lieu of an entire initial calibration, a mid-level initial calibration verification (ICV) standard may be analyzed every 10 samples for 300.0 or a low, mid, and high for 4110. Standards are analyzed prior to any QC or field samples as well as at a frequency of every ten injections (including LCS, MS, MSD, duplicates, and blanks in the count) during an analytical sequence and after the last analytical sample. These standards must recover within $\underline{+}10\%$ of the expected concentration except for the low check which is 25 % true. If applicable, EDA must be added at 50 ug/ml. For 300.1, calculate Peak Gaussian Factor using the low point check standard.

$$PGF = 1.83 \times W / w$$

Where W = peak width at ½ height

w = peak width at 1/10 height

NOTE: For 4110, CCV criteria for low, mid, and high-level verification based on concentration as follows: low 75-125 %, mid and high ±10% true.

STATE NOTE: Recoveries of all standards, including the low check, must be ±10% of the true value for South Carolina samples.

8.2.2 Following each ICV/CCV, an initial (ICB) or continuing calibration blank (CCB) must be analyzed. The ICB/CCB are aliquots of the Method Blank that are analyzed to demonstrate a continued lack of analyte carryover in the instrument. The target analyte concentration in the ICB/CCB must be less than the MDL or ½ RL, as applicable. As needed, add 50 ug/ml EDA.

8.3 Water Sample preparation

8.3.1 All samples and quality control checks must be filtered.

8.3.2 The Method Blank/ICB/CCB is prepared using approximately 5mL of reagent water and the LCS is prepared using approximately 5mL of the solution found in section 7.5.1. For each MS/MSD, take duplicate 9.5mL aliquots of a randomly selected field sample and add 500µL of Anion Stock Solution + 50uL of 1000mg/L Chlorate Primary stock standard +50uL 1000mg/L Chlorite Stock Primary.

8.4 Soil Sample Preparation

8.4.1 Sample Prep: Place 5g of sample into a 50mL centrifuge tube and using a Class A graduated cylinder dilute to 50mL with reagent water.

8.4.2 QC Prep:

- MS/MSD: 5g of sample + 2.5mL of Anion/Chloride Stock Solution + 5mL of Phosphate Intermediate Standard+ 0.25mL 1000mg/L Chlorate Primary Stock standard + 0.25mL 1000mg/L Chlorite Primary Stock Standard into 50mL centrifuge tube, diluted to 50mL using a Class A graduated cylinder with reagent water.
- Method Blank: 5g of sand into a 50mL centrifuge tube, diluted to 50mL with reagent water using a Class A graduated cylinder.
- ICV solution: 5mL of Anion/Chloride Primary Source Stock Standard + 10mL of Phosphate Primary Intermediate Standard +5mL 100mg/L Chlorate Primary Intermediate standard to 100mL reagent water.
- LCS: Weigh 5.0g of sand and into a 50mL centrifuge tube, spike with 1.0mL of Inorganic Ventures IC Secondary Source Stock standard, 2.5mL 100mg/L Chlorate Secondary Intermediate, and 2.0mL of RICCA Orthophosphate Secondary standard. Dilute to 50mL with reagent water, using a Class A graduated cylinder.

- NOTE: May vary but attempt to spike at mid-level.

8.4.3 Place all samples on a vortex agitator for at least 10 minutes, and then centrifuge.

8.4.4 Filter each sample and quality control checks through a 0.2 or 0.45 um pore Acrodisc filter or equivalent.

8.5 Screening procedure – Screen water samples and soil extracts using the test strips listed in 6.15 through 6.17. Use according to manufacturer's instructions. Determine appropriate dilutions for each sample or extract based on the screening results.

8.5.1 Test strips must never be inserted directly into a sample undergoing preparation prior to analysis. Instead, remove sample material from the original container with an appropriate non-contaminated implement (e.g., disposable pipette, glass rod) and place on the test strip.

8.6 Sample analysis

8.6.1 Type each sample and QC check, its position, and dilution factor (if applicable into the Chromeleon™ sample table. Make sure that the correct instrument program and quantitation method are selected.

8.6.2 Filter and/or use pretreatment cartridge(s) samples and standards into vials. Using 10 of sample, spike with 0.02 ml surrogate (required for method 300).1 for a 1 ug/ml concentration. Other volumes allowed. Adjust surrogate, as needed Load the vials onto the autosampler.

NOTE – some vials may use filter frits. This is acceptable.

8.6.3 Start instrument. The Chromeleon™ software will record retention times, peak areas, and concentrations.

8.6.4 The retention time window used to make identifications must be based on measurements of actual retention time variations of standards during the course of a day. Three times the standard deviation of a retention time can be used to calculate a suggested window size for a compound. However, the experience of the analyst should weigh heavily in chromatogram interpretations.

8.6.5 If the response for the peak exceeds the upper calibration standard, dilute the sample with an appropriate amount of reagent water and reanalyze.

8.6.6 If the resulting chromatogram fails to produce adequate resolution, or if identification of specific anions is questionable, spike the sample with an appropriate amount of standard and reanalyze.

NOTE: Nitrate and Sulfate exhibit the greatest amount of change, although all anions are affected to some degree. In some cases, this peak migration can produce poor resolution or misidentification.

8.6.7 The laboratory has developed a “fast chloride method” for the analysis of chloride in soil samples. This method utilizes the quality control parameters that are listed in this SOP, but the flow rate of the instrument to approximately double of the regular analysis. This results in a run time that is approximately half of the regular analysis.

9.0 DATA ANALYSIS AND CALCULATIONS

9.1 Calculations are performed by PeakNet 6 (Chromeleon™) software provided by Dionex. The software calculates results using linear regression or RF using peak area vs. concentration (Sample concentration water (mg/L) = result X dilution factor). For soils ug/g = instrument result ug/ml x extract/combustate volume in ml x dilution / sample weight in g.

9.2 See the current Quality Assurance Manual for equations associated with common calculations.

10.0 QUALITY CONTROL AND METHOD PERFORMANCE

10.1 All analysts must meet the qualifications specified ENV-SOP-MTJL-0015, *Technical Training and Personnel Qualifications* before approval to perform this method. Analysts must complete an initial demonstration of proficiency before being approved to perform this method. Continuing proficiency must be demonstrated using proficiency testing, laboratory control sample analysis and/or MDL studies. Method performance is assessed per analyst. Updated method performance records are filed and stored in a central location within the department.

NOTE: Method detection limit studies (MDLs) are required semi-annually (every 6 months) to ensure consistent instrument and analyst performance.

10.2 Use the designated Run log to record batch order and standards/reagents used during analysis. See ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

10.3 Preparation Batches

10.3.1 Extraction Batches - defined as sets of 1 - 20 samples. Must include the following: 1 Method Blank, 1 Laboratory Control Sample (LCS), 1 Matrix Spike and Duplicate per 10 samples for 300.0/300.1 or one MS/MSD part per 20 samples for 4110/9056A.

10.3.2 Analytical Batches (sequences) - must include the following: Opening ICV or CCV, Calibration Blank (ICB/CCB) following each ICV or CCV. A low, mid, and high CCV for method 4110 All samples must be bracketed by acceptable QA/QC.

10.4 Supporting Analytical Studies

10.4.1 Linear Calibration Range (LCR) Studies – Linear calibration ranges are established for each instrument consisting of a blank and at least three (3) calibration points. Sample or QC concentrations that exceed this level must be diluted to ensure accurate quantitation. LCR studies must be established at least semi-annually or when instrumentation change occurs. The correlation coefficient, r, must be $\geq$0.995 or RSD < 15 and the percent recovery for all standards must be within the limits given in Section 10.5 below. The LCR is defined by a valid upper calibration point.

10.4.2 Method Detection Limits – See also ENV-SOP-MTJL-0016, *Method Detection Limits (MDL), Limits of Detection (LOD) and Limits of Quantitation (LOQ)*. MDL studies are required initially, then every six months per EPA 300.1[14.3] or when instrumentation change occurs. Method detection limit studies are performed on clean matrices most closely matching field sample matrices.

10.4.3 Proficiency Testing (PT) – See also ENV-SOP-MTJL-0022, *Proficiency Testing Program*. Proficiency testing is performed in the Wet Chemistry department in support of environmental analyses. Environmental PTs are performed semi-annually for Water Supply (Safe Drinking Water Act), Water Pollution (Clean Water Act), and soils (RCRA) testing.

10.5 Initial Calibration – The calibration curve is analyzed weekly and must meet the correlation coefficient, r, of 0.995 of if r2 at least 0.990., or better or average RF <15%, for use in quantitation of samples.

NOTE: A curve for Method 300.0 is acceptable if Standard 1 (RL) is within ±50% of true, Standard 2 is within ±20% of true, and all other standards are within ±10% of true.

STATE NOTE: All calibration points will be rejected if outside of ±10% true value for South Carolina samples.

10.6 Method Blank/Initial & Continuing Calibration Blank (ICB/CCB) - The Method Blank/ICB/CCB concentration must be less than the Method Detection Limit or ½ RL, as needed.

10.7 Laboratory Control Sample (LCS) - The recovery of the LCS must be within +10% for 300.0/300.1 and at 15% for other methods.

10.8 Matrix Spike/Matrix Spike Duplicate (MS/MSD) - Recovery must be within ±10% of the true value for each MS and MSD and the relative percent difference (RPD) must not exceed <20%.

STATE NOTE: Per West Virginia DEP compliance for EPA Method 300, all WV samples require two (2) matrix spikes per batch of 20 samples. MSDs are not required, and minimal precision can be determined and demonstrated by the LCS/LCSD. Field sample precision can be demonstrated by the parent sample duplicate. For all other state regulatory programs, the performance of the MS/MSD meets the requirements of the published method.

10.9 Initial Calibration Verification (ICV)/Continuing Calibration Verification (CCV), mid-level - The %R of the ICV/CCV must be 90 to 110% of the expected concentration

10.10 Quality Control Sample (QCS) – On a quarterly basis (or as needed to meet data quality needs), verify the calibration standards and acceptable instrument performance with the preparation and analysis of a second source standard (different from the calibration source). The QCS requirement is met through the use of routine LCS analysis which uses which uses a second source standard that is different from the calibration source.

10.11 Reporting Limit Verification (RL 1) – EPA Method 9056A, the state of Arizona, and any batch of samples containing drinking water require the analysis of a standard at or below the routine reporting limit that must be analyzed following each calibration. The RLV is prepared from a source that is secondary to the initial calibration curve and the RLV must recover within +50% of the expected value.

STATE NOTE: For all samples analyzed from Minnesota, the reporting limit must be verified at least monthly, with each new initial calibration, or when there has been significant change to the instrument (column replacement, cleaning source, etc.) whichever is more frequent. The reporting limit verification can be performed by either re-injecting the low standard or by re-processing the low standard that was analyzed in the calibration curve. The reporting limit verification (RLV) must recovery within +40% of the expected concentration. If these criteria are not met, the RLV may be re-analyzed once, instrument maintenance can be performed, a higher concentration standard can be injected, or a new calibration curve must be generated. If a higher concentration standard is utilized, the reporting limit must be raised to the higher level verified.

10.12 Any sample analyte responses that are beyond the linear range of the calibration curve must be diluted and re-analyzed.

10.13 Surrogate for 300.1 – recovery is 90 – 115 %. Retention time shift less than 2 % for ICAL and less than 5 % for samples.

11.0 DATA VALIDATION AND CORRECTIVE ACTION

11.1 All data must undergo a primary review by the analyst. The analyst must check the performance of the initial calibration, mid-point check standards, and continuing calibrations to ensure that they meet the criteria of the method. The analyst must review any sample that has quantifiable compounds and make sure that they have been confirmed. The analyst must also verify that reported results are derived from quantitation between the RL and the highest standard of the initial calibration curve. All calculations must be checked (any dilutions, %solids, etc.). Data must be checked for the presence or absence of appropriate flags. Comments must be noted when data is flagged.

11.2 Second level review is performed on data sheets. Data review must be performed according to ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

11.3 Initial calibration - If the initial calibration does not meet the acceptance criteria, review the calibration curve for possible errors, if an error is detected, re-analyze the standard(s). If no error is identified and the failure persists, re-prepare the standards, and re-analyze the entire batch. Instrument maintenance may also be necessary prior to re-calibration.

11.4 ICV/CCV - The results of the ICV/CCV must agree within 10% of the expected value for mid and high and 25% for low; if not and analysis of a second consecutive (immediate) calibration verification fails to produce results within acceptance criteria, corrective actions shall be performed. The laboratory shall demonstrate acceptable performance after the final round of corrective action with two consecutive calibration verifications, or a new initial instrument calibration shall be performed.

11.5 Method Blank/ICB/CCB - If the Method Blank fails, rinse and re-analyze once. If the contamination still occurs, corrective actions can include instrument maintenance, reviewing data for errors and review of the calibration curve. A Method Blank must meet the acceptance criteria prior to the analysis of any field samples. Re-analyze all sample analyses not bracketed by acceptable ICB/CCBs, except as noted in section 11.11. If the contamination still occurs after maintenance has been performed, the batch must be re-prepared and re-analyzed.

General guidelines for qualifying sample results with regard to method blank quality are as follows:

- If the method blank concentration is less than the MDL and sample results are greater than the RL, then no qualification is required.
- No qualification is necessary when an analyte is detected in the method blank but not in the associated samples.
- If the concentration in a sample is more than ten times the concentration in the method blank, then no qualification is required.
- If the method blank concentration is greater than the MDL but less than the RL and sample results are greater than the MDL, then qualify associated sample results to indicate that analyte was detected in the method blank.

- If the method blank concentration is greater than the RL, further corrective action and qualification is required. An analyst should consult their supervisor for further instruction.

11.6 LCS/QCS - If failure occurs, re-analyze the LCS once. If failure(s) persists, determine the cause of the failure. The cause of the failure could be improperly prepared standards, the instrument or one of its components may require maintenance or replacement, the instrument needs to be re-calibrated, the reagents may need to be re-prepped, etc. (Check instrument manual for additional information). When the cause of the failure has been corrected, re-calibrate or re-verify the calibration and begin the analysis again. If the failure still occurs after maintenance has been performed the batch must be re-prepared and re-analyzed. A passing LCS must be analyzed with each analytical batch; however, if LCS is high and samples are ND, they may be reported.

11.7 MS/MSD - Matrix Spike failures must be flagged with a J5 (high) or J6 (low). If there is an RPD failure, report the result with a J3 qualifier. Matrix spikes that are over the calibration range shall be qualified with an E.

11.8 Sample Duplicate - If the RPD is >20%, the sample and duplicate must be reported with a “J3” qualifier. If a sample duplicate is above the acceptable range for the RPD and the sample concentration is <5X the RL, then the value can be flagged with a “P1” qualifier indicating that the RPD calculation is not applicable at that concentration.

11.9 RLV - The results of the RLV must agree within 25 % the expected value; if not, re-analyze the RLV once. If the failure persists, terminate the analysis, determine the cause of the failure, and correct the problem. Corrective actions include instrument maintenance, reviewing calculations and the calibration curve.

STATE NOTE: Drinking water samples analyzed using this procedure for compliance cannot be qualified.

11.10 Data that does not meet acceptable QC criteria may be acceptable for use in certain circumstances.

11.10.1 If the MS/MSD fails (recovery <30% or >150%, and/or the RPD >30%) in an initial analysis and again upon re-analysis, the data is released with an appropriate qualifier and the failure is accepted as matrix related.

11.10.2 If a calibration verification standard and/or the LCS is above the acceptable QC criteria and all samples being bracketed are below the reporting limit, the data is acceptable based on high calibration bias with undetectable concentrations in the field samples. Any positive samples require re-analysis.

11.10.3 If the RPD for a sample duplicate is above acceptance limits and the sample concentration is less than five times the reporting limit, the value can be reported with a “P1” qualifier, indicating that the RPD calculation is not applicable at that concentration.

12.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

12.1 The EPA requires that laboratory waste management practice to be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner. See *Pace National Waste Management Plan.*

12.2 See ENV-SOP-MTJL-0046, *Environmental Sustainability & Pollution Prevention*.

13.0 METHOD MODIFICATIONS/CLARIFICATIONS

13.1 None. Modifications have been made to the Eluent solution per the instrument manufacturer’s conditions for the column utilized and is allowed by method.

14.0 REFERENCES

14.1 Installation Instructions and Troubleshooting Guide for the IonPac AS14 Guard Column and IonPac AS14 Analytical Column, DIONEX Corporation.

14.2 U.S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes, Method 300.1, Revision 1.0, 1997.

14.3 U.S. Environmental Protection Agency, Manual for the Certification of Laboratories Analyzing Drinking Water, January 2005

14.4 Standard Methods for Examination of Water and Wastewater, 23nrdEd. or online version.

14.6 US EPA, SW846, Update IV, 9056A 2/07.

STANDARD OPERATING PROCEDURE
TITLE: Determination of Elements in Water and Solids by Ion Chromatography
(EPA Methods 300.0, 9056, 9056A, and SM 4110B)
ISSUER: Pace National – Mt. Juliet, Tennessee

Attachment I: Revision History

Current Version (Pace National):

Date	Description of Revisions
5/17/2021	Update per South Carolina DHEC request. Revised Sections 7.3, 8.2.1, 10.4.1, 10.5, and 10.8.

Superseded Versions (ESC Lab Sciences SOP #340319):

Version	Date	Description of Revisions
0	4/3/00	Origination
1	8/21/00	
2	9/13/00	
3	12/21/00	
4	10/16/01	
5	11/5/02	
6	9/5/03	
7	11/3/04	
8	4/19/05	
9	6/27/06	
10	11/23/07	Technical and Quality Review and update.
11	2/12/09	Technical and Quality Review and update; Added state notes; clarified calibration and holding times; Ohio VAP approved 2/12/09.
12	11/23/10	Technical and Quality Review and update; Revised sections 2.3, 2.11, 6.1, 6.13, 7.1, 7.3.1, 7.5, 8.1, 8.2, 8.3, 9.2, 10.4 through 10.12, 11.1 through 11.4, and 12.1; Added section 1.3 (state note), 2.13, 2.14, 6.14, 8.2.2 (state note), 8.6, 9.3, 9.4, 10.4 (state note), 10.5 (state note), 10.13 (including state note), 11.5 through 11.11, and 13.5.
13	2/23/12	Technical and Quality Review and update; Revised sections 2.4, 2.9, 2.10, 6.1, 6.3, 8.3.1, 8.4.4, ; Added state note in section 1.0 and note in section 10.1; Added sections 1.3.1, 2.15 through 2.22; Removed section 7.2.
14	9/7/12	Technical and Quality Review and update; Revised sections 7.4, 8.1.1, 8.1.2, 8.2.1, 8.4.2, 8.5, 8.6, 9.1, 10.3, 10.9, and 13.1; Added sections 13.6, 14.7 through 14.9; Removed section 2.22, 9.2, 13.2, and 13.3.
15	6/23/14	Technical and Quality Review and update; Revised sections 2.14, 4.4, 6.5 through 6.7, 7.1, 7.4, 7.5, 9.3 and 10.3.2; Added state notes in section 8.3.2, 10.3.1. 10.8. and added sections 4.5, 9.6, 10.4, 13.5 and 14.10; Segregated Ohio VAP requirements in ESC SOP 340319OH.
16	8/20/2015	Technical and Quality Review and update. Revised Sections 1.3.1, 4.5, 7.1, 10.3.1 (including State Note), and 10.3.2.
17	4/6/2016	Technical and quality review and update. Revised Sections 1.3, 1.3.1, 2.1, 2.3, 2.4, 4.4, 8.1, 8.2.1, 8.2.2, 8.4.3, 8.6.1, 8.6.2, 9.2,9.3, 10.6, 10.7, 10.10, 11.4, 11.5, 11.7, 11.11.1, and 12.2. Added Attachment III. Deleted Sections 2.5 through 2.21, 5.2.1, 5.2.2, 7.2, and 8.3.3, 9.4 through 9.6.
18	11/28/2017	Technical and quality review and update. Header and signature block re-formatting. Revised Sections 3.1, 4.4, 7.3, 8.1.1, 10.3.2, 10.4.1, 10.5, 10.9, 10.11, 11.4, 11.9, and Attachment III Table 5. Deleted Sections 2.3, 2.3.1, and renumbered as necessary. Added Section 6.18.

Superseded Versions (Pace National):

Date	Description of Revisions
7/23/19	Added header and footer. Revised 8.4.1 and 8.4.2
5/10/19	Revised Sections 1.1, 1.2, 2.2, 4.4, 7.3, 8.1.5. 8.3.2, 8.4.2, 10.5. Added Sections 7.2.5, 7.2.6, 7.4.2, 7.4.3, 7.4.4. Deleted section 8.1.6 and deleted attachment II.
3/1/19	Technical and quality review and update. Deleted header, footer and signature bar. Revised sections 1.0, 1.3, 1.3.1, 3.1, 3.2, 4.4, 4.5, 6.8, 6.9, 6.10, 6.11, 6.12, 6.13, 6.14, 6.15, 6.16, 6.17, 6.18, 7.1, 7.2, 7.2.2, 7.2.3, 7.3, 7.4, 7.4.1, 7.4.2, 8.1.1, 8.1.2, 8.2.1, 8.2.2, 8.3, 8.3.2, 8.4.2, 8.4.4, 8.6, 8.6.1, 8.6.3, 9.1, 10.1, 10.2, 10.3, 10.3.1, 10.3.2, 10.4, 10.4.1, 10.4.2, 10.4.3, 10.7, 10.8, 10.11, 11.2, 11.6, 11.7, 11.8, 11.11.2, 11.11.3, 12.1, 12.2, 14.3, 14.4, 14.5, 14.6, 14.7, 14.8, 14.9 and 14.10. Deleted sections 5.5.2, 7.2.1, 7.4.2, 7.4.3 and 13.5. Added sections 7.2.1, 7.2.4, 7.4.2, 7.4.3 and 8.6.7. Revised Attachment I. Revised Attachment II section 4.10.
5/8/2020	Technical and quality review and update. Replaced section 3.0, Health and Safety. Revised Tables in section 7.3. Revised sections 8.1.2 and 8.1.5.
3/1/2021	Technical and quality review and revision. Revised Sections 1.0, 1.1, 1.2, 2.1, 2.2, 4.2, 4.3, 4.4, 5.1.1, 5.2, 5.3, 7.3, 7.4, 7.5, 7.6, 7.4.2, 7.4.4, 7.4.5, 7.4.6, 8.1.2, 8.1.4, 8.1.5, 8.2.1, 8.2.2, 8.3.1, 8.3.2, 8.4.2, 8.6.5, 8.6.6, 9.2, 10.1, 10.3.1, 10.3.2, 10.4.1, 10.5, 10.6, 10.7, 10.8, 10.9, 10.10, 10.11, 10.12, 11.4, 11.5, 11.6, 11.9, and 11.10. Deleted Sections 13.2, 13.3, 13.4, 13.5, 14.5, 14.6, 14.7, 14.8, 14.9, and 14.10.

Attachment II: DoD Requirements

1.0 Equipment/Instrument Maintenance

Instrument maintenance must be performed routinely to optimize instrument performance and improve chromatography. Maintenance is performed on an "as needed" basis and, when performed, is documented in a maintenance logbook. A new calibration curve must be analyzed following any major maintenance performed on the analytical system.

2.0 Computer Hardware and Software

PeakNet 6 (Chromeleon™) software

3.0 Troubleshooting

Table 1. Dionex ICS-2100 Troubleshooting Guide

Problem	Cause	Treatment
Leaks	Leaking Fitting	Locate the source of the leak. Tighten or, if necessary, replace the liquid line connection.
	Broken Liquid Line	Replace the line and fittings with the same length and internal diameter tubing.
	Blocked or improperly installed line	Make sure the lines are not crimped or otherwise blocked. Also, if the blocked line is a waste line, make sure it is not elevated at any point after it exits the Dionex ICS-2100. If a line is blocked, replace it.
	Loose pump check valve	Make sure the check valves are firmly seated in the pump head. If they are not, tighten them carefully with an open-end wrench just until the leak stops. If the leak persists, replace the check valve.
	Leaking seal wash port	Leaking from the seal wash port indicates a leaking piston seal. Replace the seal.
	Damaged pump piston seal	Replace the piston seal. If the leak persists, replace the piston.
	Pump head not tight against casting	Carefully tighten the pump head mounting nuts just until the leak stops. DO NOT OVERTIGHTEN!

Table 1. Dionex ICS-2100 Troubleshooting Guide

Problem	Cause	Treatment
Pump Difficult to Prime or Loses Prime	Empty eluent reservoir and/or no eluent connected	Fill the reservoir. Make sure all connections are secure.
	Eluent improperly or insufficiently degassed	Check the vacuum degas settings.
	End-line filter is dirty or clogged	When new, end-line filters (P/N 045987) are pure white. If the system is in continuous operation, change the end-line filter weekly, or whenever it becomes discolored. Replace the filter more often if bacterial buildup is visible or if the eluent does not contain solvent.
	Blockages in inlet tubing	Kinked or clogged tubing causes the pump to be “starved” for eluent. Replace the tubing and fittings.
	Dirty check valve	Clean or replace the pump check valve.
	Liquid leaks at junction between pump head and pump casting	Use a wrench to tighten the two acorn nuts that attach the pump head to the pump housing. Tighten the nuts evenly. If the leak persists, replace the piston seal.
Pump Does Not Start	No power	Check that the power cord is plugged in. Check the main power fuses and replace, if needed.
	No communication between Dionex ICS-2100 and Chromeleon	Verify that the USB cable is connected correctly. For connection and setup information, refer to the Dionex ICS-2100 installation instructions.
	Pump is turned off	Turn on the pump from either the Chromeleon Control panel or the Dionex ICS-2100 touch screen HOME page.
	Flow rate is set to 0	Set the flow rate from either the Chromeleon Control panel or the Dionex ICS-2100 touch screen HOME page.

Table 1. Dionex ICS-2100 Troubleshooting Guide

Problem	Cause	Treatment
No Flow	Pump waste or priming valve open	Close the valves by turning the knobs clockwise until finger tight. DO NOT OVERTIGHTEN! Overtightening may damage the valve and the pump head.
	Flow rate is set to 0	Set the flow rate from either the Chromeleon Control panel or the Dionex ICS-2100 touch screen HOME page.
	Eluent valve is closed	Open the eluent valve from the Dionex ICS-2100 Control panel in Chromeleon or from the touch screen PUMP page.
	Pump not primed	Prime the pump.
	Broken pump piston	Replace the piston.
	Eluent generator degas tubing assembly ruptured	Replace the Dionex EluGen cartridge holder
Baseline Noise or Drift	Flow system leak	Check all fittings and liquid lines for leaks. Tighten or, if necessary, replace all liquid line connections.
	Trapped gases	Release any trapped gases in the cell by loosening the lines to and from the cell and then retightening them. Also loosen and retighten the fittings to and from the suppressor eluent ports.
	Pump not primed	Prime the pump.
	Incorrect eluent	Check the EGC concentration setting.
	Inadequate system backpressure	Add backpressure tubing between the injection valve and the ELUENT OUT port on the EGC to maintain a pressure of 16 ± 0.7 MPa (2300 ± 100 psi).

4.0 Other Requirements

4.1 All hardcopy laboratory notebooks must be reviewed by the Supervisor, or their designee, on a monthly basis.

4.2 If not self-explanatory (e.g., a typo or transposed number), corrections to technical and quality records shall also include a justification for the change.

4.3 A person performing a manual integration must sign and date each manually integrated chromatogram and record the rationale for performing manual integration. Electronic signatures are acceptable.

4.4 The results of calibration and verification of support equipment must be within the specifications required of the application for which this equipment is used, or the equipment must be removed from service until repaired. Calibration and verification records, including those of established correction factors, must be maintained. In the absence of method-specific requirements, the minimum requirements are as follows:

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Balance calibration check [Using two standard weights that bracket the expected mass]	Daily prior to use	Top-loading balance: ±2% or ±0.02g, whichever is greater Analytical balance: ±0.1% or ±0.5 mg, whichever is greater
Verification of standard mass [Using weights traceable to the International System of Units (SI) through a NMI	Every 5 years	Certificate of Calibration from ISO/IEC 17025 accredited calibration laboratory
Monitoring of refrigerator/freezer temperatures	Daily (i.e., 7 days per week) [use MIN/MAX thermometers or data loggers equipped with notification of out of control event capabilities if personnel not available to record daily]	Refrigerators: 0˚C to 6˚C Freezers: ≤-10˚C
Thermometer verification check [Using a thermometer traceable to the SI through an NMI] [Performed at two temperatures that bracket the target temperature(s). Assume linearity between the two bracketing temperatures.] [If only a single temperature is used, at the temperature of use]	Liquid in glass: Before first use and annually Electronic: Before first use and quarterly	Apply correction factors or replace thermometer
Volumetric labware	Class B: By lot before first use Class A and B: Upon evidence of deterioration	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on 10 replicate measurements)
Non-volumetric labware [Applicable only when used for measuring initial sample volume and final extract/ digestates volume]	By lot before first use or upon evidence of deterioration	Bias: Mean within ±3% of nominal volume Precision: RSD ≤3% of nominal volume (based on 10 replicate measurements)
Mechanical volumetric pipette	Quarterly	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on minimum of 3 replicate measurements) [Note: for variable volume pipettes, the nominal volume is the volume of use]
Glass microliter syringe	Upon receipt and upon evidence of deterioration	General Certificate of Bias & Precision upon receipt Replace if deterioration is evident
Drying oven temperature check	Daily prior to and after use	Within ±5% of set temperature

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Water purification system	Daily prior to use	See method blank criteria given in Section 4.20 of this attachment

4.5 The expiration date of the prepared standard shall not exceed the expiration date of the primary standard. All containers must bear a preparation date.

4.6 To avoid preparing non-representative samples, the laboratory shall not “target” within a relatively small mass range (e.g., 1.00 ± 0.01g) because such targeting will produce non-representative subsamples if the sample has high heterogeneity. The laboratory shall not manipulate the sample material so the sample aliquot weighs exactly 1.00g ± 0.01g, as an example.

4.7 In the absence of project-specific requirements, the minimum standard data qualifiers to be used are:

U Analyte was not detected and is reported as less than the LOD or as defined by the customer. The LOD has been adjusted for any dilution or concentration of the sample.

J The reported result is an estimated value (e.g., matrix interference was observed, or the analyte was detected at a concentration outside the quantitation range).

B Blank contamination. The recorded result is associated with a contaminated blank.

N Non-target analyte. The analyte is a tentatively identified compound using mass spectrometry or any non-customer requested compounds that are tentatively identified.

Q One or more quality control criteria failed (e.g., LCS recovery, surrogate spike recovery, or CCV recovery).

Additional data qualifiers may be used, or different letters or symbols to denote the qualifiers listed above, as long as they are appropriately defined and their use is consistent with project-specific requirements (e.g., QSM 5.0, the contract, and project-planning documents).

4.8 If the time of the sample collection is not provided, assume the most conservative time of day. For the purpose of batch processing, the start and stop dates and times of the batch preparation shall be recorded.

4.9 Each preparation method listed on the scope of accreditation must have quarterly LOD/LOQ verifications. However, not all possible combinations of preparation and cleanup techniques are required to have LOD/LOQ verifications. If LOD/LOQ verifications are not performed on all combinations, the laboratory must base the LOD/LOQ verifications on the worst-case basis (preparation method with all applicable cleanup steps).

4.10 After each MDL determination, the laboratory must establish the LOD by spiking a quality system matrix at a concentration of at least 2 times but no greater than four times the

MDL. This spike concentration establishes the LOD and the concentration at which the LOD shall be verified. It is specific to each suite of analyte, matrix, and method (including sample preparation). The following requirements apply to the initial LOD establishment and to the LOD verifications:

- The apparent signal to noise (S/N) ratio at the LOD must be at least three and the results must meet all method requirements for analyte identification (e.g., ion abundance, second column confirmation, or pattern recognition). For data systems that do not provide a measure of noise, the signal produced by the verification sample must produce a result that is at least three standard deviations greater than the mean method blank concentration. This is initially estimated based on a minimum of four method blank analyses and later established with a minimum of 20 method blank results.
- If the LOD verification fails, then the laboratory must repeat the MDL determination and LOD verification or perform and pass two consecutive LOD verifications at a higher spike concentration and set the LOD at the higher concentration.
- The laboratory shall maintain documentation for all MDL determinations and LOD verifications.
- The DL and LOD must be reported for all analyte-matrix-methods suites, unless it is not applicable to the test or specifically excluded by project requirements.

4.11 The LOD shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOD verifications on a one per batch basis. All verification data will be in compliance, reported, and available for review.

4.12 For DoD, at a minimum, the LOQ shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOQ verifications on a one per batch basis.

4.13 All initial instrument calibrations must be verified with a standard obtained from a second manufacturer prior to analyzing any samples. The use of a standard from a second lot obtained from the same manufacturer (independently prepared from different source materials) is acceptable for use as a second source standard. The concentration of the second source standard shall be at or near the midpoint of the calibration range. The acceptance criteria for the initial calibration verification must be at least as stringent as those for the continuing calibration verification.

4.14 Exclusion of calibration points without documented scientifically valid technical justification is not permitted.

4.15 The concentration of the CCV standard shall be greater than the low calibration standard and less than or equal to the midpoint of the calibration range.

4.16 All CCVs analyzed must be evaluated and reported. If a CCV fails, reanalysis or corrective actions must be taken.

- If a CCV fails, the laboratory can immediately analyze two additional consecutive CCVs (immediately is defined as starting a consecutive pair within one hour; no samples can be run between the failed CCV and the two additional CCVs). This approach allows for spurious failures of analytes to be reported without reanalysis of samples. Any corrective actions that change the dynamics of the system (e.g., clip column, clean injection port, run blanks) requires that all samples since the last acceptable CCV be reanalyzed.

- Both of these CCVs must meet acceptance criteria in order for the samples to be reported without reanalysis.
- If either of these two CCVs fail or if the laboratory cannot immediately analyze two CCVs, the associated samples cannot be reported and must be reanalyzed.
- Corrective action(s) and recalibration must occur if the above scenario fails. All affected samples since the last acceptable CCV must be reanalyzed.
- Flagging of data for a failed CCV is only appropriate when the affected samples cannot be reanalyzed. The laboratory must notify the client prior to reporting data associated with a failed CCV.

4.17 The results of all MS/MSDs must be evaluated using the same acceptance criteria used for the DoD LCS limits (see Attachment Tables 3 and 4) or project limits, if specified. If the specific analyte(s) are not available in the Attachment Tables 3 and 4, the laboratory shall use their LCS in-house limits (see the LIMS) as a means of evaluating MS/MSDs. The MS and MSD must be spiked with all reported analytes.

4.19 Surrogate spike results shall be compared with DoD LCS limits (see Attachment Tables 3 and 4) or acceptance criteria specified by the client. If these criteria are not available, the laboratory shall compare the results with its in-house statistically established LCS criteria (see the LIMS).

4.20 The method blank shall be considered to be contaminated if:

- The concentration of any target analyte (chemical of concern) in the blank exceeds 1/2 the LOQ and is greater than 1/10th the amount measured in any associated sample, or 1/0th the regulatory limit, whichever is greater.
- The concentration of any common laboratory contaminant in the blank exceeds the LOQ.
- If a method blank is contaminated as described above, then the laboratory shall reprocess affected samples in a subsequent preparation batch, except when sample results are below the LOD. If insufficient sample volume remains for reprocessing, the results shall be reported with appropriate data qualifiers.

4.21 Sporadic Marginal Exceedances are not allowed for target analytes (chemicals of concern as identified by a project) without project-specific approval. Target analytes are considered those few analytes that are critical for the success of a project (such as risk drivers) where sporadic marginal exceedances cannot be allowed. Laboratories should consult with clients whenever long lists of analytes are requested for analysis to determine if marginal exceedances will not be allowed.

4.22 DoD considers the same analyte exceeding the LCS control limit two (2) out of three (3) consecutive LCS to be indicative of non-random behavior, which requires corrective action and reanalysis of the LCS.

Table 3. LCS Control Limits – Method 9056 Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
24959-67-9	Bromide	222	101	5.1	86	116
16887-00-6	Chloride	612	100.9	4.7	87	115
16984-48-8	Fluoride	300	100.3	9.1	73	128
14797-55-8	Nitrate	680	99.2	4	87	111
14797-65-0	Nitrite	419	100.3	4.9	86	115
14265-44-2	Phosphate	142	102.4	3.8	91	114
14808-79-8	Sulfate	305	100.9	4.7	87	115

Table 4. LCS Control Limits – Method 9056 Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
24959-67-9	Bromide	2199	100.3	3.2	91	110
16887-00-6	Chloride	4948	98.5	4	87	111
16984-48-8	Fluoride	3251	99.7	4	88	112
14797-55-8	Nitrate	3192	99.7	3.9	88	111
14797-65-0	Nitrite	2583	98.9	3.9	87	111
14265-44-2	Phosphate	843	97.8	6.1	80	116
14808-79-8	Sulfate	4155	99.2	4.1	87	112

Table 5. Quality Control Requirements – Common Anions Analysis by IC

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration (ICAL) for all analytes	ICAL prior to sample analysis.	$r^2 \geq 0.99$.	Correct problem, then repeat ICAL.	Flagging criteria are not appropriate.	Minimum 3 standards and a calibration blank. No samples shall be analyzed until ICAL has passed.
Retention Time window position establishment	Once per multipoint calibration.	Position shall be set using the midpoint standard of the ICAL curve when ICAL is performed. On days when ICAL is not performed, the initial CCV is used.	NA.	NA.	Calculated for each analyte.
Retention Time (RT) window width	At method set-up and after major maintenance (e.g., column change).	RT width is ± 3 times standard deviation for each analyte RT over a 24-hour period.	NA.	NA.	Calculated for each analyte.
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis.	All reported analytes within established RT windows. All reported analytes within ± 10% of true value.	Correct problem. Rerun ICV. If that fails, repeat ICAL.	Flagging criteria are not appropriate.	Freshly prepared ICV. No samples shall be analyzed until calibration has been verified.

Table 5. Quality Control Requirements – Common Anions Analysis by IC

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Continuing Calibration Verification (CCV)	Before sample analysis; after every 10 field samples; and at the end of the analysis sequence.	All reported analytes within established retention time windows. All reported analytes within ± 10% of true value.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since the last successful CCV. Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since the last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed. Retention time windows are updated per the method.

Table 5. Quality Control Requirements – Common Anions Analysis by IC

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Method Blank (MB)	One per preparatory batch.	No analytes detected > 1/2 LOQ or > 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater.	Correct problem. If required, reprep and reanalyze MB and all QC samples and all field samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid method blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Laboratory Control Sample (LCS)	One per preparatory batch.	A laboratory must use Table 3 and 4 limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Correct problem, then re-prep and reanalyze the LCS and all samples in the associated preparatory batch for all reported analytes, if sufficient sample material is available.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Must contain all reported analytes. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Table 5. Quality Control Requirements – Common Anions Analysis by IC

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Matrix Spike (MS)	One per preparatory batch.	A laboratory must use Table 3 and 4 limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified.	Follow project specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	Must contain all reported analytes. For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference (i.e., matrix effect or analytical error.)
Matrix Spike Duplicate (MSD) or Matrix Duplicate (MD)	One per preparatory batch.	A laboratory must use Table 3 and 4 limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits if project limits are not specified. MSD or MD: RPD of all analytes ≤ 15% (between MS and MSD or sample and MD).	Follow project specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	Must contain all reported analytes. The data shall be evaluated to determine the source of difference. For Sample/MD: RPD criteria only apply to analytes whose concentration in the sample is greater than or equal to the LOQ.

Document Information

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Document Title: BTEX (Method 8021B, 602, SM6200C 2th) and Gasoline Range Organics (Methdo 8015B, 8015C, 8015D) by GC (with provisions for Calif-Lo, NWTPH-Gx, OA1, WI GRO (synthetic), Wyoming LAUST Req., GRO Luoisiana, AK101 GRO)	
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All dates and times are in Central Time Zone.

ENV-SOP-MTJL-0087

QM Approval

Name/Signature	Title	Date	Meaning/Reason
Steven Miller (006597)	Manager - Quality	10 Feb 2021, 12:24:28 PM	Approved

Management Approval

Name/Signature	Title	Date	Meaning/Reason
Christopher Johnson (006487)	Manager - Operations	10 Feb 2021, 12:24:59 PM	Approved
Kayla Coble (006639)	Supervisor	10 Feb 2021, 12:26:04 PM	Approved

1.0 SCOPE AND APPLICATION

STATE NOTE: For samples analyzed in conjunction with the Ohio Voluntary Action Program (VAP) please utilize ENV-SOP-MTJL-0086.

1.1 BTEXM/GRO by gas chromatograph determines the concentration of benzene, toluene, ethylbenzene, m, p & o-xylene, MTBE, and gasoline range organics (C_6 - C_{10}) (range defined in Method 8015B) in solution. All matrices, including groundwater, aqueous samples, TCLP extracts, wastewater, soils, sludge, sediments, and other solid wastes, can be analyzed by this method. Wisconsin GRO and AK101 GRO are determined by this method. Samples analyzed by the GRO-Louisiana method are quantitated using a carbon range of C_6 – C_{10}.

1.2 The data shown in Attachment II provides the reporting limits for analytes in clean aqueous samples for each instrument currently running this method; however, reporting limits are subject to change to address matrix issues, to better meet client/project/regulatory needs or to improve laboratory method performance.

1.3 Method Detection Limits (MDLs) are performed and evaluated based on ENV-SOP-MTJL-0016. Updated MDL records are filed and stored in a central location within the department.

1.3.1 Limit of Detection (LOD) and Limit of Quantitation (LOQ) studies are completed at the frequency required by the TNI standard per the procedure identified in the ENV-SOP-MTJL-0016, *Method Detection Limits (MDL), Limits of Detection (LOD) and Limits of Quantitation (LOQ).* Should the procedure be utilized for DOD support; then the frequency of these studies must meet the requirements of the current DOD QSM.

2.0 METHOD SUMMARY AND DEFINITIONS

2.1 Samples (except for those to be prepared by 5035A) require no preparation before analysis unless the concentration of the analyte is great enough to require a serial dilution.

In samples being analyzed by 5035A, an aliquot of the methanol extract is used to prepare the necessary dilution in 5mL of DI water.

2.2 This SOP describes the determination of concentrations of benzene, toluene, ethylbenzene, MTBE, and m, p, & o-Xylene by PID and gasoline range organics by FID. This method uses purge and trap to determine these concentrations. The BTEXM compounds and GRO concentrations are determined by internal standard calibration using fluorobenzene as the internal standard. Sample Introduction Method: The volatile compounds are introduced into the gas chromatograph by the EPA Purge-and-Trap Method 5030, SW-846.

2.2.1 Samples are placed in vials and purged with helium gas. The purged volatile compounds are transported to a trap (Supelco Purge Trap G) that is at 40°C. The trap is rapidly heated at the end of the purge cycle to 200°C and the volatile compounds desorb to the capillary column. After passing through this column, the compounds first pass by the PID, which detects double bonds, and then by the FID, which detects compounds that burn. As they pass by these detectors, an electrical signal is transmitted to a computer or integrator and causes an electrical peak to be recorded. The area underneath these peaks can be compared to known concentrations to determine the concentrations of BTEXM compounds in the sample.

2.3 Gasoline Range Organics (GROs) - Correspond to the range of alkanes from C_6 to C_{10} and covering a boiling point range of approximately 60ºC – 170ºC.

2.4 See the current Quality Assurance Manual for other definitions associated with terms found in this document.

3.0 HEALTH AND SAFETY

3.1 The toxicity or carcinogenicity of each chemical or sample being diluted in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

3.2 The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets (SDS) for all hazardous chemicals are available to all personnel. Employees must abide by the environmental, health, and safety (EHS) policies and procedures specified in this SOP and in the Pace National Chemical Hygiene / Safety Manual.

3.3 Personal protective equipment (PPE) such as safety glasses and/or side shields, gloves, a laboratory coat, and shoes that are not cloth, canvas, and/or perforated must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure. When handling glass, needles, knives, or any material with a potential sharp edge, employees must use cut-resistant gloves.

3.4 Spill kits are located in each laboratory department. Employees are to familiarize themselves with the location and contents of each spill kit in their area.

3.5 Universal precautions should be observed when performing any tests or procedures. Hard surfaces, instrument surfaces may be contaminated and should be handled according to good laboratory practices.

3.6 Contact your supervisor or local EHS coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure. Any accidents involving personnel or sample supplies are to be reported immediately to either the Manager and/or to the Safety Officer.

4.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

4.1 All samples must have been collected using a sampling plan that addresses the considerations of this method.

4.2 Holding Times, Storage and Container Requirements

4.2.1 Water (EPA 5030) – See ENV-SOP-MTJL-131 for more information

Aqueous samples must be collected in triplicate in 40mL vials with the pH adjusted to <2 with HCl and stored at ≤6ºC (not frozen). Sample must be analyzed within 14 days of collection. Samples not preserved with HCl must be analyzed within seven days of collection.

4.2.1.1 Samples that do not have a pH <2 are qualified with a G1 if analyzed past seven days of collection.

4.2.2 Soil (EPA 5035A) – See ENV-SOP-MTJL-0129 for more information

4.2.2.1 Sample Collection Kit – sampling kits for VOC soil samples contain at a minimum, one 2oz. jar for bulk sample collection, 2-40mL pre-weighed vials containing a magnetic stir bar, and a 5mL aliquot of preservative solution. The preservative solution in these vials is 20% sodium bisulfate solution in reagent water. Also included in the kit is a 40mL vial containing 5mL purge and trap grade methanol. The kit also contains a core sampler. Terra Core samplers are routinely used but equivalent samplers may be utilized depending on project specific needs. Samples are collected by field personnel and resealed then transported to the laboratory chilled at ≤6°C (not frozen).

4.2.2.2 Alternate kits can be provided with core samplers and a 2oz. jar for sample collection. Samples are collected by field personnel and resealed then transported to the laboratory chilled at ≤6°C (not frozen).

4.2.2.3 Sample must be analyzed within 14 days of collection. Low concentration samples that are **NOT** preserved with sodium bisulfate must be frozen or analyzed within 48 hours of collection. Upon receipt, these samples are frozen extending the holding time to 14 days.

4.2.2.4 Unprepared bulk samples coming into the laboratory are prepped as two low concentration samples and one high concentration sample if sufficient sample has been provided.

STATE NOTE: Soil and Water samples received from the states of Missouri or Kansas may be preserved with tri-sodium phosphate and have a resulting pH > 12.

4.3 **STATE NOTE:** AK101 Soil/Sediment Collection Procedure - Soils and Sediments: Soil and sediment samples require special procedures to minimize the loss of volatile organic compounds during transit from the field to laboratory. **Please note that this sample preservation is different from SW-846 Method 8021B. The use of sodium bisulfate as a preservative is not acceptable.**

4.3.1 Soil or sediment samples must be collected into appropriately sized containers and submerged in surrogated methanol.

4.3.2 Solid samples must be collected with minimum disturbance into tared jars with a Teflon™-lined septum fused to the lid. Jars should be 4oz. or larger. 25mL aliquots of methanol (includes 1.25µL of a surrogate solution at 50µg/mL) are carefully added to the undisturbed soil until the sample is submerged.

4.3.3 It is extremely important that the weight of the jar, the weight of the methanol/surrogate solution, and the weight of the sample collected be known. These must either be measured directly, or sufficient information documented so that these weights can be calculated.

4.3.4 The ratio of soil to methanol used to calculate the MDL and PQL offered in the AK101 method was 1:1 (w:w). However, absorbent, organic soils such as muskeg and tundra require a higher methanol-to-sample ratio, while beach sand may tolerate a lower ratio.

4.3.5 Soil for volatiles analysis can be collected using any coring device that minimizes soil disturbance. Any scraping, stirring, or similar activity results in a loss of volatiles during sampling. A sufficient number of samples must be collected to provide for backup in case of breakage.

4.3.6 Although it is not necessary to refrigerate all methanol preserved samples at 4° ± 2°C after collection and until analysis is complete, collected samples must be kept below 25°C.

4.3.7 A second surrogate, added to the methanol and soil mixture after sample collection, may be used in addition to, but not in place of, the surrogate with which the field methanol preservative was prepared.

4.3.8 A reagent methanol trip blank must be prepared in the same manner as the sample vials and must contain surrogated methanol. One trip blank must be included with each shipping container and must be stored and analyzed with the field samples. Trip blank analysis is not required if all samples in a shipping container are less than the project specific cleanup level.

4.3.9 Field blanks may be added to the sampling protocol and are prepared in the field by addition of surrogated methanol to the prepared container, as required by the Assessment Firm or the Project Manager.

4.3.10 A sample of the same soil to be analyzed for GRO must be collected into a moisture-proof container for per cent moisture determination. This sample is processed as soon as possible upon arrival at the laboratory to assure that the resulting moisture determination is representative of the preserved sample as surveyed.

4.3.11 Trip blanks, field blanks, method blanks, etc. are prepared from the same batch of solvent, reagents, and vials as are used for sample preservation.

4.3.12 Twenty-eight days is the maximum holding time for soil and sediment samples collected under this section.

4.3.13 Because the jars are pre-weighed, it is extremely important that the sampler put evidence tape on the kit ONLY, or the bubble bags in which the sample bottles are shipped, and not on the individual bottles. Removal of evidence tape is extremely difficult and the additional weight biases final results. Also, the glue on the evidence tape can contribute to the volatiles concentration in the sample.

4.3.14 Trip blanks, field blanks, and bottle blanks are prepared as appropriate to meet the quality assurance goals of the project plan.

4.3.15 28 days is the maximum holding time for AK101 soil samples preserved with MeOH. If BTEX is included, the holding time is 14 days.

4.4 Samples submitted for analysis that do not meet the requirements contained within this section must be addressed before performing the logging process within the laboratory. In some cases, exceeding the appropriate preservation and storage criteria can cause significant bias in the resulting data. Clients may need to resubmit samples where the conditions during shipment cause uncertainty regarding sample integrity. If samples do not meet the requirements for preservation, sampling, shipment and storage and the client approves the completion of the analytical process, sample results can be qualified per the ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

5.0 INTERFERENCES

5.1 Matrix interference can result in samples with high concentrations of volatile organic compounds (VOC). This interference can cause the resulting peaks to not be clear and concise. This can lead to misidentification of compounds and/or poor quantitation of those compounds. This problem can be solved by diluting the sample.

5.2 Carryover from previous samples must be monitored through the use of sample blanks. When a sample with a high concentration of VOC's is followed by a low-level sample, false peaks may result from carryover. Sample blanks are used to clean the instrument.

6.0 EQUIPMENT AND SUPPLIES

The operation, cleaning and scheduled maintenance procedures prescribed by the equipment manufacturer are followed as provided in the Operator’s Manuals. Documentation of maintenance or system modifications is recorded in a maintenance logbook which accompanies each instrument.

6.1 <u>Instrumentation</u>

- Designated Instruments: VOCGC #1, #3, #4, #5, #6, #10, #12, #14, #15
- Use (method #’s): 8021B; 8015B, 8015C & 8015D
- Model #: HP 5890/6890 or equivalent
- Column (type, brand, size): J&W Scientific DB VRX 75m x 0.450mm, 2.55µm or equiv.
- Detector: GC FID, PID
- Software name and version: HP Chemstation G1701BA B.01.00, C.01.00 or equivalent
- Sample introduction system: Archon Autosampler, Encon P & T, or equivalent

6.2 <u>Glassware</u>

Volumetric – glassware equipped with penny head ground glass stopper. The volumetric flasks and graduated cylinders are cleaned by rinsing with methanol and laboratory reagent water. The volumetrics are dried in a low temperature oven at less than 120°C. Never use a brush or strong alkali solution to clean the volumetrics.

6.3 <u>Glass Sample (VOA) and Standard Vials:</u>

6.3.1 "42.5mL" VOA vials with a Teflon™/silicone septa and polypropylene open-top cap.

6.3.2 8mL vials with Teflon™/silicone/Teflon™ septa and polypropylene open-top cap. (Used to store unused standards.)

6.3.3 2mL vials with Teflon™ lined screw caps.

6.4 <u>Miscellaneous:</u>

6.4.1 Stainless Steel Spatula, tongue depressors

6.4.2 Teflon™-coated stir bars, 8mm x 16mm

6.4.3 Laboratory Blank Matrix: Sand, glass beads, etc. is prepared by rinsing clean with methanol and laboratory reagent water several times. The matrix is baked in an oven at 175°C overnight to remove any volatiles and is then stored in the sealed container used for baking. The clean laboratory matrix may be purged with carrier grade helium or nitrogen to remove trapped volatiles.

6.5 Oven: Fisher IsoTemp Forced-Air Oven with capabilities of 100°C, or equivalent

6.6 Top-loading Balance, capable of weighing to 0.01g, or equivalent

7.0 REAGENTS AND STANDARDS

7.1 All reagents and standards must be recorded in the appropriate preparation log and assigned a unique number. See ENV-SOP-MTJL-0041, *Standards Logger – Tree Operation*. Additional information regarding reagent preparation can be found in the Standards Logger (Tree) digital archive system. All spiking solutions and surrogate standard solutions should be replaced at least every six (6) months, or sooner, if a problem is detected unless otherwise noted.

7.2 **Reagents**

7.2.1 Nanopure water or equivalent: Nanopure water is used in all blanks to assure that it contains less than the method detection limit (MDL) of all compounds of interest. The blank must be assessed to ensure that the water does not show any detection of any VOC compounds.

7.2.2 Methanol, CH_3OH (VWR™ #EM-MX0480-1 or equivalent) - purge and trap grade, demonstrated to be free of target analytes. Store isolated from other solvents in the designated flammables cabinet.

7.2.3 Sodium Bisulfate, $Na_2S_2O_3$ from QEC, Level 3 certified in 40mL vials, or equivalent

7.2.4 Sodium Bisulfate monohydrate, 99% for analysis, ACROS Organics or equivalent

7.3 **Stock Standards:** Stock solutions may be prepared from pure standard materials or purchased as certified solutions. These standards are prepared in methanol. Store stock standards in vials at <u>≤</u>10°C.

7.3.1 BTEXM/GRO Calibration Standard – NSI PVOC/GRO mixture UST-360, or equivalent is used for the BTEXM compounds, and Restek certified BTEX in unleaded gas composite Cat # 30237, or equivalent, is used for 8015 GRO/AK101. The stock standards are prepared from standards with the following components and approximate concentrations:

Benzene	1000µg/mL
Toluene	1000µg/mL
Ethylbenzene	1000µg/mL
M & P-xylene	2000µg/mL
o-xylene	1000µg/mL
MTBE	1000µg/mL
n-Pentane	1000000µg/mL
GRO	5500µg/mL

7.3.2 Synthetic WISGRO Calibration Standard – NSI PVOC/GRO mixture UST-360, or equivalent, while the LCS is from Restek Cat # 30095 revised WISC PVOC/GRO mixture or equivalent. The stock standard is prepared from a standard with the following components and concentrations:

MTBE	1000µg/mL
Benzene	1000µg/mL
Toluene	1000µg/mL
Ethylbenzene	1000µg/mL
m-xylene	1000µg/mL
p-xylene	1000µg/mL
o-xylene	1000µg/mL
1,2,4-trimethylbenzene	1000µg/mL
GRO (sum of rep. comp.)	10000µg/mL
1,3,5-TMB	1000µg/mL
Naphthalene	1000µg/mL

7.3.3 BTEXM/GRO Laboratory Control Standard - Restek revised WISC PVOC/GRO mix cat# 30095 or equivalent for BTEXM and NSI Gas composite Q-4643 or equivalent for 8015 GRO/AK101: Concentrations as stated in 7.3.2.

7.3.4 GRO Retention Time Marker: Restek revised WISC PVOC/GRO mix cat#30095 or equivalent for BTEXM and NSI Gas composite Q4643. n-Pentane standard – Fox Scientific, Inc. pure grade or equivalent. Concentrations as stated in 7.3.1

7.4 Intermediate ICV/CCV/LCS Standards

7.4.1 BTEX ICV from NSI (UST-360) is certified BTEX in unleaded gas. The LCS is from Restek Cat#30095. Secondary dilution standards of BTEXM/GRO Standard: This intermediate standard is stored with minimal headspace in the same manner as the stock standard. 2.5mL of BTEXM solution from 7.3.1 in 50mL of methanol has the following concentrations. The GRO standard is not diluted.

Benzene	50µg/mL
Toluene	50µg/mL
Ethylbenzene	50µg/mL
M & P-xylene	100µg/mL
O-xylene	50µg/mL
MTBE	50µg/mL
n-Pentane	50µg/mL
GRO	5500µg/mL

(Syringe sizes needed: 5mL, 25µL, 10µL, 1 µL & 0.5 µL)

7.4.2 WISGRO's working standard is prepared by mixing 2.5mL of synthetic WISGRO standard into 47.5mL of methanol to make a 50ppm working standard which is then used to prepare all calibration standards.

7.5 Calibration standards:

Calibration standards are prepared in reagent water at a minimum of five concentration levels. The lowest standard must be at or below the RL. The calibration standards are prepared from the primary source (which is a different Lot # than the LCS) according to the instructions in 7.3. This is the intermediate stock. Use the measurements listed below to produce each calibration point. The concentration varies slightly with lot number.

BTEXM/GRO (Soil Calibration)

	Conc. ppm	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL
	Stock listed in 7.3.1	0.05	.1	.5	1	2.5	5	10	20	25
GRO ppm	5500	0.055 µg/mL	0.11 µg/mL	0.55 µg/mL	1.1 µg/mL	2.75 µg/mL	5.5 µg/mL	11 µg/mL	-	-
GRO Surrogate - a,a,a-TFT		200µg/L	202µg/L	204µg/L	206µg/L	208µg/L	210µg/L	212µg/L	-	-
Benzene ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100µg/L	200µg/L	250µg/L
Toluene ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100µg/L	200µg/L	250µg/L
Ethylbenzene ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100µg/L	200µg/L	250µg/L
m&p Xylene ppb	50	1µg/L	2µg/L	10µg/L	20µg/L	50µg/L	100µg/L	200µg/L	400µg/L	500µg/L
o Xylene ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100µg/L	200µg/L	250µg/L
MTBE ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100µg/L	200µg/L	250µg/L
BTEX Surrogate - a,a,a-TFT		200µg/L	202µg/L	204µg/L	206µg/L	208µg/L	210µg/L	212µg/L	216µg/L	218µg/L

*Prepared in 5mLs of DI water

BTEXM/GRO (Water Calibration)

	Conc. ppm	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL
	Stock listed in 7.3.1	0.5	1	5	10	25	50	100	200	250
GRO ppm	5500	0.055 µg/mL	0.11 µg/mL	0.55 µg/mL	1.1 µg/mL	2.75 µg/mL	5.5 µg/mL	11 µg/mL	-	-
GRO Surrogate - a,a,a-TFT		200µg/L	202µg/L	204µg/L	206µg/L	208µg/L	210µg/L	212µg/L	-	-
Benzene ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
Toluene ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
Ethylbenzene ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
m&p Xylene ppb	50	1µg/L	2µg/L	10µg/L	20µg/L	50µg/L	100µg/L	200µg/L	400µg/L	500µg/L
o Xylene ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
MTBE ppb	50	0.5µg/L	1µg/L	5µg/L	10µg/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
BTEX Surrogate - a,a,a-TFT		200µg/L	202µg/L	204µg/L	206µg/L	208µg/L	210µg/L	212µg/L	216µg/L	218µg/L

*Prepared in 50mLs of DI Water

Synthetic GRO (Soil Calibration)

	Conc. ppm	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL
	Stock listed in 7.3.1	.05	.1	.5	1	2.5	5	10	20	25
GRO ppm	500			0.05 µg/mL	0.1 µg/mL	0.25 µg/mL	0.5 µg/mL	1.0 µg/mL	2.0 µg/mL	2.5 µg/mL
Benzene ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
Toluene ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
Ethylbenzene ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
m&p Xylene ppb	50	1µg/L	2ug/L	10µg/L	20ug/L	50µg/L	100ug/L	200µg/L	400ug/L	500µg/L
o Xylene ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
MTBE ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L

*Prepared in 5mLs of DI water

Synthetic GRO (Water Calibration)

	Conc. ppm	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL	Amt.uL
	Stock listed in 7.3.1	.5	1	5	10	25	50	100	200	250
GRO ppm	500			0.05 µg/mL	0.1 µg/mL	0.25 µg/mL	0.5 µg/mL	1.0 µg/mL	2.0 µg/mL	2.5 µg/mL
Benzene ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
Toluene ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
Ethylbenzene ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
m&p Xylene ppb	50	1µg/L	2µg/L	10µg/L	20ug/L	50µg/L	100ug/L	200µg/L	400ug/L	500µg/L
o Xylene ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L
MTBE ppb	50	0.5µg/L	1µg/L	5µg/L	10ug/L	25µg/L	50µg/L	100ug/L	200µg/L	250µg/L

*Prepared in 50mLs of DI Water

7.6 **Internal standard Fluorobenzene** 100,000µg/mL - NSI Cat # Q-4187 or equivalent.

7.7 **Surrogate** ααα-trifluorotoluene 100,000µg/mL - NSI Cat # Q-4187 or equivalent.

7.8 **Surrogate/Internal standard preparation**: Commercially-prepared ααα-TFT at 100,000 µg/mL and Fluorobenzene at 100,000µg/mL are purchased from NSI for use in making an internal standard/surrogate mixture. This mixture is prepared by diluting 1mL of the NSI mixture into 99mL of methanol (100mL total volume). It is injected automatically by the instrument at a rate of 1µL per 5mL purge volume. This results in a 200µg/L solution of internal standard/surrogate. Check daily to make sure that the instrument reservoir has adequate IS/Surr solution.

> STATE NOTE: For Wisconsin GRO/PVOC and AK101 samples, the internal standard/surrogate stock mix has Fluorobenzene at 100,000µg/mL and ααα-trifluorotoluene at 20,000µg/mL. The working standard is prepared by diluting 0.250mL of the stock mix to a final volume of 50mL using methanol.

7.9 **Solvent:** Methanol Fisher GC Resolve A457-4 or equivalent: High res.- GC grade.

7.10 **Spike Solution (LCS/MS/MSD):** For the LCS, spike the LCS spike solution prepared in section 7.3.1 into duplicate aliquots of a clean matrix. For the soil MS/MSD, prepare the spikes using the same as LCS solution except, introduce 5µl of the solution prepared in 7.3.1 directly into separate aliquots of the selected field sample or 50µl for water matrices.

NOTE: LCSD are analyzed as required per state or agency requirements.

8.0 PROCEDURE

8.1 **Analysis Summary:** Volatile compounds are introduced into the gas chromatograph by purge and trap, via an autosampler. If soil samples are high in contamination, a methanolic extraction may be necessary prior to purge and trap analysis. Soils require method 5035A for sample preparation, See ENV-SOP-MTJL-0129 for more information.

8.2 Gas Chromatography Conditions:

The particular settings for all instruments are subject to change at any time. See each individual instrument for the current autosampler, purge-and-trap, and gas chromatograph settings. Typical conditions are given in the following table:

Item	Setting
Autosampler and Purge-and-Trap	
Trap	G trap
Valve Oven Temperature	110°C
Transfer Line Temperature	110°C
Purge Time	11 minutes
Purge Flow	40mL/minute
Dry Purge Time	1 minute
Desorb Preheat Temperature	220°C
Desorb Temperature	230°C
Desorb Time	1 minute
Bake Temperature	230°C
Bake Time	2 minutes
Gas Chromatograph	
Inlet Temperature	250°C
Split Ratio	0.8:1
Column	Rtx-VRX 75m x .45mm x 2.55µm
Column Flow	10mL/minute; Hold 6 minutes
	Ramp 2mL/minute to 22mL/minute
Oven Program	45°C
	Ramp 10°C/minute to 75°C
	Hold 1 minute
	Ramp 15°C/minute to 80°C
	Ramp 30°C/minute to 230°C
	Hold 5.67 minutes
Detector Temperature	300°C

8.3 **Calibration:** Method 8015, 8021B BTEXM, WI GRO, and GROMAR require a five-point calibration curve. This curve must have a % RSD of <20% for each of the BTEXM/GRO compounds. In the event that RF criteria are not met, linear regression may be used. In order to use this option, the correlation coefficient of the calibration curve must be a minimum of 0.990 or better. Equal weighting factors or 1/x regressions may be used.

STATE NOTE: Linear regression is required for quantitation of **WI GRO** samples.
PVOC is acceptable on average response.

STATE NOTE: AK101 GRO must have %RSD < 25%.

8.3.1 **Retention Time Marker:** GRO by 8015, WI GRO, and Synthetic GRO quantitation is performed using "baseline to baseline" integration. The area is summed from the marker compounds of MTBE to 1,2,4-trimethylbenzene, representing C_6 to C_{10}. These markers are evaluated, and RT's changed when appropriate. The instrument response attributed to the surrogate and internal standard is not included.

Retention Time Marker standards are analyzed at the beginning of each analytical run.

STATE NOTE: For NWTPH-Gx, the retention time range for gasoline integration must, at a minimum, include toluene through naphthalene. For surrogates that elute within the retention time range used for TPH integration, the analyst must subtract the area of the surrogate(s) from the total area of the TPH peak to yield the appropriate area of the petroleum product.

STATE NOTE: For AK101, the retention time range for gasoline integration must include the resolved and unresolved components that elute between and including C_6 (hexane) and C_9 (nonane) to end at the peak start time of C_{10} (decane). Quantitation must be performed using "baseline to baseline" integration.

8.4 Gas chromatographic analysis:

Typical Batch order for loading the autosampler when a calibration is run:

Sample/QC Type	Use
Cleanup Blank	Verify system is contamination free
Retention Marker	Verify windows for gasoline ranges. Also required to be analyzed every 24 hours for AK101 and GROMAR. And every 12 hours for GROWY.
Calibration standard(s)	Initial 5-point calibration or single-point calibration verification. MUST be mid-point standard.
Second Source Cal. Verification (SSCV)	Second Source verification of initial calibration.
Laboratory Control Sample(s)	Laboratory blank, spiked with known amount(s) of analyte of interest
Matrix Spike/Matrix Spike Dup.	Sample spiked with known amount(s) of analytes of interest
Method blank	Ensure that carry over has not occurred from the calibration standard, and that the analytical system does not show contamination above the established detection limits
Methanol Blank	Laboratory blank spiked with 200 µL laboratory grade methanol to show no contamination for methanol preserved samples
1 to 20 samples	Client samples

Typical Batch order for loading the autosampler when a calibration is not run:

Sample/QC Type	Use
Cleanup Blank	Verify system is contamination free
Retention Marker	Verify windows for gasoline ranges. Required to be analyzed every 24 hours for AK101 and GROMAR. And every 12 hours for GROWY.
Initial Calibration Verification (ICV)	Verify initial 5-point calibration.
Laboratory Control Sample(s)	Laboratory blank, spiked with known amount(s) of analyte of interest
Matrix Spike/Matrix Spike Dup.	Sample spiked with known amount(s) of analytes of interest
Method blank	Ensure that carry over has not occurred from the calibration standard, and that the analytical system does not show contamination above the established detection limits
Methanol Blank	Laboratory blank spiked with 200 µL laboratory grade methanol to show no contamination for methanol preserved samples
1 to 20 samples	Client samples

8.4.1 Water/liquid Samples

Samples are received in 40mL vials containing HCl as a preservative. The autosampler removes 5mL of sample, mixes the sample with 1µL of internal standard/surrogate mix, and heats the sample for 30 seconds at 40°C. The sample then purges for 11min at ambient temp to drive off all VOC's to the trap. The trap is desorbed for one minute at 175°C before entering the column for analysis.

8.4.2 Soil/Sediment Samples (Water Purge) - Collected in soil Jar

Weigh 5 grams of soil into a 40mL vial containing a stir bar. Add 5mL of bisulfate and tighten cap. The autosampler injects the sample with 1µl of internal standard/surrogate mix. The autosampler moves the vial into a heating chamber and heats the sample for 1 minute at 40°C. The sample then purges for 11min at 40°C to drive off all VOC's to the trap. The trap is desorbed for one minute at 175°C before entering the column for analysis.

8.4.3 Soil/Sediment Samples - Collected in Encore (Encore "like") Sampling Device

The sample is collected using an Encore or Encore "like" sampling device. The device is designed to sample soil at approximately 5g. The sample is placed into a pre-weighed 40mL vial containing a stir bar and 5mL of Sodium Bisulfate, as a preservative. Weigh the vial to determine the weight of the soil. WISGRO is 25g of soil into 25mL of methanol.

$$\text{Soil Sample Weight (g)} = \text{Total weight of Vial and Soil (g)} - \text{Pre-weigh value (g)}$$

Record the determined weight of the sample and load onto the autosampler. The autosampler injects the sample with 1µL of internal standard/surrogate mix. The autosampler moves the vial into a heating chamber and heats the sample for 30 seconds at 40°C. The sample then purges for 11min at 40°C to drive off all

VOC's to the trap. The trap is desorbed for one minute at 175°C before entering the column for analysis.

8.4.4 High Level Soil/Sediment Sample (Methanol Extraction) – Collected in Soil Jar

NOTE: Samples known to have high concentrations greater than 250ppb may be collected in a 2oz. Sample jar with no headspace.

Weigh 5g of soil sample and place in vial. Add 5mL of Methanol and vortex for 30 seconds. Using a gas tight microsyringe, measure a maximum of 200µL of methanol extract and inject into a vial containing 5mL of water. Enter the sample multiplier as 25X. The autosampler injects the sample with 1µL of internal standard/surrogate mix. The autosampler moves the vial into a heating chamber and heats the sample for 30 seconds at 40°C. The sample then purges for 11min at 40°C to drive off all VOC's to the trap. The trap is desorbed for 1 minute at 175°C before entering the column for analysis. For PVOCGRO soil samples 25g of soil is placed into a vial with 25mL of methanol. If the weight of the soil exceeds 35g the sample is discarded. If the weight of the sample is >26g but <35g methanol is added until the volume of methanol in mL is equal to the weight of the soil in g.

STATE NOTE: For WI PVOC/GRO samples, a maximum of 100µL may be injected into 5mL for a multiplier of 50x. Sonicate Wisconsin soils in the methanol for 20 minutes.

8.5 **Quantitation:**

8.5.1 Quantitation of GRO is performed by the internal standard method. The concentration of Gasoline Range Organics in the sample is determined from a summation of the total responses within the ranges specified in the table below, using the calibration curve. No area other than that relating to the internal standard or surrogates may be subtracted from the GRO retention time window in calculating GRO results. WISGRO is evaluated by the external standard method. WISGRO no IS/SURR areas are subtracted and range is from the beginning of MTBE and to the conclusion of Naphthalene.

Product(s)	Range	Description
GRO, GROWY, GROAZ, GROMAR, GROMI, GROPORT, OA1	C_6-C_{10}	Peak start of MTBE to the conclusion of 1,2,4-Trimethylbenzene peak
AK101	C_6-C_{10}	Peak start of MTBE to the peak start of 1,2,4-Trimethylbenzene peak
GROWM	C_6-C_{10}	Peak start of MTBE to the conclusion of the Naphthalene peak
GROCA, GROIN	C_5-C_{12}	Peak start of Pentane to the conclusion of Naphthalene peak

Product(s)	Range	Description
GROOH, NWTPHGX	C_6-C_{12}	Peak start of MTBE to the conclusion of the Naphthalene peak

8.5.2 Integration must be "baseline to baseline" as opposed to a "valley to valley". Baseline to baseline is defined here as a flat baseline drawn parallel to the x-axis of the chromatogram that includes all responses within the retention time window. The correct baseline coincides with a horizontal line drawn through the lowest point in the chromatogram before the end of the window. The lowest point may be within the window, before the window, or before the solvent front. Baseline to baseline integration does not include the solvent peak. Placement of the baseline is determined for each sample.

8.5.3 BTEX/MTBE quantitation is performed using "total area vs selected peak".

STATE NOTE: For WI PVOC/GRO samples, all peaks (and baseline rises) outside the window are to be addressed. If area outside the window is detected it must not be quantitated as part of the GRO result. Add report remark that peaks or baseline rises were detected outside the window.

8.6 For acceptance criteria and corrective actions, see sections 10.0 & 11.0.

9.0 DATA ANALYSIS AND CALCULATIONS

9.1 AK101 Moisture Correction: In order to report results for volatiles analysis of samples containing significant moisture (>10%) content on an "as received" basis, the calculated concentration needs to be corrected using the total solvent/water mixture volume represented as Vt. This total solvent/water volume is calculated as follows:

$$\mu\text{L solvent/water } V_t = \left[\frac{\text{mL of solvent} + (\%\text{ moisture} \times \text{g of sample})}{100}\right] \times 1000\ \mu\text{L/mL}$$

9.2 See the current Quality Assurance Manual for equations associated with common calculations.

10.0 QUALITY CONTROL AND METHOD PERFORMANCE

10.1 All analysts must meet the qualifications specified in ENV-SOP-MTJL-0015, *Technical Training and Personnel Qualifications* before approval to perform this method. Analysts must complete an initial demonstration of proficiency before being approved to perform this method. Continuing proficiency must be demonstrated using proficiency testing, laboratory control sample analysis and/or MDL studies. Method performance is assessed per analyst. Updated method performance records are filed and stored in a central location within the department.

10.2 Use the designated Run log to record batch order and standards/reagents used during analysis. See ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

10.3 Initial Calibration – Initial calibration curves must meet the criteria found in the following table. One concentration of the calibration standards must be at or below the RL. The remaining concentration should encompass the linear working range of the instrument.

In most cases, %RSD or linear regression is acceptable. When using linear regression, equal weighting factors or 1/x regressions may be used.

Analytical Method	Min. # of Calibration Standards Required	Initial Calibration Acceptance Criteria	
		%RSD	Linear Correlation Coefficient
EPA 8015B, 8015C, 8015D	5	≤20%	≥0.990
EPA 8021B	5	≤20%*	≥0.990*
WI PVOC	5	≤20%*	≥0.990*
WI GRO	5	NA	≥0.990
NWTPH-Gx	5	≤20%	≥0.990
EPA 602	3	≤10%	≥0.990
OA1	3	≤20%	≥0.995
AK101	3	<25%	NA
GROMAR	5	<20%	>0.990

* required for each target analyte being reported for this method.

NA indicates that this process cannot be used for this method.

NOTE: For USACE samples the correlation coefficient must be ≥0.995.

10.4 Second Source Calibration Verification (SSCV) – Initial calibration curves must be verified with a second source prior to analyzing any samples. Recoveries from a mid-point standard made from a secondary source not used to generate the calibration curve must be within ±20% of the true value before sample analysis may begin.

STATE NOTE: For samples analyzed in conjunction with AK101, recoveries from a mid-point standard made from a secondary source not used to generate the calibration curve must be within ±25%

10.5 Initial Calibration Verification (ICV)/Continuing Calibration Verification (CCV) – Before beginning a sample run, a midpoint check standard (ICV) is analyzed initially to ensure accurate instrument calibration. Continuing calibration verification (CCV) must be checked after every 20 samples. Acceptance criteria for the specific methods are listed in the table below.

Analytical Method	Continuing Calibration Acceptance Criteria
EPA 8015B, 8015C, 8015D	± 20% of Expected Value
EPA 8021B	± 20% of Expected Value
WI PVOC	± 15% of Expected Value
WI GRO	± 20% of Expected Value
NWTPH-Gx	± 20% of Expected Value
EPA 602	± 30% of Expected Value
OA1	± 20% of Expected Value
AK101	± 25% of Expected Value
GROMAR	± 20% of Expected Value

10.6 Method Blank – Method Blanks contain reagent water that are analyzed following successful calibration and/or verification to ensure that the analytical system is free from interferences prior to the analysis of field samples. The acceptance criterion for all method blanks is less than the method detection limit.

NOTE: For Methanol Soils, a Methanol Blank is analyzed.

10.6.1 If more than one instrument blank or method blanks are analyzed, evaluate, and assess the blank and field samples under the same conditions for possible mid-level standard carryover using the subsequent blank after the mid-level standard on a per analyte basis.

STATE NOTE: For samples analyzed in conjunction with AK101, blank subtraction is not permitted. Blanks should be reported by value for data quality assessment.

NOTE: Additional blanks may be submitted with client batches to verify that no cross contamination occurs during shipping of samples and there is no contamination contributed from the sampling equipment. Additional blanks may also be analyzed to ensure that the analytical system remains clean following the analysis of highly contaminated samples.

10.7 Methanol Blank **–** Method blank with 200ul of Laboratory Grade Methanol add to verify reagent is free of contamination.

10.8 Matrix Spike/Matrix Spike Duplicate - are run every 20 samples when enough sample is available or requested by client. The analyst also verifies that the spikes are at the appropriate levels. Spiking levels correspond to the midpoint of the calibration curve. Acceptance criteria are available in the LIMS. If the spike recovery does not meet criteria, verify matrix interference, and apply qualifiers.

10.9 Laboratory Control Sample (LCS)– An LCS is required with each batch and evaluated using the QC limits in LIMS for BTEXM/GRO by Method 8015. Levels correspond to the midpoint of the calibration curve.

STATE NOTE: An LCSD must be analyzed for WI samples and the LCSD must be analyzed at the conclusion of the analytical batch. WI GRO LCS must be within 80-120% for both soil and water. The RPD cannot exceed 20% for either matrix.

STATE NOTE: AK101 GRO LCS must be within 60-120% for both soil and water. An LCS and LCSD are required with each batch. The RPD cannot exceed 20% for either matrix. Surrogates in AK101 must meet 60% to 120% recovery in Blanks, LCS, and LCSD.

10.10 Surrogates - must be assessed for all samples and QC in the batch. Alpha, Alpha, Alpha - TFT recovery must be within acceptance criteria listed in LIMS.

STATE NOTE: The WI PVOC Surrogate must be within >80% for both soil and water and are analyzed from the PID only.

STATE NOTE: Surrogates in AK101 must meet 60% to 120% recovery in Blanks, LCS, and LCSD. Surrogates in field samples must meet 50-150% for both soil and water. For ease of analysis, the control limits used by the laboratory as found in LIMS, exceed the method required limits, but allow for running these samples in conjunction with other TPH analyses.

STATE NOTE: Surrogates in NWTPH-Gx must meet 50-150% for both soil and water. For ease of analysis, the control limits used by the laboratory as found in LIMS, exceed the method required limits, but allow for running these samples in conjunction with other TPH analyses.

10.11 Internal standard - IS fluorobenzene, response must be within acceptance limits for all samples and quality control samples. The internal standard response must be within 50% - 200% of the response of the calibration verification standard.

10.12 Dilutions - All sample analytical results must be below the high standard of the calibration curve.

10.13 IDOC's - The analyst must demonstrate proficiency in performing the analysis as outlined in ENV-SOP-MTJL-0014, *Technical Training and Personnel Qualifications*. Method proficiency must be re-demonstrated anytime a major method modification is made, a major software revision is added, or a major instrument modification is made.

STATE NOTE: Wisconsin GRO requires analysis of five replicates for initial demonstration of capability. Waters must be analyzed at a concentration of 100µg/L, with recoveries falling between 80-120% of the known concentration and the RSD must be <20% to be acceptable. Soils must be analyzed at a concentration of 10mg/kg, with recoveries falling between 75-120% of the known concentration and the RSD must be <20% to be acceptable.

10.14 Retention time windows - are calculated over a 72-hr period by taking the average RT of each compound in the ICV and calculating ±3 SD from this average. This is the retention time window. Retention time windows can vary between instruments.

STATE NOTE: Wisconsin GRO requires verification of the retention time window at the beginning of each data and whenever a new GC column is installed. This can be accomplished as part of the calibration verification.

10.15 Manual Integration – All manual integrations must comply with the requirements found in ENV-SOP-MTJL-0024, *Manual Integration Procedure*. Before and after integrations must be available for review by the secondary data reviewer.

10.16 RLV – The reporting limit verification when analyzed must recover within ±50% of the target concentration for the standard. This can be assessed with the %error calculation in capture software during ICAL evaluation.

STATE NOTE: For all samples analyzed from Minnesota, the reporting limit must be verified at least monthly, with each new initial calibration, or when there has been significant change to the instrument (column replacement, cleaning source, etc.) whichever is more frequent. The reporting limit verification can be performed by either re-injecting the low standard or by re-processing the low standard that was analyzed in the calibration curve. The reporting limit verification (RLV) must recovery within ±40% of the expected concentration. If this criterion is not met, the RLV may be re-analyzed once, instrument maintenance can be performed, a higher concentration standard can be injected, or a new calibration curve must be generated. If a higher concentration standard is utilized, the reporting limit must be raised to the higher level verified.

CLIENT NOTE: For Marathon/MPC LLC/SSA samples a reporting level check standard must be analyzed after each calibration and must recover within 60-140%. If recovery of 60-140% is not met, the reporting limit must be raised, and a back calculation performed at that level. This process must be repeated until an acceptable RL recovery is achieved.

11.0 DATA VALIDATION AND CORRECTIVE ACTION

11.1 All data must undergo a primary review by the analyst. The analyst must check the performance of the initial calibration, mid-point check standard and continuing calibrations to ensure that they meet the criteria of the method. The analyst should review any sample that has quantifiable compounds and make sure that they have been confirmed, if needed. The analyst must also verify that reported results are derived from quantitation between the required RL and the highest standard of the initial calibration curve. All calculations must be checked (any dilutions, %solids, etc.). Data must be checked for the presence or absence of appropriate flags. Comments should be noted when data is flagged.

11.2 All data must undergo a second analyst review. The analyst checking the data must check the performance of the initial calibration, mid-point check standard and continuing calibrations to ensure that they meet the criteria of the method.

11.2.1 The analyst should look at any sample that has quantifiable compounds and check the integration.

11.2.2 All surrogate recoveries must be checked to see if they are within limits.

11.2.3 Blanks must be clean of all interfering peaks.

11.2.4 Quality control criteria should be checked for the LCS, LCSD, MS, and MSD.

11.2.5 Data must be checked for the presence or absence of appropriate flags. Comments should be noted when data is flagged.

11.2.6 See ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

11.2.7 See ENV-SOP-MTJL-0018, *Corrective and Preventive Action*.

11.3 Initial calibration - If the initial calibration does not meet the criteria for acceptance using response/calibration factors, then linear regression can be utilized, as long as the correlation coefficient meets the necessary criteria. If the linear regression criteria cannot be met, additional corrective actions are required. Standards must be reviewed and re-prepared, if necessary. Instrument maintenance may also be required, including column clipping/replacement, source cleaning, etc. When corrective actions have been completed, the instrument must be re-calibrated and the acceptance criteria must be met for the analytes of interest prior to the analysis of any field samples.

11.4 Initial/Calibration Check Standard (ICV/CCV) - When the initial or continuing calibration verification is beyond the acceptance criteria and analysis of a second consecutive (immediate) calibration verification fails to produce results within acceptance criteria, corrective actions shall be performed. The laboratory shall demonstrate acceptable performance after the final round of corrective action with two consecutive calibration verifications, or a new initial instrument calibration shall be performed.

11.5 Method Blank – If the method blank shows any detectable amount greater than the MDL, the laboratory performance is assumed to be out of control and the problem must be corrected. Corrective actions include re-analysis twice. If the failure persists, re-analyze the entire batch of samples, if submitted sample volume permits. Qualification of data, where the blank result is below 1/2RL is acceptable.

General guidelines for qualifying sample results with regard to method blank quality are as follows:

- If the method blank concentration is less than the MDL and sample results are greater than the RL, then no qualification is required.
- No qualification is necessary when an analyte is detected in the method blank but not in the associated samples.
- If the concentration in a sample is more than ten times the concentration in the method blank, then no qualification is required.
- If the method blank concentration is greater than the MDL but less than the RL and sample results are greater than the MDL, then qualify associated sample results to indicate that analyte was detected in the method blank.
- If the method blank concentration is greater than the RL, further corrective action and qualification is required. An analyst should consult their supervisor for further instruction.

11.6 Matrix Spike/Matrix Spike Duplicate - Assess that matrix spike/matrix spike duplicates were analyzed at required frequency, and that results are within acceptance criteria. Spike failure results in the use of a "J" or “V” flag. If a “J” flag is used, it is followed by the appropriate number, which further explains the failure concerning high or low response. The “V” flag is used to indicate that the sample concentration was too high to accurately evaluate the spike recovery.

11.7 Laboratory Control Sample (LCS) – A Laboratory Control Sample (LCS) is run every 20 samples. Levels correspond to the midpoint of the calibration curve.

STATE NOTE: WI GRO LCS must be within 80-120% for both soil and water. An LCS and LCSD are required with each batch. The RPD cannot exceed 20% for either matrix. Failure of the LCS results in a required of all samples within the batch.

STATE NOTE: AK101 GRO LCS must be within 60-120% for both soil and water with RPD not exceeding 20%. Surrogates in AK101 must meet 60% to 120% recovery in laboratory control samples – Blanks, LCS, and LCSD.

If the control does not perform within the ranges listed in LIMS, the laboratory performance is assumed to be out of control and the problem must be corrected. Corrective action can include re-analysis, if instrument malfunction is suspected, or re-preparation and re-analysis of the entire batch, if the failure is suspected as either extraction or sample related.

11.8 Surrogates - If the recovery is not within limits stated in LIMS, confirm that there are no errors in the calculations, surrogate solutions and standards. Check the instrument performance. Examine the chromatograms for interfering peaks and integrated areas. Re-calculate the data and/or re-analyze the field sample if any of the above checks reveal a problem. When permitted, flag the data "J1" (surrogate high) or “J2” (surrogate low).

11.8.1 High recoveries may be due to co-eluting matrix interference: examine the sample chromatogram.

11.8.2 Low recoveries may be due to the sample matrix.

STATE NOTE: The surrogate for WI PVOC must recovery >80% for both matrices.

11.9 Internal standard - The internal standard area counts must be monitored for all CCVs. ISTDs must recover within 50% to 200% of the area counts from the internal standard area counts of the midpoint standard of the most recent initial calibration sequence. If any internal standard response is beyond the acceptable recovery, corrective action is required. Corrective action can take to form of checking the original calculations to ensure accuracy, re-analysis of the CCV to verify initial results, instrument maintenance (i.e., column clipping or changing, inlet liner cleaning/replacement, etc.) or re-calibration.

The internal standard responses and retention times in the check calibration standard must be evaluated immediately after or during data acquisition. If the retention time for any internal standard changes by more than 30 seconds from the last calibration verification, the chromatographic system must be inspected for malfunctions and corrections must be made, as required. When corrections are made, re-analysis of the CCV or a complete re-calibration is necessary, depending on the impact of the correction on the analytical system.

Internal standards must be monitored for each sample. ISTDs in samples must meet the –50% to +200% criteria when compared to the ISTDs in the daily CCV or mid-level of the calibration curve, on 12h shifts when full calibration is performed. Possible corrective actions include: if instrument malfunction is suspected, or re-preparation and re-analysis, if the failure is suspected as either extraction or sample related. If the sample has an obvious matrix interferent and the internal standard recovery is greater than 200%, the sample can be diluted (if acceptable reporting limits can be achieved) to minimize the interference or the sample must be re-extracted and re-analyzed to confirm the original results.

11.10 RLV - If the acceptance criteria are not met, the RLV may be re-analyzed once, instrument maintenance can be performed, a higher concentration standard can be injected, or a new calibration curve must be generated. If a higher concentration standard is utilized, the reporting limit must be raised to the higher level verified.

11.11 Second Source Calibration Verification (SSCV)

12.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

12.1 The EPA requires that laboratory waste management practice to be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner. See ENV-SOP-MTJL-0051*, Waste Management Plan.*

12.2 See ENV-SOP-MTJL-0046, *Environmental Sustainability & Pollution Prevention*.

13.0 METHOD MODIFICATIONS/CLARIFICATIONS

13.1 Provisions for additional QC and specific variations have been added.

13.2 Modifications to this method are noted in the body of the text as state notes. Compliance analyses performed in conjunction with specific state requirements must be performed as noted within the specific state(s) note listed.

13.3 Adjustments to the concentrations of standards/spiking solutions, standards providers, and quality control are subject to change to better meet client/project/regulatory needs or to improve laboratory method performance.

13.4 With the exception of samples for WI PVOC/GRO, a maximum of 200µL of methanol extract is injected into 5mL of water for a multiplier of 25X. For WI PVOC/GRO samples, a maximum of 100µL is injected into 5mL for a multiplier of 50X.

14.0 REFERENCES

14.1 *Nonhalogenated Organics Using GC/FID*, SW-846 Method 8015B, Revision 2, December 1996.

14.2 Aromatic and Halogenated Volatiles by Gas Chromatography using Photoionization and/or Electrolytic Conductivity Detectors, SW-846 Method 8021B, Revision 2, December 1996.

14.3 *Modified GRO Method for Determining Gasoline Range Organics,* Wisconsin DNR, September 1995.

14.4 *R211 – Specific Requirements*: *Wyoming Storage Tank Remediation Testing Laboratory Accreditation Program, A2LA Document* R211, June 30, 2015.

14.5 *Method 602 – Purgeable Aromatics*, 40 CFR Part 136 Appendix A.

14.6 *Volatile Organic Compounds Purge and Trap Capillary-Column Gas Chromatographic Method*, SM 6200C, Standard Methods for the Examination of Water and Wastewater.

14.7 *Method for Determination of Volatile Petroleum Hydrocarbons (Gasoline),* Iowa Method OA-1 Revision 7/27//93, The University of Iowa, Hygienic Laboratory.

14.8 *Leaking Underground Fuel Tank Guidance Manual*, California State Water Resources Control Board, September 2012.

14.9 State of Alaska, Dept. of Env. Conservation, Contaminated Sites Laboratory Approval Memorandum, Soil Moisture Corrected Reporting by EPA Method 8000C, February 2008.

14.10 *NWTPH-Gx Volatile Petroleum Products Method for Soil and Water*, Oregon Department of Environmental Quality.

14.11 *Method AK101 for the Determination of Gasoline Range Organics*, Version 4/08/02.

14.12 *Nonhalogenated Organics by Gas Chromatography,* SW-846 Method 8015C, Revision 3, February 2007.

14.13 *Nonhalogenated Organics Using GC/FID*, SW-846 Method 8015D, Revision 4, June 2003.

14.14 *Determinative Chromatographic Separations*, SW846 Method 8000B, Revision 2, September 1996.

14.15 *Determinative Chromatographic Separations*, SW846 Method 8000C, Revision 3, March 2003.

14.16 *Louisiana Department of Environmental Quality Leaking Underground Storage Tank Program Quality Assurance Project Plan,* Louisiana DEQ, Revision 10, 5/6/2008.

Attachment I: Revision History

Current Version (Pace National):

Date	Description of Revisions
2/10/2021	Revision to change AK101 calibration standard. Revised Header as well as Sections 7.3.1 and 7.3.3.

Superseded Versions (ESC Lab Sciences SOP#330351):

Version	Date	Description of Revisions
0	8/94	Origination
1	7/95	
2	12/28/98	
3	9/1/99	
4	8/22/00	
5	11/1/01	
6	4/29/02	
7	4/23/03	
8	11/3/03	
9	4/14/04	
10	8/15/06	
11	11/30/07	Technical and Quality Review and update.
12	1/10/08	Addition of Section 4.5.4 - AK101 requirements.
13	2/23/09	Clarification of spike solutions in section 7.9; addition of state notes; inclusion of calculations for average response factors, linear calibration, and correlation coefficient; addition of corrective actions in section 11.3 through 11.8; Clarifications in sections 12.0 & 13.0. Ohio VAP approved 2/23/09.
14	3/23/12	Technical and Quality Review and update. Added sections 1.3.1, 2.14 through 2.28, 10.13, and state/client notes in sections 1.0, 8.3.2, 8.5.2, and 11.10; Revised Attachments II and III and sections 1.2, 2.4, 7.1, 7.5, 7.8, 8.3, 9.1 through 9.8, 10.3 through 10.12, 11.1 through 11.9, 12.1, 14.7, 14.9, and 14.10; Incorporated previous minor revisions.
15	6/10/13	Technical and Quality Review and update. Added sections 4.5, 10.14 and 11.10, ; Deleted WY note in sections 8.0 and MN note in section 11.11.4, Revised Attachment III and sections 1.2, 6.1, 7.1, 7.4.1, 7.8, 8.3, 8.4 and 14.4.
16	10/24/14	Technical and Quality Review and update. Deleted state note in sections 2.1, 4.2.2.2, 8.0, 8.3.2, 10.5, 11.5 and 11.8; Deleted sections 7.3.3, 7.4.3 and 8.4; Revised sections 1.1, 2.4, 6.1, 7.5, 10.4 and 11.4.
17	8/5/2015	Technical and Quality Review and update. Revised Sections 8.4.4.1, 12.2, and 13.1. Added Section 13.4. Added State Note in Sections 4.2.1 and 8.4.4.1.
18	9/2/2015	Header and signature block formatting update. Added Attachment IV.
19	8/31/2016	Technical and quality review and update. Header and signature block re-formatting. Revised Sections 1.0, 1.3.1, 2.4, 4.2.2.2.2, 4.5, 6.1, 6.3.1, 6.4.3, 7.3.1, 7.3.2, 7.3.4, 7.4.1, 7.7, 8.0, 8.2, 8.3.2, 8.3.3, 8.3.4, 8.3.5, 8.3.6, 8.4, 8.4.1, 8.4.2, 8.4.3, 8.4.1, 8.5.1, 8.5.2, 9.1, 9.210.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.13, 10.14, 11.2.8, 11.4, 11.5, 11.6, 11.7, 11.8, and Attachment 2 Section 4.5. Deleted Sections 2.5 through 2.28, 6.4.2, 7.1, 9.3 through 9.8, and 11.11.1. Added Sections 6.3.3 and 7.2.4.
20	2/72017	Technical and quality review and update. Revised Sections 1.0, 1.3, 4.4.2, 8.0, 8.3, 8.3.5, 8.4, 8.4.1, 8.4.3, 10.5, and 14.1 through 14.16. Deleted Section 8.3.1. Added Sections 4.2.1.1, 8.5.3, and 10.4.
21	11/28/2017	Update as corrective action for 2017 A2LA audit. Changed ESC logo. Revised Section 3.1 and Attachment III Table 5.

Version	Date	Description of Revisions
22	3/2/2018	Update as corrective action for 2017 A2LA audit. Technical and Quality review and update. Revised sections 2.3, 3.3, 4.2.1, 4.2.1.1, 6.1, 6.3.2, 6.4.1, 7.2.1, 7.7, 7.8, 8.4.1, 8.4.2, 8.4.3, 8.4.5, 10.5, 14.1 through 14.10, and 14.12 through 14.16. Deleted state note in section 4.2.1. Added section 10.6.1.

Superseded Versions (Pace National):

Date	Description of Revisions
6/6/2019	Technical and quality review and update. Deleted header, footer and signature block. Revised sections 1.0, 1.1, 1.3, 1.3.1, 2.1, 3.1, 4.2.1, 4.2.2, 4.4.2, 4.4.15, 4.5, 6.1, 7.1, 7.2.2, 7.2.3, 7.3.1, 7.3.2, 7.4.1, 7.5, 7.8, 7.10, 8.1, 8.2, 8.3.1, 8.4, 8.4.1, 8.4.5, 8.5.1, 8.5.2, 8.5.3, 10.1, 10.2, 10.3, 10.5, 10.8, 10.10, 10.12, 10.14, 11.2.7, 11.2.8, 11.7, 12.1 and 12.2. Deleted sections 4.2.2.1, 4.2.2.2, 4.3, 8.3.2, 8.3.3, 8.3.4, 8.3.5, 11.2.2, 11.11, 11.11.1, 11.11.2, 11.11.3 and renumbered as necessary. Added sections 4.2.2.1, 4.2.2.2, 4.2.2.3, 4.2.2.4, 11.11 and renumbered as necessary. Revised Attachments I and II.
6/13/2020	Technical and quality review and update. Added header and footer.

Attachment II: Routine Reporting Limits*

Compound	RL SOIL (mg/Kg) 1g sample size	RL Water (mg/L)
Benzene	0.0025	0.0005
Toluene	0.025	0.005
Ethylbenzene	0.0025	0.0005
M & P Xylenes	0.0050	0.0010
O Xylenes	0.0025	0.0005
MTBE	0.0250	0.005/ 0.001
GRO	0.5	0.10
Compound	**RL methanol (mg/Kg) extract by 5035A**	**RL Sodium bisulfate (mg/Kg)**
Benzene	0.025 (AK101 0.020)	0.0005
Toluene	0.25	0.005/ 0.001
Ethylbenzene	0.025	0.0005
M & P Xylenes	0.050	0.0010
O Xylenes	0.025	0.0005
MTBE	0.250	0.005/ 0.001
GRO	5.0	0.10

**See section 13.3.*

Attachment III: DOD Requirements

1.0 Equipment/Instrument Maintenance

Instrument maintenance must be performed routinely to optimize instrument performance and improve chromatography. Commonly performed maintenance includes baking traps and columns, changing injection port liners, etc. A new calibration curve must be analyzed following any major maintenance performed on the analytical system.

2.0 Computer Hardware and Software

Software name and version: HP Chemstation G1701BA Version B.01.00 or equivalent

3.0 Troubleshooting

Table 1. GC Troubleshooting Guide

Problem	Cause	Treatment
No Peaks	Syringe clogged	Clean or replace syringe
	Detector/Software/Computer failure	Check cables. Restart computer.
	Column Leaks	Use new ferrules.
	Broken Column	If at ends, clip column. If in the middle or multiple sites, replace column.
Peaks too Small	Split too high	Reduce split
	Column connection leaks	Check column installation. Search for leaks. Replace ferrules.
	Injector temperature too low	Check temperature program. Increase injector temperature.
	Dirty PID	Clean PID.
Retention Times Change	Gas flow too low or too high	Replace septum. Check gas regulator.
	Oven temperature unstable	Check temperature program. Check temperature with external thermometer.
	Column blocked	Compare flow at column entrance to outlet. Replace column.
Constantly Rising Baseline	Leak at column entrance or injection septum.	Check column installation; search for leaks; replace ferrules.
	Injector contaminated.	Make a run at lower injector temperature; if the baseline improves, replace liner, use low bleed or high temperature septa.
	Column contaminated.	Cut two turns from column entrance; rinse column with solvent (only chemically bonded phases); otherwise replace column or use guard column.
	Detector contaminated.	Clean detector.
	Increase of temperature too fast.	Decrease temperature gradient and end temperature.
	Poor gas quality.	Use gas grades recommended for GC; for longer supply lines from gas source to GC use gas purification cartridges directly connected to the GC.

Table 1. GC Troubleshooting Guide

Problem	Cause	Treatment
Increasing Baseline at High Temperatures	Decomposition of the stationary phase.	Check for leaks, matrix check for compatibility with the column.
	Column contaminated.	Cut two turns from column entrance; rinse column with solvent (only chemically bonded phases); otherwise replace column or use guard column.
	Increase of temperature too fast / end temperature too high.	Decrease temperature gradient and end temperature.
	Column not properly conditioned.	Condition column according to manufacturers' instructions (while column is not connected to the detector).
	Detector contaminated	Clean detector according to manufacturers' instructions.
	Poor gas quality.	Use gas grades recommended for GC; for longer supply lines from gas source to GC use gas purification cartridges directly connected to the GC.
Plateaus at Certain Temperatures	Steps in temperature program too drastic.	Avoid very short and strong heating periods.
Fronting	Column overload.	Decrease injection volume; dilute sample.
	Sample vaporizes too slowly, not evenly or condenses.	Increase injector temperature (consider max. temperature limits of the column).
	Analytes coelute.	Change temperature program or use column with different selectivity.
	Sample decomposes.	Check temperature program, oven temperature (external thermometer); if analytes are not temperature-stable, reduce injector temperature; replace liner.
	Column absorbs or decomposes analytes.	Check capillary ends; check intact deactivation using the test mixture; for poor results shorten both column ends by about 10 cm; or replace column; if column test does not show any defects: a) use a column with thicker film b) use phase with better deactivation c) use column with special selectivity.
Tailing	Sample vaporizes too slowly, not evenly or condenses.	Increase injector temperature (consider max. temperature limits of the column).
	System leaks.	Check column installation; search for leaks; replace ferrules.
	Analytes coelute.	Change temperature program or use column with different selectivity.
	Sample decomposes.	Check temperature program, oven temperature (external thermometer); if analytes are not temperature-stable, reduce injector temperature; replace liner by a deactivated one.

Table 1. GC Troubleshooting Guide

Problem	Cause	Treatment
	Column absorbs or decomposes analytes.	Check capillary ends; check intact deactivation using the test mixture; for poor results shorten both column ends by about 10 cm; or replace column; if column test does not show any defects: a) use a column with thicker film b) use phase with better deactivation c) use column with special selectivity.
	Split rate too low.	Increase split rate.
	Column overload.	Decrease injection volume; dilute sample.
Split Peaks	Solvent and column not compatible.	Change solvent or use guard column.
	Solvent mixtures with large differences in boiling point and polarity.	Use just one solvent.
	Sample decomposes.	Check temperature program, oven temperature (external thermometer); if analytes are not temperature-stable, reduce injector temperature; replace liner by a deactivated one.
	Analytes coelute.	Modify temperature program or use longer column; possibly change column polarity.
	Detector overload.	Inject less; control make-up flow.

4.0 Other Requirements

4.1 All hardcopy laboratory notebooks must be reviewed by the Supervisor, or their designee, on a monthly basis.

4.2 If not self-explanatory (e.g., a typo or transposed number), corrections to technical and quality records shall also include a justification for the change.

4.3 A storage blank must be stored with all volatile organic samples, regardless of suspected concentration levels.

4.4 A person performing a manual integration must sign and date each manually integrated chromatogram and record the rationale for performing manual integration. Electronic signatures are acceptable.

4.5 The results of calibration and verification of support equipment must be within the specifications required of the application for which this equipment is used or the equipment must be removed from service until repaired. Calibration and verification records, including those of established correction factors, must be maintained. In the absence of method-specific requirements, the minimum requirements are as follows:

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Balance calibration check [Using two standard weights that bracket the expected mass]	Daily prior to use	Top-loading balance: ±2% or ±0.02g, whichever is greater Analytical balance: ±0.1% or ±0.5 mg, whichever is greater
Verification of standard mass [Using weights traceable to the International System of Units (SI) through a NMI	Every 5 years	Certificate of Calibration from ISO/IEC 17025 accredited calibration laboratory
Monitoring of refrigerator/freezer temperatures	Daily (i.e., 7 days per week) [use MIN/MAX thermometers or data loggers equipped with notification of out of control event capabilities if personnel not available to record daily]	Refrigerators: 0˚C to 6˚C Freezers: ≤-10˚C
Thermometer verification check [Using a thermometer traceable to the SI through an NMI] [Performed at two temperatures that bracket the target temperature(s). Assume linearity between the two bracketing temperatures.] [If only a single temperature is used, at the temperature of use]	Liquid in glass: Before first use and annually Electronic: Before first use and quarterly	Apply correction factors or replace thermometer
Volumetric labware	Class B: By lot before first use Class A and B: Upon evidence of deterioration	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on 10 replicate measurements)
Non-volumetric labware [Applicable only when used for measuring initial sample volume and final extract/ digestates volume]	By lot before first use or upon evidence of deterioration	Bias: Mean within ±3% of nominal volume Precision: RSD ≤3% of nominal volume (based on 10 replicate measurements)
Mechanical volumetric pipette	Quarterly	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on minimum of 3 replicate measurements) [Note: for variable volume pipettes, the nominal volume is the volume of use]
Glass microliter syringe	Upon receipt and upon evidence of deterioration	General Certificate of Bias & Precision upon receipt Replace if deterioration is evident
Drying oven temperature check	Daily prior to and after use	Within ±5% of set temperature
Water purification system	Daily prior to use	See method blank criteria given in Section 4.20 of this addendum

4.6 The expiration date of the prepared standard shall not exceed the expiration date of the primary standard. All containers must bear a preparation date.

4.7 To avoid preparing non-representative samples, the laboratory shall not "target" within a relatively small mass range (e.g., 1.00 ± 0.01g) because such targeting will produce non-representative subsamples if the sample has high heterogeneity. The laboratory shall not manipulate the sample material so the sample aliquot weighs exactly 1.00g ± 0.01g, as an example.

4.8 In the absence of project-specific requirements, the minimum standard data qualifiers to be used are:

U	Analyte was not detected and is reported as less than the LOD or as defined by the customer. The LOD has been adjusted for any dilution or concentration of the sample.
J	The reported result is an estimated value (e.g., matrix interference was observed, or the analyte was detected at a concentration outside the quantitation range).
B	Blank contamination. The recorded result is associated with a contaminated blank.
N	Non-target analyte. The analyte is a tentatively identified compound using mass spectrometry or any non-customer requested compounds that are tentatively identified.
Q	One or more quality control criteria failed (e.g., LCS recovery, surrogate spike recovery, or CCV recovery).

Additional data qualifiers may be used, or different letters or symbols to denote the qualifiers listed above, as long as they are appropriately defined and their use is consistent with project-specific requirements (e.g., QSM 5.0, the contract, and project-planning documents).

4.9 If the time of the sample collection is not provided, assume the most conservative time of day. For the purpose of batch processing, the start and stop dates and times of the batch preparation shall be recorded.

4.10 Each preparation method listed on the scope of accreditation must have quarterly LOD/LOQ verifications. However, not all possible combinations of preparation and cleanup techniques are required to have LOD/LOQ verifications. If LOD/LOQ verifications are not performed on all combinations, the laboratory must base the LOD/LOQ verifications on the worst-case basis (preparation method with all applicable cleanup steps).

4.11 After each MDL determination, the laboratory must establish the LOD by spiking a quality system matrix at a concentration of at least 2 times but no greater than four times the MDL. This spike concentration establishes the LOD and the concentration at which the LOD shall be verified. It is specific to each suite of analyte, matrix, and method (including sample preparation). The following requirements apply to the initial LOD establishment and to the LOD verifications:

- The apparent signal to noise (S/N) ratio at the LOD must be at least three and the results must meet all method requirements for analyte identification (e.g., ion abundance, second column confirmation, or pattern recognition). For data systems that do not provide a measure of noise, the signal produced by the verification sample must produce a result that is at least three standard deviations greater than the mean method blank concentration. This is initially estimated based on a minimum of four method blank analyses and later established with a minimum of 20 method blank results.

- If the LOD verification fails, then the laboratory must repeat the MDL determination and LOD verification or perform and pass two consecutive LOD verifications at a higher spike concentration and set the LOD at the higher concentration.
- The laboratory shall maintain documentation for all MDL determinations and LOD verifications.
- The DL and LOD must be reported for all analyte-matrix-methods suites, unless it is not applicable to the test or specifically excluded by project requirements.

4.12 The LOD shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOD verifications on a one per batch basis. All verification data will be in compliance, reported, and available for review.

4.13 For DoD, at a minimum, the LOQ shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOQ verifications on a one per batch basis.

4.14 All initial instrument calibrations must be verified with a standard obtained from a second manufacturer prior to analyzing any samples. The use of a standard from a second lot obtained from the same manufacturer (independently prepared from different source materials) is acceptable for use as a second source standard. The concentration of the second source standard shall be at or near the midpoint of the calibration range. The acceptance criteria for the initial calibration verification must be at least as stringent as those for the continuing calibration verification.

4.15 Exclusion of calibration points without documented scientifically valid technical justification is not permitted.

4.16 The concentration of the CCV standard shall be greater than the low calibration standard and less than or equal to the midpoint of the calibration range.

4.17 All CCVs analyzed must be evaluated and reported. If a CCV fails, reanalysis or corrective actions must be taken.

- If a CCV fails, the laboratory can immediately analyze two additional consecutive CCVs (immediately is defined as starting a consecutive pair within one hour; no samples can be run between the failed CCV and the two additional CCVs). This approach allows for spurious failures of analytes to be reported without reanalysis of samples. Any corrective actions that change the dynamics of the system (e.g., clip column, clean injection port, run blanks) requires that all samples since the last acceptable CCV be reanalyzed.
- Both of these CCVs must meet acceptance criteria in order for the samples to be reported without reanalysis.
- If either of these two CCVs fail or if the laboratory cannot immediately analyze two CCVs, the associated samples cannot be reported and must be reanalyzed.

- Corrective action(s) and recalibration must occur if the above scenario fails. All affected samples since the last acceptable CCV must be reanalyzed.
- Flagging of data for a failed CCV is only appropriate when the affected samples cannot be reanalyzed. The laboratory must notify the client prior to reporting data associated with a failed CCV.

4.18 The results of all MS/MSDs must be evaluated using the same acceptance criteria used for the DoD LCS limits (see Addendum Tables 3 and 4) or project limits, if specified. If the specific analyte(s) are not available in the Addendum Tables 3 and 4, the laboratory shall use their LCS in-house limits (see the LIMS) as a means of evaluating MS/MSDs. The MS and MSD must be spiked with all reported analytes.

4.19 Surrogate spike results shall be compared with DoD LCS limits (see Addendum Tables 3 and 4) or acceptance criteria specified by the client. If these criteria are not available, the laboratory shall compare the results with its in-house statistically established LCS criteria (see the LIMS).

4.20 The method blank shall be considered to be contaminated if:

- The concentration of any target analyte (chemical of concern) in the blank exceeds 1/2 the LOQ and is greater than 1/10th the amount measured in any associated sample, or 1/0th the regulatory limit, whichever is greater;
- The concentration of any common laboratory contaminant in the blank exceeds the LOQ;
- If a method blank is contaminated as described above, then the laboratory shall reprocess affected samples in a subsequent preparation batch, except when sample results are below the LOD. If insufficient sample volume remains for reprocessing, the results shall be reported with appropriate data qualifiers.

4.21 Sporadic Marginal Exceedances are not allowed for target analytes (chemicals of concern as identified by a project) without project-specific approval. Target analytes are considered those few analytes that are critical for the success of a project (such as risk drivers) where sporadic marginal exceedances cannot be allowed. Laboratories should consult with clients whenever long lists of analytes are requested for analysis to determine if marginal exceedances will not be allowed.

4.22 DoD considers the same analyte exceeding the LCS control limit two (2) out of three (3) consecutive LCS to be indicative of non-random behavior, which requires corrective action and reanalysis of the LCS.

Table 3. LCS Control Limits – Method 8015 (MOD) Solid Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
460-00-4	4-Bromofluorobenzene	1263	100.7	11.1	67	134
303-04	Diesel Range Organics (DRO)	2184	85.2	15.7	38	132
307-27	Gasoline Range Organics (GRO)	1134	100.3	7.2	79	122
307-51	Motor Oil	658	72.2	11.2	39	106
84-15-1	o-Terphenyl	314	87.4	14.1	45	130

Table 4. LCS Control Limits – Method 8015 (MOD) Water Matrix

CAS ID	Analyte	N Records	Mean	Standard Deviation	Lower Control Limit	Upper Control Limit
460-00-4	4-Bromofluorobenzene	756	101	10.8	69	133
303-04	Diesel Range Organics (DRO)	1757	83.7	16	36	132
307-27	Gasoline Range Organics (GRO)	971	99.9	7.3	78	122
307-51	Motor Oil	573	76.9	12.1	41	113
84-15-1	o-Terphenyl	299	90.5	11.4	56	125
630-02-4	Octacosane	130	101.1	13.8	60	142

Table 5. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration (ICAL) for all analytes (including surrogates)	At instrument set-up and after ICV or CCV failure, prior to sample analysis.	ICAL must meet one of the three options below: **Option 1:** RSD for each analyte ≤ 20%; **Option 2:** linear least squares regression for each analyte: $r^2 \geq 0.99$; **Option 3:** non-linear least squares regression (quadratic) for each analyte: $r^2 \geq 0.99$.	Correct problem then repeat ICAL.	Flagging is not appropriate.	Minimum 5 levels for linear and 6 levels for quadratic. Quantitation for multicomponent analytes such as chlordane, toxaphene, and Aroclors must be performed using a 5-point calibration. Results may not be quantitated using a single point. No samples shall be analyzed until ICAL has passed.
Retention Time window position establishment	Once per ICAL and at the beginning of the analytical sequence.	Position shall be set using the midpoint standard of the ICAL curve when ICAL is performed. On days when ICAL is not performed, the initial CCV is used.	NA	NA	Calculated for each analyte and surrogate.
Retention Time (RT) window width	At method set-up and after major maintenance (e.g., column change).	RT width is ± 3 times standard deviation for each analyte RT from the 72-hour study.	NA	NA	Calculated for each analyte and surrogate. Only applicable if internal standard calibration is not used.

Table 5. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis.	All reported analytes within established RT windows. All reported analytes within ± 20% of true value.	Correct problem, rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.
Continuing Calibration Verification (CCV)	Before sample analysis, after every 10 field samples, and at the end of the analysis sequence with the exception of CCVs for Pesticides multi-component analytes (i.e., Toxaphene, Chlordane), which are only required before sample analysis.	All reported analytes and surrogates within established RT windows. All reported analytes and surrogates within ± 20% of true value.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since the last successful CCV; Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since the last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Table 5. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Internal Standards (IS)	If employed, every field sample, standard, and QC sample.	Retention time within ± 0.06 RRT UNITS from retention time of the midpoint standard in the ICAL; Internal standard signal (area or height) within -50% to +100% of ICAL midpoint standard. On days when ICAL is not performed, the daily initial CCV can be used.	Inspect GC for malfunctions and correct problem. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	If corrective action fails in field samples, data must be qualified and explained in the Case Narrative. Apply Q-flag to analytes associated with the non-compliant IS. Flagging is not appropriate for failed standards.	NA
Method Blank (MB)	One per preparatory batch.	No analytes detected >1/2 LOQ or > 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater.	Correct problem. If required, reprep and reanalyze MB and all samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid method blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Table 5. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Laboratory Control Sample (LCS)	One per preparatory batch.	A laboratory must use Table 3 and 4 limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits (see the LIMS) if project limits are not specified.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Matrix Spike (MS)	One per preparatory batch.	A laboratory must use Table 3 and 4 limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits (see the LIMS) if project limits are not specified.	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference (i.e., matrix effect or analytical error).
Matrix Spike Duplicate (MSD) or Matrix Duplicate (MD)	One per preparatory batch.	A laboratory must use Table 3 and 4 limits for batch control if project limits are not specified. If the analyte(s) are not listed, use in-house LCS limits (see the LIMS) if project limits are not specified. RPD ≤ 30% (between MS and MSD or sample and MD).	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	The data shall be evaluated to determine the source of difference. For Sample/MD: RPD criteria only apply to analytes whose concentration in the sample is greater than or equal to the LOQ.

Table 5. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Surrogate Spike	All field and QC samples.	QC acceptance criteria specified by the project, if available; otherwise use Table 3 and 4 limits or in-house LCS limits (see the LIMS) if analyte(s) are not listed.	Correct problem, then reprep and reanalyze all failed samples for all surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference is present, reanalysis may not be necessary, but the client must be notified prior to reporting data, and failures must be discussed in the case narrative.	Apply Q-flag to all associated analytes if acceptance criteria are not met and explain in the case narrative.	Alternative surrogates are recommended when there is obvious chromatographic interference.
Confirmation of Positive Results (second column)	All results greater than the DL must be confirmed (except for single column methods such as TPH by Method 8015 where confirmation is not an option or a requirement).	Calibration and QC criteria for second column are the same as for initial or primary column analysis. Results between primary and secondary column RPD ≤ 40%.	NA	Apply J-flag if RPD > 40%. Discuss in the Case Narrative.	Use project-specific reporting requirements if available; otherwise, use method requirements if available; otherwise report the result from the primary column.

Document Information

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Document Title: Method for the determination if Extractable Petroleum Hydrocarbons by GC/FID (IDNR OA-2 and NWTPH-Dx, Including HCID by Modified EPA Method 8015)	
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All dates and times are in Central Time Zone.

ENV-SOP-MTJL-0095

QM Approval

Name/Signature	Title	Date	Meaning/Reason
Fallon Labeots (006500)	Quality Analyst 1	06 Apr 2021, 02:55:38 PM	Approved

Management Approval

Name/Signature	Title	Date	Meaning/Reason
Shakir Wani (010007)	Manager	30 Mar 2021, 08:53:45 AM	Approved

STANDARD OPERATING PROCEDURE
TITLE: Method for the determination if Extractable Petroleum Hydrocarbons by GC/FID (IDNR OA-2 and NWTPH-Dx, Including HCID by Modified EPA Method 8015)
ISSUER: Pace National – Mt. Juliet, Tennessee

1.0 SCOPE AND APPLICATION

1.1 This standard operating procedure is designed to identify and measure the concentration of semi-volatile petroleum products in water and soil as identified in the state specific OA-2 and Northwest NWTPH-Dx methods as well as Louisiana (LA) samples requesting Diesel and Motor Oil. These products include kerosene, jets fuels, diesel fuels, fuel oils, lubricating oils, hydraulic fluids, mineral and/or insulating oils. The resulting chromatogram is compared to standards prepared from various commercial products. Quantitation is based on the response factor for the product most nearly matching the sample chromatogram. These petroleum products are composed of a complex mixture of compounds and the resulting chromatogram is a characteristic fingerprint pattern, which can be used for product identification. A comparison is made to a calibration curve generated from the product most closely matching the resulting environmental sample fingerprint.

1.2 The hydrocarbon identification (HCID) method, as defined for use in NWTPH methodology, is a qualitative and semi-quantitative procedure for use as a screening tool for sites where the petroleum products are unknown and/or when multiple petroleum products are suspected to be present. This procedure is used to identify the types of petroleum present at the site and can be used to demonstrate TPH levels significantly below the regulatory limit; however when samples contain TPH above method defined reporting limits, the quantitation of samples must be performed using NWTPH-Gx for gasoline range analytes and NWTPH-Dx for diesel and motor oil range analytes.

1.3 Carbon Ranges for the two published methods contained in this procedure vary slightly.

1.3.1 For NWTPH-Dx the DRO range is C_{12}-C_{24} and the RRO range is C_{24} – C_{40}. The HCID carbon ranges for the Gasoline fraction is C_7 – C_{12}, DRO is C_{12} – C_{24} and the RRO range is C_{24} – C_{30}. NWTPH-Dx and HCID analyses can easily be performed using the same analytical criteria by changing the retention times identified using the RT marker solution described in section 7.12. LA ranges are C_{10}-C_{28} Diesel and C_{28}-C_{40} Motor oil.

1.3.2 The OA-2 RT windows are set based on elution of all peaks in the specific petroleum product. Daily calibration is verified using a Diesel and a Motor Oil Standard; however, analysts use reference standards for additional petroleum products to provide clients with information concerning samples that match the chromatographic pattern for Hydraulic Fluid/#6 Fuel Oil/Mineral Spirits/Kerosene. Additional products for instrument calibration include Gasoline for the state of Iowa.

1.4 Quantitation Limits – The Reporting Limit (RL) is the lowest calibration concentration used by ESC. These may be raised based on method or client needs.

Organics Ranges:	Water (ppm)	Soil (ppm)
Gasoline Range (GRO)*	0.1	4
Diesel Range (DRO)	0.1	4
Residual Range (RRO)	0.25 (0.1 for LA)	10 (4 for LA)

*where applicable

1.5 An MDL study must be completed at least annually or more frequently if major instrumentation changes occur. Method Detection Limits (MDLs) are performed based onENV-SOP-MTJL-0016, *Method Detection Limits (MDL), Limits of Detections (LOD) and Limits of Quantitation (LOQ)*. Updated MDL records are filed and stored in a central location within the department.

1.5.1 Limit of Detection (LOD) and Limit of Quantitation (LOQ) studies are completed at the frequency required by the TNI standard per the procedure identified in the ENV-SOP-MTJL-0016, *Method Detection Limits (MDL), Limits of Detections (LOD) and Limits of Quantitation (LOQ).* Should the procedure be utilized for DOD support; then the frequency of these studies must meet the requirements of the current DOD QSM.

1.6 See Attachment II of this SOP for specific procedures to be utilized for support of U.S. Department of Defense (DoD) projects.

2.0 METHOD SUMMARY AND DEFINITIONS

2.1 One liter of water (EPA 3510), 100mL of water (EPA 3510 Reduced Volume) 40mL of water (EPA 3511), or 12.5 to 15 grams of soil (EPA 3546) is spiked with a surrogate compound and extracted with methylene chloride. The extract is dried and concentrated to a volume that meets client requested RL. One to 50µL of the extract, dependent on the instrument and extraction method utilized, is injected into a capillary column gas chromatograph equipped with a flame ionization detector (FID). Quantitation is performed by comparing the total chromatographic area to the response of the product that most nearly matches the pattern of the sample chromatogram. All chromatographic peaks eluting within the retention time windows of the petroleum product will be considered. The default petroleum product for reporting purposes for this procedure is #2 diesel fuel. For sample preparation instructions, see ENV-SOP-MTJL-0115for water samples (EPA 3510), ENV-SOP-MTJL-0118for soil samples (EPA 3546), ENV-SOP-MTJL-0118for large volume injector samples (EPA 3511), or ENV-SOP-MTJL-0113for reduced volume samples (3510RV).

STATE NOTE: OA-2 for Iowa requires the extraction of 1L aqueous samples. Reduced volume (100mL) extraction is not permitted at this time for compliance samples.

2.2 See the current Quality Assurance Manual for definitions associated with terms found in this document.

3.0 HEALTH AND SAFETY

3.1 The toxicity or carcinogenicity of each chemical material used in the laboratory has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be as low as reasonably achievable.

3.2 The laboratory maintains documentation of hazard assessments and OSHA regulations regarding the safe handling of the chemicals specified in each method. Safety data sheets (SDS) for all hazardous chemicals are available to all personnel. Employees must abide by the environmental, health, and safety (EHS) policies and procedures specified in this SOP and in the Pace National Chemical Hygiene / Safety Manual.

3.3 Personal protective equipment (PPE) such as safety glasses and/or side shields, gloves, a laboratory coat, and shoes that are not cloth, canvas, and/or perforated must be worn in designated areas and while handling samples and chemical materials to protect against physical contact with samples that contain potentially hazardous chemicals and exposure to chemical materials used in the procedure. When handling glass, needles, knives, or any material with a potential sharp edge, employees must use cut-resistant gloves.

3.4 Concentrated corrosives present additional hazards and are damaging to skin and mucus membranes. Use these acids, bases, or oxidizers in a fume hood whenever possible with the appropriate PPE designed for handing these materials. If eye or skin contact occurs, flush with large volumes of water. When working with acids, always add acid to water to prevent violent reactions. Any processes that emit large volumes of solvents (evaporation/concentration processes) must be in a hood or apparatus that prevents employee exposure.

3.5 Spill kits are located in each laboratory department. Employees are to familiarize themselves with the location and contents of each spill kit in their area.

3.6 Universal precautions should be observed when performing any tests or procedures. Hard surfaces, instrument surfaces may be contaminated and should be handled according to good laboratory practices.

3.7 Contact your supervisor or local EHS coordinator with questions or concerns regarding safety protocol or safe handling procedures for this procedure. Any accidents involving personnel or sample supplies are to be reported immediately to either the Manager and/or to the Safety Officer.

4.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

4.1 All samples must have been collected using a sampling plan that addresses the considerations of this method.

4.2 Water samples are collected in the appropriate size glass containers with Teflon™ lined caps for the extraction method being utilized. For additional information, see the appropriate extraction SOP. Soils are collected in a glass jar with a Teflon™-lined cap. The samples are stored at 4 ± 2°C from the time of collection until the time of extraction. Extraction must be performed on waters within seven (7) days for OA-2 and unpreserved NWTPH-Dx and HCID water samples; 14 days for NWTPH-Dx, LA and HCID waters that have been preserved with HCl to a pH <2; and within 14 days for all soils. All analyses must take place within 40 days of extraction.

4.3 PETROLEUM SAMPLES PRESERVATION AND HOLDING TIMES

Aqueous samples should be preserved to a pH of less than 2 with sodium bisulfate, hydrochloric acid, or sulfuric acid. The type of preservative and resultant pH should be documented on the field chain of custody documentation. If the aqueous sample is preserved to a pH of less than 2, the holding time is 14 days from collection to extraction and 40 days from extraction to analysis. If the aqueous sample is not preserved, the holding time is 7 days from collection to extraction.

All 8015 and state specific method holding times have been set to the maximum holding time allowed – 14 days for waters and soils.

EXCEPTIONS: Holding time for aqueous samples expires 7 days from collection for the following method / protocols

FLPRO, OA2, MADEP, EPHTN, DROWM

No test can be extended past the default holding time listed.

For all aqueous samples, pH must be taken and documented to represent the sample pH at the time of extraction. If pH **>2** before the default holding time has expired, additional evaluation for proper qualification is required.

- Extracted within 7 days of collection = NO qualification
- Extracted after 7 days of collection = G1 qualification

STATE NOTE: holding time qualification is not impacted by pH of the sample at the time of extraction for the following state methods / protocols

EPHTN, FLPRO, EPHCT, DROWM, AK102/103, TPHKS, OA2, MADEP

Any sample extracted past the listed holding time should be qualified regardless of pH

- If logged with less than half the holding time remaining = T8
- All other reasons = Q

Below is a list of petroleum tests that require T2 qualification for *preservation* if sample pH>2 at the time of extraction.

FLPRO, EPHCT, DROWM, AK102/103, TPHKS, MADEP

4.4 Sample extracts shall be stored in appropriately sized vials with Teflon™-lined closures (screw or crimp top) at 4 ± 2°C.

4.5 All glassware must be pre-washed in warm detergent and rinsed with de-ionized water. Before use, solvent rinse all extraction glassware with acetone and methylene chloride. See ENV-SOP-MTJL-0057, *Glassware Cleaning.*

5.0 INTERFERENCES

5.1 Interferences can be caused by the following

5.1.1 Contaminated solvents or reagents

5.1.2 Sample processing hardware or glassware

5.1.3 Contaminated carrier gas

5.1.4 GC parts, column surfaces or detectors

5.1.5 Sample matrix

5.1.6 Other organic compounds; including chlorinated hydrocarbons, phenols and phthalate esters are measurable. As defined in the method, the EPH results include these compounds.

5.2 Method interferences are reduced by washing all glassware with hot, soapy water followed by rinsing with tap water, acetone, and methylene chloride. Reagent blanks must be analyzed with each batch or for every 20 samples to demonstrate that the samples are free from method interferences.

5.3 High purity reagents must be used to minimize interference problems.

5.4 Contamination by carryover can occur whenever high-level and low-level samples are sequentially analyzed. Whenever an unusually concentrated sample is encountered, it should be followed by an analysis of a solvent blank to check for cross-contamination.

5.5 Common Chemical Contaminants:

General organic compounds: Animal and vegetable oil and grease, chlorinated hydrocarbons, phenols, and phthalate esters are measurable under the conditions of this method. Compounds eluting within the chromatographic retention window will be included in the diesel range organic results. If excessive interferences are noted, it may be necessary to utilize extract clean-up procedures such as those specified in SW-846.

Phthalate Esters*:* Special precautions must be taken to avoid contamination by phthalate esters. Phthalate esters are common plasticizers, frequently found in labware and supplies. Some of the phthalate peaks will fall within the retention window and be included in the quantitation of the diesel range organics. Care must be exercised to minimize the presence of phthalates by avoiding the use of plastics wherever possible.

High molecular weight compounds*:* Samples containing high molecular weight compounds may cause residual instrument contamination. A solvent blank (injection of pure solvent) should be analyzed after such a sample to ensure that the chromatograph system is free from interferences before proceeding with additional sample analyses. To reduce carryover, the chromatography column may also require an extended bake-out to remove the high molecular weight material.

6.0 EQUIPMENT AND SUPPLIES

6.1 Syringes: (Use the following brands or equivalent)

Hamilton VWR™ Cat #	Syringe Size
60361-136	10µL
60376-230	25µL
60376-220	100µL
60376-558	1mL

6.2 Volumetric Flasks, "Class A", with ground glass stoppers – sizes ranging from 10mL to 100mL

6.3 Gas Chromatograph (or equivalent)

Instrument names:	SVGC #7, 21, 13,16 & 36 or equivalent
Use (method #'s):	Method 8015, 8015MOD and state specific petro methods
Model #:	HP 6890 and 7890
Heating elements:	Restek – GC Racer
Column:	Zebron ZB-5 (15m or 30m) x .25mm x .5/.25µm or equiv.
Detector:	FID
Gases used (grade):	H_2, Air – Zero Grade, N2

Temperature programs can be found in each instrument's maintenance log.

7.0 REAGENTS AND STANDARDS

7.1 All reagents and standards must be recorded in the appropriate preparation log and assigned a unique number. See ENV-SOP-MTJL-0041, *Standards Logger – Tree Operation*. Additional information regarding reagent preparation can be found in the Standards Logger (Tree) digital archive system. All spiking solutions and surrogate standard solutions should be replaced at least every six (6) months or sooner if a problem is detected unless otherwise noted.

7.2 Reagent water: Carbon filtered de-ionized water

7.3 Methylene Chloride: Burdick and Jackson Pesticide grade - VWR™ #BJ300-4 or equivalent

7.4 Acetone: Pesticide grade - EM Science OmniSolv VWR™ #EM-AX0116-1 or equivalent

7.5 Sodium Sulfate (ACS): granular, anhydrous - EM Science VWR™ # EMSX0760E-3 or equivalent

7.6 Silica gel: Chromatographic grade; 60-200 mesh

7.7 Stock Standard Solution: Stock standards are pre-made and purchased from NSI, Absolute Standards, Ultra Scientific or equivalent. See Table 7.9 for preparation instructions for working calibration standards. Transfer the stock standard solution into a Teflon™-sealed screw cap bottle. Store away from light with minimal headspace at -10°C to -20°C.

EPH Stock Standard: 50,000µg/mL of 1:1 Diesel/Motor Oil Solution catalog number UST-450H, or equivalent. Separate standards may be purchased for each Diesel #2 and Motor Oil.

7.7.1 Intermediate for extractions using 3510, and 3546: Dilute 1mL of Stock EPH or Diesel Fuel #2 Stock to a total of 5mL of methylene chloride. The final concentration is 10,000µg/mL.

7.7.2 Intermediate for 3511 or 3510RV: Dilute 40µL of Stock EPH Stock or Diesel Fuel #2 to a total of 10mL of methylene chloride. The final concentration is 200µg/mL.

7.8 OTP Standard: NSI catalog number 1341H-02-09 Ortho-Terphenyl 10,000µg/mL

7.8.1 Intermediate: Dilute 0.5mL of Stock OTP to a total of 5mL of methylene chloride. The final concentration is 1,000µg/mL.

7.8.2 Intermediate for LVI: Dilute 20µL of Stock OTP to a total of 10mL of methylene chloride. The final concentration is 20µg/mL.

7.9 Gas Stock Standard: 50,000µg/mL NSI catalog number UST-135-07

7.9.1 Intermediate: Dilute 0.5mL of

Stock Unleaded Gasoline to a total of 5mL of methylene chloride. The final concentration is 5,000µg/mL. This is only used for samples logged as OA2IOWA & HCID.

7.10 Calibration Standards: Using the standards created in sections 7.7 through 7.9, dilute the intermediates to prepare calibration standards per the tables below (specific calibration points for petroleum products may be adjusted to meet client RLs).

Table 7.10.1: Example Calibration Curve Standard Preparation for 3510 & 3546 extractions

Conc. of EPH/OTP	Volume of EPH/OPT (µL) Intermediate (10,000pppm)	Volume (µL) of MeCl2 added	Final Volume (mL)
100/1	10	990	1
200/2	20	980	1
400/4	40	960	1
1000/10	100	900	1
2000/20	200	800	1
4000/40	400	600	1
5000/50	500	500	1
7500/75	750	250	1
10000/100	1000	-	1

Table 7.10.2: Example Calibration Curve Standard Preparation for 3510RV & 3511 extractions

Conc. of EPH/OTP	Volume of EPH/OPT (µL) Intermediate (200pppm)	Volume (µL) of $MeCl_2$ added	Final Volume (mL)
2/0.02	10	990	1
4/0.04	20	980	1
10/0.1	50	950	1
20/0.2	100	900	1
40/0.4	200	800	1
50/0.5	250	750	1
80/0.8	400	600	1
100/1	500	500	1
200/2	1000	-	1

Table 7.10.3: Example Gasoline Calibration Curve Standard Preparation for 3510 & 3546 extractions for HCID and OA2IOWA

Conc Of Gas (PPM)	Volume(µL) of Gas Int (5000 PPM)	Volume (µL) of $MeCl_2$ added	Final Volume(mL)
100	20	980	1
400	80	920	1
1000	200	800	1
2500	500	500	1
5000	1000	0	1

* For LVI: Perform a 50x dilution of above calibration.

7.11 Stock Laboratory Control Solution: The standard is pre-made and purchased from Ultra Scientific (at a concentration of 1500µg/mL diesel). This second source is used for spiking the Laboratory Control Sample/ Laboratory Control Sample Duplicate and the

Matrix Spike/Matrix Spike Duplicate. For water samples by 3510 extraction, 1mL is added. For soil by 3546 extraction, 0.5mL is added. For waters by EPA 3511 extraction, 40µL is added. For waters by 3510RV extraction, 100µL is added.

7.12 Surrogate Standard Solution: Ortho-Terphenyl is used as the surrogate in this analysis. The surrogate standard used for instrument calibration is purchased from NSI (catalog number 1341H-02) at a concentration of 10000µg/mL (or equivalent). May also be prepared from neat (Sigma-Aldrich® OTP: T2800-25G). A 20µg/ml intermediate is made in 1L. For water samples by 3510 extraction, 1mL is added. For soil by 3546 extraction, 0.5mL is added. For waters by EPA 3511 extraction, 40µL is added. For waters by 3510RV, 100µL is added.

7.13 Carbon Number Marker Compounds – The regulatory state sets quantitation ranges based on carbon number. Table 7.13 lists the compounds used as marker compounds for various carbon number ranges. The marker compounds standard is purchased from Ultra Scientific, catalog number SFL-601.

Table 7.13: Carbon Number Marker Compounds

Carbon Number	Compound	Approximate Retention Time (min.)[1]
8	n-Octane	0.37
10	n-Decane	0.83
12	n-Dodecane	1.25
14	n-Tetradecane	1.63
16	n-Hexadecane	1.99
18	n-Octadecane	2.33
20	n-Eicosane	2.64
22	n-Docosane	2.93
24	n-Tetracosane	3.19
26	n-Hexacosane	3.45
28	n-Octacosane	3.71
30	n-Triacontane	3.95
32	n-Dotricontane	4.19
34	n-Tetratricontane	4.42
36	n-Hexatriacontane	4.65
38	n-Octatriacontane	4.85
40	n-Tetracontane	5.05

[1] Approximate retention times. Actual retention times are verified during instrument calibration. These RT's are subject to change and are shown here as a representation only. These RT's will vary from instrument to instrument.

8.0 PROCEDURE

8.1 Sample Preparation

8.1.1 Water samples are extracted according to SW-846 Method 3510 (ENV-SOP-MTJL-0115, *Separatory Funnel Liquid-Liquid Extraction*). Soil samples are extracted using Method 3546 (ENV-SOP-MTJL-0118, *Microwave Extraction*) with standard volume GC split/splitless injectors. Smaller volumes of water samples are extracted using Method 3511 (ENV-SOP-MTJL-0122, *Microextraction Procedure*) and Method 3510RV (ENV-SOP-MTJL-0113, *Reduced Volume*

Separatory Funnel Liquid-Liquid Extraction - for use with large volume GC injectors).

STATE NOTE: Iowa/OA-2 requires the extraction of 1L aqueous samples. Reduced volume (100mL) extraction is not permitted for compliance samples at this time.

8.1.2 Multi-phasic Samples

Choice of the procedure for separating multiphase samples is highly dependent on the objective of the analysis. With a sample in which some of the phases tend to separate rapidly, the percent weight or volume of each phase should be calculated and each phase should be individually analyzed for the required analytes.

An alternate approach is to obtain a homogeneous sample and attempt a single analysis on the combination of phases. This approach will give no information on the abundance of the analytes in the individual phases other than what can be implied by solubility.

A third alternative is to select phases of interest and to analyze only those selected phases. This tactic must be consistent with the sampling/analysis objectives or it will yield insufficient information for the time and resources expended.

8.1.3 Soil samples are extracted according to SW-846 Method 3546 (ENV-SOP-MTJL-0118, *Microwave Extraction Procedure*).

8.1.4 For samples receiving Silica Gel Treatment, see ENV-SOP-MTJL-0123for procedure.

NOTE: For NWTPH-Dx Analyses: When determinations are for heavy fuel oils (e.g., #6 Fuel Oil, Bunker-C, etc.) and samples require cleanup, then standards that have also undergone cleanup must be used to calibrate the GC.

8.2 Gas Chromatography

8.2.1 Recommended conditions: Check Cyberlab for individual instrument conditions. Each instrument has optimum operating conditions and programs that are set for each method.

8.3 Calibration

8.3.1 Before beginning calibration or analysis, run methylene chloride blanks to ensure that the instrument does not have any contamination from previous use. If the instrument is clean after one solvent blank, calibration or calibration verification and sample analysis may begin. If multiple solvent blanks must be run, instrument maintenance should be performed, followed by methylene chloride blanks to ensure the system is free of contamination. Before any new calibration curve is run for HCID/NW/LA, a marker standard comprising of C_8-C_{40} is analyzed to set calibration range and retention times (Section 7.13). Retention times are set based on elution and resolution of all peaks per petroleum product when analyzing for OA-2.

8.3.2 Load the autosampler with the calibration standards and a carbon number marker standard. A calibration curve with a minimum of three points must be analyzed for OA-2 analysis, while a minimum of five points is required for NWTPH-Dx, LA & HCID analysis. The stock standards described in Sections 7.7 through 7.9 are used for the calibration curves.

8.3.3 The retention time range for integration must be adjusted to incorporate the majority of the components of the petroleum product or products present in the standards or samples. These components must be integrated into the baseline as a group. Depending on integration parameters on the instrument used, a baseline may need to be forced under the resolved group.

8.3.4 In lieu of running a full initial calibration, the working calibration factor or calibration curve may be verified on each working day by the injection of a mid-range calibration standard.

8.4 Retention Time Window Definitions

8.4.1 When applicable, a locator is injected every 12/24 hours per method and routinely RT windows are set using ±0.05 minutes before the apex of the first needed eluting carbon range marker to ±0.05min after the apex of the last needed eluting carbon range. Retention times are set based on approximate ±0.05min from elution and resolution of all peaks per petroleum product when analyzing for OA-2.

8.4.2 Retention time windows must be calculated for the surrogate standard on each GC column and whenever a new GC column is installed. Retention time information must be recorded in the run log. The run log must reflect the date that the retention time windows are calculated and the dates of the standards used to calculate the windows. The data is retained by the laboratory and is traceable through the use of the run log. Retention time windows should be recalculated whenever a new column is installed or major instrument maintenance is performed.

NOTE: For those surrogates which elute within the retention time range used for integration of a petroleum product for NWTPH-Dx, the analyst must subtract the area of the surrogate from the total area to yield the appropriate area of the petroleum product.

8.5 Gas Chromatograph Analysis

The typical order for loading the autosampler is detailed below.

Sample/QC Type	Use
Solvent Blank	Verify system is contamination free
Calibration standard(s)	Minimally initial 3-point calibration (OA-2) or 5-point calibration (NWTPH-Dx, LA & HCID) per product
Initial Calibration Verification (ICV)	Verify initial calibration with mid-range standard
Method Blank	Ensure that carryover has not occurred from the calibration standard, and that the analytical system does not show contamination above the established detection limits
Laboratory Control Samples	Extracted laboratory blank, spiked with known amount of analyte of interest
Matrix Spikes	Client sample, spiked with known amount of analyte of interest

Sample/QC Type	Use
1 to 20 samples	Client samples
Continuing Calibration Verification (CCV)	Single-point calibration verification standard. See Section 8.3.4 for criteria.
Solvent Blank	Verify system is contamination free
1 to 20 samples	Client samples
Solvent Blank	Verify system is contamination free (optional)
Continuing Calibration Verification (CCV)	Single-point calibration verification standard.

8.5.1 Samples are analyzed by GC/FID. Suggested injection volume is 1- 50µL, depending on the extraction method utilized, using the conditions established in 8.2.

8.5.2 After the initial calibration has been performed, verify the calibration by analysis of a secondary sourced, mid-point calibration verification standard. A midpoint standard must also be run after every 20 samples and at the end of each sequence. Calculate the percent difference of the response factor from the mean response factor. The response factors must have a percent difference of less than the method limit as specified in Section 10.10.

CLIENT NOTE: See Attachment II to this document for alternate DOD requirements.

8.5.3 At a minimum, a methylene chloride blank must be run in every sequence to determine the area generated on normal baseline bleed under the conditions prevailing in the 24-hour period. Projecting a horizontal baseline between the retention times for the regulatory state marker compounds generates this area. Methylene chloride blanks should also be run after samples suspected of being highly concentrated to prevent carryover.

8.5.4 If the product concentration exceeds the linear range of the method in the final extract, the extract must be diluted and re-analyzed.

8.5.5 Calibration and verification for these methods is based on default petroleum products Diesel and Motor Oil. If additional products are identified, analyst may need to inject a calibration for the identified product and re-analyze samples. If using a calibration on file – verification of that calibration may occur after injection and identification in samples and must meet method criteria defined in section 10.6.

9.0 DATA ANALYSIS AND CALCULATIONS

See the current Quality Assurance Manual for equations associated with common calculations.

10.0 QUALITY CONTROL AND METHOD PERFORMANCE

10.1 All analysts must meet the qualifications specified in ENV-SOP-MTJL-0015, *Technical Training and Personnel Qualifications* before approval to perform this method. Analysts must complete an initial demonstration of proficiency before being approved to perform this method. Continuing proficiency must be demonstrated using proficiency testing, laboratory control sample analysis and/or MDL studies. Method performance is assessed per analyst. Updated method performance records are filed and stored in a central location within the department.

10.2 Use the designated Run log to record batch order and standards/reagents used during analysis. See ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

10.3 Batches are defined as sets of 1 - 20 samples. Batch analysis must include the following: 1 method blank for every 12 hours or 20 samples, 1 Laboratory Control Sample (LCS), 1 Laboratory Control Sample Duplicate (LCSD), 1 Initial Calibration Verification (ICV), 1 Matrix Spike/Spike Duplicate (MS/MSD), where submitted sample volume permits, 1 Continuing Calibration Verification (CCV) every 20 samples and at end of run. All batch information must be maintained in the preparation documentation assigned to the department.

NOTE: For NWTPH-Dx, analyze a duplicate sample per set of 10 or fewer samples (10%).

CLIENT NOTE: See Attachment II of this document for alternate DOD requirements.

10.4 Initial Calibration **–** Minimally, run a 3-point initial calibration curve (OA-2) or 5-point initial calibration curve (NWTPH-Dx,LA & HCID) using the primary source standards each time major instrument maintenance occurs, or if the CCV does not meet acceptance criteria.

For OA-2 and LA analysis, if the percent relative standard deviation (%RSD) is <20% over the working range, linearity through the origin can be assumed and the calibration factor can be used in place of a calibration curve. If the %RSD is >20%, then a calibration curve must be generated by linear regression. If the linear regression correlation coefficient is greater than 0.990, then the curve is deemed acceptable.

For NWTPH-Dx & HCID analysis, the calibration curve must have a linear correlation coefficient of at least 0.990.

10.5 Method Blanks - The method blank must not contain any petroleum hydrocarbons over the method detection limit.

CLIENT NOTE: See Attachment II of this document for alternate DOD requirements.

10.6 Initial/Continuing Calibration Verification (ICV/CCV) - Run a mid-point Initial Calibration Verification (ICV) using the primary source standards on a daily basis before sample analysis. In addition, run a CCV every 20 samples during an analytical sequence and at the conclusion of the analytical sequence. Run the diesel fuel standard as the default petroleum product to verify calibration for this method.

CLIENT NOTE: See Attachment II of this document for alternate DOD requirements.

For OA-2 and LA analysis, if the response for the continuing calibration standard varies from the predicated response by more than ±20%, the calibration is deemed unacceptable.

For NWTPH-Dx/HCID analysis, if the response for the continuing calibration standard varies from the predicated response by more than ±15%, the calibration is deemed unacceptable.

All samples must be bracketed by calibration verification standards that meet the acceptance criteria.

10.7 LCS/LCSD/MS/MSD - Run a laboratory control standard/laboratory control standard duplicate (LCS/LCSD) and matrix spike/matrix spike duplicate (MS/MSD) using secondary standards (Section 7.11). The percent recoveries must be within 50-150% for both the LCS/LCSD and MS/MSD. The relative percent difference should not exceed 20%.

10.8 Surrogate - Ortho-Terphenyl is used for the surrogate in this analysis. The surrogate recovery must be within the limits in the LIMS. This criteria is subject to change based on historical data.

10.9 Retention Time – Retention time of the target analytes are based on the retention time marker analyzed every 24 hours using the standard described in section 7.13, or based on elution/resolution of each product. Retention times must be updated as needed to ensure accuracy of the target analytes being reported for each product.

10.10 SSCV – The SSCV must be analyzed to ensure the accuracy of each calibration curve. The SSCV must recover within ±20% of the target concentration.

10.11 Field blanks, duplicates, and matrix spikes are recommended for specific sampling programs. Matrix spikes should use the spike levels specified for laboratory control samples.

10.12 In-house generated limits must be calculated and applied when sufficient data points are available. Control limits must be established for both precision and accuracy.

10.13 Any sample analyte responses that are beyond the linear range of the calibration curve must be diluted and re-analyzed.

10.14 Manual Integration – All manual integrations must comply with the requirements found in ENV-SOP-MTJL-0024, *Manual Integration Procedure*. Before and after integrations must be available for review by the secondary data reviewer.

11.0 DATA VALIDATION AND CORRECTIVE ACTION

11.1 All data must undergo a second analyst review. The analyst checking the data must check the performance of the initial calibration, mid-point check standard, and continuing calibration standards to ensure that they meet the criteria of the method. See ENV-SOP-MTJL-0014, *Data Handling and Reporting*.

11.1.1 The analyst should look at any sample that has quantifiable compounds and check the integration.

11.1.2 All calculations must be checked.

11.1.3 All surrogate recoveries must be checked to see if they are within limits.

11.1.4 Blanks must be clean of all interfering peaks.

11.1.5 Quality control criteria should be checked for the LCS, LCSD, MS, and MSD.

11.1.6 Data must be checked for the presence or absence of appropriate flags. Comments should be noted when data is flagged.

11.2 Initial Calibration – If the criteria listed in section 10.4 are not met, the calibration curve should be visually inspected. Instrument maintenance may be necessary. Standards may also require re-preparation. The instrument must then be re-calibrated.

11.3 ICV/CCV - In the case where the value obtained on the ICV/CCV exceeds the requirements of the method and analysis of a second consecutive (immediate) calibration verification fails to produce results within acceptance criteria, corrective actions shall be performed. The laboratory shall demonstrate acceptable performance after the final round of corrective action with two consecutive calibration verifications, or a new initial instrument calibration shall be performed.

11.4 Method Blanks - If the method blank contains hydrocarbons over the MDL, re-analyze the blank once. If contamination still occurs, perform corrective action. In some instances, the batch may need to be re-extracted and re-analyzed.

General guidelines for qualifying sample results with regard to method blank quality are as follows:

- If the method blank concentration is less than the MDL and sample results are greater than the RL, then no qualification is required.
- No qualification is necessary when an analyte is detected in the method blank but not in the associated samples.
- If the concentration in a sample is more than ten times the concentration in the method blank, then no qualification is required.
- If the method blank concentration is greater than the MDL but less than the RL and sample results are greater than the MDL, then qualify associated sample results to indicate that analyte was detected in the method blank.
- If the method blank concentration is greater than the RL, further corrective action and qualification is required. An analyst should consult their supervisor for further instruction.

11.5 LCS/LCSD/MS/MSD - If any of the QC samples are outside the acceptance limits, the entire batch must be re-extracted and reanalyzed. If insufficient sample volume remains, contact the organics manager. It may be necessary to qualify the data with a “J4” to indicate the LCS/LCSD was out of method limits, a “J3” to indicate the RPD was exceeded, a “J5” to indicate the spike recovery was high or a “J6” to indicate the spike recovery was low.

11.6 Surrogate - If recoveries are outside of the established limits verify calculations, dilutions, and standard solutions are all correct. Verify instrument performance. If the problem cannot be corrected then the samples must be re-extracted. If sample was consumed during first analysis, then flag the sample with a “J1” qualifier showing the recovery was high or a “J2” showing the recovery was low.

11.6.1 High recoveries may be due to co-eluting matrix interference: examine the sample chromatogram.

11.6.2 Low recoveries may be due to the sample matrix.

11.7 SSCV - In the case where the value obtained on the SSCV exceeds the requirements of the method, a second SSCV standard should be analyzed. If analysis of the second standard also fails to meet method acceptance criteria, instrument maintenance can be performed and a third standard prepared and analyzed. If the third check standard fails, additional corrective action must be performed before any samples may be analyzed. Additional corrective action steps can include: preparation of new standards, purchase of new stock standards, more extensive instrument maintenance, etc. An acceptable SSCV must be analyzed prior to the analysis of field samples.

11.8 See ENV-SOP-MTJL-0018, *Corrective and Preventive Action.*

12.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

12.1 The EPA requires that a laboratory waste management practice be conducted consistent with all applicable federal and state laws and regulations. Excess reagents, samples and method process wastes must be characterized and disposed of in an acceptable manner. See ENV-SOP-MTJL-0051 *Waste Management Plan.*

12.2 See ENV-SOP-MTJL-0046, *Environmental Sustainability & Pollution Prevention*.

13.0 METHOD MODIFICATIONS/CLARIFICATIONS

13.1 The use of microwave technology to prepare soil/solid samples is a modification to this method; however the laboratory maintains an archive of data that demonstrates, at a minimum, equivalency of the two processes. Microwave preparation is a Federal EPA approved method contained within SW-846 since February 2007.

13.2 The use of microextraction technology in conjunction with large volume injections used to prepare aqueous samples are a modification to the NWTPH-Dx and HCID methods; however the laboratory maintains an archive of data that demonstrates, at a minimum, equivalency of the two processes.

13.3 OA-2 IOWA Analysts are required to communicate to TSR/Client if sample more closely resembles a petroleum product that is not used for calibration and verification. A case narrative will be added as needed to address the petroleum pattern present in the sample or if the reported value does not represent a petroleum pattern.

14.0 REFERENCES

14.1 *SW-846 Test Methods for Evaluating Solid Waste*, USEPA 3rd Edition; Methods 8000B/C, 8015B/C/D, 3510B/C, 3511, and 3546.

14.2 *OA-2 Extractable Petroleum Products (And Related Low Volatility Organic Compounds*, Iowa Department of Natural Resources.

14.3 *NWTPH-Dx Semi-Volatile Petroleum Products Method for Soil and Water*, based on Oregon's Department of Environmental Quality TPH-D and Washington's Department of Ecology WTPH-D methods.

14.4 *NWTPH-HCID Hydrocarbon Identification Method for Soil and Water*, based on Oregon's Department of Environmental Quality TPH-D and Washington's Department of Ecology WTPH-D methods.

Attachment I: Revision History

Current Version (Pace National):

Date	Description of Revisions
3/28/2021	Revised header. Replaced section 3.0, Health and Safety. Added section 4.3 and renumbered as necessary.

Superseded Versions (formerly ESC Lab Sciences SOP #330358):

Version	Date	Description of Revisions
0	8/16/04	Origination
1	8/17/09	Technical and Quality Review and update.
2	1/13/12	Technical and Quality Review and update. Revised sections 1.1, 1.3, 1.4, 2.1, 2.2, 2.4, 4.2, 4.3, 6.2, 7.7 through 7.12, 8.1, 8.3, 8.4, 8.5, 9.1 through 9.5, 10.4, 10.9, 10.10, 11.3, 11.7, and 12.1; Added sections 1.2, 2.12 through 2.17, 10.13, 10.14, 11.8, 13.2, and 14.4.
3	8/7/14	Technical and Quality Review and update. Revised sections 1.3, 2.1, 4.4, 5.2, 6.3, 7.1, 7.6 through 7.11, 8.1.1, 8.1.3, 8.3.4, 8.5, 10.3, 10.6, 13.2 and 14.1; Added state note in sections 2.1 and 8.1.1; Added sections 1.5.1 2.18, 2.19 and 13.3; Deleted sections 7.4 and Attachment II.
4	9/16/14	Technical and Quality Review and update. Revised Tables 7.9.1, 7.9.2, and sections 1.3.2, 1.4, 7.6,7.10, 8.3.1, 8.4.1, 10.9, 11.3 and 13.3; Added section 8.5.5.
5	2/3/2016	Technical and quality review and update. Header and signature block re-formatting. Revised Sections 1.1, 1.2, 1.3, 1.4, 1.5, 1.5.1, 2.1, 2.2, 6.3, 7.1, 7.7, 7.7.1, 7.7.2, 7.8.1, 7.8.2, 7.9.1, 7.10, 7.11, 7.12, 8.1.1, 8.1.3, 8.3.1, 8.3.2, 8.4, 8.5, 8.5.2, 9.1, 10.3, 10.5, 10.6, 11.3, 11.4, 11.9, and 12.2. Added Section 1.6, 7.6, and Attachment II. Deleted Sections 2.3 through 2.19 and 9.2 through 9.6.
6	11/29/2017	Technical and quality review and update. Header and signature block reformatting. Revised sections 1.3.2, 2.1, 3.1, 7.1, 7.10, 8.1.1, 8.1.4, 8.3.1, 8.3.2, 8.4.1, 8.4.2, 8.5.2, 9.0, 10.3, 10.4, 10.5, 10.6, 10.7, 10.9, 11.1, 11.2, 11.3, 13.3, Attachment II Table 2, and Attachment II Table 3. Deleted Section 11.8 and all subsections.

STANDARD OPERATING PROCEDURE

TITLE: Method for the determination if Extractable Petroleum Hydrocarbons by GC/FID (IDNR OA-2 and NWTPH-Dx, Including HCID by Modified EPA Method 8015)

ISSUER: Pace National – Mt. Juliet, Tennessee

Superseded Versions (Pace National):

Date	Description of Revisions
1/20/2019	Technical and quality review and update. Deleted header, footer and signature block. Revised sections 1.5, 1.5.1, 2.1, 3.0, 4.2, 4.4, 5.1, 6.1, 6.2, 6.3, 7.1, 7.4, 7.5, 7.6, 7.7, 7.7.1, 7.7.2, 7.8, 7.8.1, 7.8.2, 7.9, 7.9.1, 7.11, 7.12, 7.13, 8.1.1, 8.1.3, 8.1.4, 8.5.1, 10.1, 10.2, 10.3, 10.4, 10.6, 10.8, 10.14, 11.1, 11.6, 11.8, 12.1, 12.2, 14.1, 14.2, 14.3 and 14.4. Revised Tables 7.10.1, 7.10.2 and 7.10.3. Revised Attachment I. Revised Attachment II sections 4.10, 4.17 and 4.19 and corrected numbering.
12/1/2019	Inserted header and footer. Revised sections 6.3, 12.2.

Attachment II: DoD Requirements

1.0 Equipment/Instrument Maintenance

Instrument maintenance must be performed routinely to optimize instrument performance and improve chromatography. Commonly performed maintenance includes cleaning/repairing detector, column clipping/replacement, injector port cleaning/changing liner, etc. A new calibration curve must be analyzed following any major maintenance performed on the analytical system.

2.0 Computer Hardware and Software

Software name and version: HP Chemstation G1701DA or equivalent

3.0 Troubleshooting

Table 1. GC Troubleshooting Guide

Problem	Cause	Treatment
No Peaks	Syringe clogged	Clean or replace syringe
	Detector/Software/Computer failure	Check cables. Restart computer.
	Column Leaks	Use new ferrules.
	Broken Column	If at ends, clip column. If in the middle or multiple sites, replace column.
Peaks too Small	Split too high	Reduce split
	Column connection leaks	Check column installation. Search for leaks. Replace ferrules.
	Injector temperature too low	Check temperature program. Increase injector temperature.
	Dirty ECD	Clean ECD.
Retention Times Change	Gas flow too low or too high	Replace septum. Check gas regulator.
	Oven temperature unstable	Check temperature program. Check temperature with external thermometer.
	Column blocked	Compare flow at column entrance to outlet. Replace column.
Constantly Rising Baseline	Leak at column entrance or injection septum.	Check column installation; search for leaks; replace ferrules.
	Injector contaminated.	Make a run at lower injector temperature; if the baseline improves, replace liner, use low bleed or high temperature septa.
	Column contaminated.	Cut two turns from column entrance; rinse column with solvent (only chemically bonded phases); otherwise replace column or use guard column.
	Detector contaminated.	Clean detector.
	Increase of temperature too fast.	Decrease temperature gradient and end temperature.
	Poor gas quality.	Use gas grades recommended for GC; for longer supply lines from gas source to GC use gas purification cartridges directly connected to the GC.

Table 1. GC Troubleshooting Guide

Problem	Cause	Treatment
Increasing Baseline at High Temperatures	Decomposition of the stationary phase.	Check for leaks; matrix check for compatibility with the column.
	Column contaminated.	Cut two turns from column entrance; rinse column with solvent (only chemically bonded phases); otherwise replace column or use guard column.
	Increase of temperature too fast / end temperature too high.	Decrease temperature gradient and end temperature.
	Column not properly conditioned.	Condition column according to manufacturers' instructions (while column is not connected to the detector).
	Detector contaminated	Clean detector according to manufacturers' instructions.
	Poor gas quality.	Use gas grades recommended for GC; for longer supply lines from gas source to GC use gas purification cartridges directly connected to the GC.
Plateaus at Certain Temperatures	Steps in temperature program too drastic.	Avoid very short and strong heating periods.
Fronting	Column overload.	Decrease injection volume; dilute sample.
	Sample vaporizes too slowly, not evenly or condenses.	Increase injector temperature (consider max. temperature limits of the column).
	Analytes coelute.	Change temperature program or use column with different selectivity.
	Sample decomposes.	Check temperature program, oven temperature (external thermometer); if analytes are not temperature-stable, reduce injector temperature; replace liner.
	Column absorbs or decomposes analytes.	Check capillary ends; check intact deactivation using the test mixture; for poor results shorten both column ends by about 10 cm; or replace column; if column test does not show any defects: a) use a column with thicker film b) use phase with better deactivation c) use column with special selectivity.

Table 1. GC Troubleshooting Guide

Problem	Cause	Treatment
Tailing	Sample vaporizes too slowly, not evenly or condenses.	Increase injector temperature (consider max. temperature limits of the column).
	System leaks.	Check column installation; search for leaks; replace ferrules.
	Analytes coelute.	Change temperature program or use column with different selectivity.
	Sample decomposes.	Check temperature program, oven temperature (external thermometer); if analytes are not temperature-stable, reduce injector temperature; replace liner by a deactivated one.
	Column absorbs or decomposes analytes.	Check capillary ends; check intact deactivation using the test mixture; for poor results shorten both column ends by about 10 cm; or replace column; if column test does not show any defects: a) use a column with thicker film b) use phase with better deactivation c) use column with special selectivity.
	Split rate too low.	Increase split rate.
	Column overload.	Decrease injection volume; dilute sample.
Split Peaks	Solvent and column not compatible.	Change solvent or use guard column.
	Solvent mixtures with large differences in boiling point and polarity.	Use just one solvent.
	Sample decomposes.	Check temperature program, oven temperature (external thermometer); if analytes are not temperature-stable, reduce injector temperature; replace liner by a deactivated one.
	Analytes coelute.	Modify temperature program or use longer column; possibly change column polarity.
	Detector overload.	Inject less; control make-up flow.

4.0 Other Requirements

4.1 All hardcopy laboratory notebooks must be reviewed by the Supervisor, or their designee, on a monthly basis.

4.2 If not self-explanatory (e.g., a typo or transposed number), corrections to technical and quality records shall also include a justification for the change.

4.3 A person performing a manual integration must sign and date each manually integrated chromatogram and record the rationale for performing manual integration. Electronic signatures are acceptable.

4.4 The results of calibration and verification of support equipment must be within the specifications required of the application for which this equipment is used or the equipment must be removed from service until repaired. Calibration and verification records, including those of established correction factors, must be maintained. In the absence of method-specific requirements, the minimum requirements are as follows:

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Balance calibration check [Using two standard weights that bracket the expected mass]	Daily prior to use	Top-loading balance: ±2% or ±0.02g, whichever is greater Analytical balance: ±0.1% or ±0.5 mg, whichever is greater
Verification of standard mass [Using weights traceable to the International System of Units (SI) through a NMI	Every 5 years	Certificate of Calibration from ISO/IEC 17025 accredited calibration laboratory
Monitoring of refrigerator/freezer temperatures	Daily (i.e. 7 days per week) [use MIN/MAX thermometers or data loggers equipped with notification of out of control event capabilities if personnel not available to record daily]	Refrigerators: 0˚C to 6˚C Freezers: ≤-10˚C
Thermometer verification check [Using a thermometer traceable to the SI through an NMI] [Performed at two temperatures that bracket the target temperature(s). Assume linearity between the two bracketing temperatures.] [If only a single temperature is used, at the temperature of use]	Liquid in glass: Before first use and annually Electronic: Before first use and quarterly	Apply correction factors or replace thermometer
Volumetric labware	Class B: By lot before first use Class A and B: Upon evidence of deterioration	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on 10 replicate measurements)
Non-volumetric labware [Applicable only when used for measuring initial sample volume and final extract/ digestates volume]	By lot before first use or upon evidence of deterioration	Bias: Mean within ±3% of nominal volume Precision: RSD ≤3% of nominal volume (based on 10 replicate measurements)
Mechanical volumetric pipette	Quarterly	Bias: Mean within ±2% of nominal volume Precision: RSD ≤1% of nominal volume (based on minimum of 3 replicate measurements) [Note: for variable volume pipettes, the nominal volume is the volume of use]
Glass microliter syringe	Upon receipt and upon evidence of deterioration	General Certificate of Bias & Precision upon receipt Replace if deterioration is evident

Table 2. Support Equipment Checks

Performance Check	Frequency	Acceptance Criteria
Drying oven temperature check	Daily prior to and after use	Within ±5% of set temperature
Water purification system	Daily prior to use	See method blank criteria given in Section 4.20 of this addendum

4.5 The expiration date of the prepared standard shall not exceed the expiration date of the primary standard. All containers must bear a preparation date.

4.6 To avoid preparing non-representative samples, the laboratory shall not “target” within a relatively small mass range (e.g., 1.00 ± 0.01g) because such targeting will produce non-representative subsamples if the sample has high heterogeneity. The laboratory shall not manipulate the sample material so the sample aliquot weighs exactly 1.00g ± 0.01g, as an example.

4.7 In the absence of project-specific requirements, the minimum standard data qualifiers to be used are:

U Analyte was not detected and is reported as less than the LOD or as defined by the customer. The LOD has been adjusted for any dilution or concentration of the sample.

J The reported result is an estimated value (e.g., matrix interference was observed or the analyte was detected at a concentration outside the quantitation range).

B Blank contamination. The recorded result is associated with a contaminated blank.

N Non-target analyte. The analyte is a tentatively identified compound using mass spectrometry or any non-customer requested compounds that are tentatively identified.

Q One or more quality control criteria failed (e.g., LCS recovery, surrogate spike recovery, or CCV recovery).

Additional data qualifiers may be used, or different letters or symbols to denote the qualifiers listed above, as long as they are appropriately defined and their use is consistent with project-specific requirements (e.g., QSM 5.0, the contract, and project-planning documents).

4.8 If the time of the sample collection is not provided, assume the most conservative time of day. For the purpose of batch processing, the start and stop dates and times of the batch preparation shall be recorded.

4.9 Each preparation method listed on the scope of accreditation must have quarterly LOD/LOQ verifications. However, not all possible combinations of preparation and cleanup techniques are required to have LOD/LOQ verifications. If LOD/LOQ verifications are not performed on all combinations, the laboratory must base the LOD/LOQ verifications on the worst case basis (preparation method with all applicable cleanup steps).

4.10 After each MDL determination, the laboratory must establish the LOD by spiking a quality system matrix at a concentration of at least two (2) times but no greater than four times the MDL. This spike concentration establishes the LOD and the concentration at which the LOD shall be verified. It is specific to each suite of analyte, matrix, and method (including sample preparation). The following requirements apply to the initial LOD establishment and to the LOD verifications:

- The apparent signal to noise (S/N) ratio at the LOD must be at least three and the results must meet all method requirements for analyte identification (e.g., ion abundance, second column confirmation, or pattern recognition). For data systems that do not provide a measure of noise, the signal produced by the verification sample must produce a result that is at least three standard deviations greater than the mean method blank concentration. This is initially estimated based on a minimum of four method blank analyses and later established with a minimum of 20 method blank results.

- If the LOD verification fails, then the laboratory must repeat the MDL determination and LOD verification or perform and pass two consecutive LOD verifications at a higher spike concentration and set the LOD at the higher concentration.

- The laboratory shall maintain documentation for all MDL determinations and LOD verifications.

- The DL and LOD must be reported for all analyte-matrix-methods suites, unless it is not applicable to the test or specifically excluded by project requirements.

4.11 The LOD shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOD verifications on a one per batch basis. All verification data will be in compliance, reported, and available for review.

4.12 For DoD, at a minimum, the LOQ shall be verified quarterly. In situations where methods are setup and used on an infrequent basis, the laboratory may choose to perform LOQ verifications on a one per batch basis.

4.13 All initial instrument calibrations must be verified with a standard obtained from a second manufacturer prior to analyzing any samples. The use of a standard from a second lot obtained from the same manufacturer (independently prepared from different source materials) is acceptable for use as a second source standard. The concentration of the second source standard shall be at or near the midpoint of the calibration range. The acceptance criteria for the initial calibration verification must be at least as stringent as those for the continuing calibration verification.

4.14 Exclusion of calibration points without documented scientifically valid technical justification is not permitted.

4.15 The concentration of the CCV standard shall be greater than the low calibration standard and less than or equal to the midpoint of the calibration range.

4.16 All CCVs analyzed must be evaluated and reported. If a CCV fails, reanalysis or corrective actions must be taken.

- If a CCV fails, the laboratory can immediately analyze two additional consecutive CCVs (immediately is defined as starting a consecutive pair within one hour; no samples can be run between the failed CCV and the two additional CCVs). This approach allows for spurious failures of analytes to be reported without reanalysis of samples. Any corrective actions that change the dynamics of the system (e.g., clip column, clean injection port, run blanks) requires that all samples since the last acceptable CCV be reanalyzed.

- Both of these CCVs must meet acceptance criteria in order for the samples to be reported without reanalysis.
- If either of these two CCVs fail or if the laboratory cannot immediately analyze two CCVs, the associated samples cannot be reported and must be reanalyzed.
- Corrective action(s) and recalibration must occur if the above scenario fails. All affected samples since the last acceptable CCV must be reanalyzed.
- Flagging of data for a failed CCV is only appropriate when the affected samples cannot be reanalyzed. The laboratory must notify the client prior to reporting data associated with a failed CCV.

4.17 The results of all MS/MSDs must be evaluated using the same acceptance criteria used for the LCS limits (see LIMS) or project limits, if specified. The MS and MSD must be spiked with all reported analytes.

4.18 Surrogate spike results shall be compared with DoD LCS limits (see LIMS) or acceptance criteria specified by the client. If these criteria are not available, the laboratory shall compare the results with its in-house statistically established LCS criteria (see the LIMS).

4.19 The method blank shall be considered to be contaminated if:

- The concentration of any target analyte (chemical of concern) in the blank exceeds 1/2 the LOQ and is greater than 1/10th the amount measured in any associated sample, or 1/0th the regulatory limit, whichever is greater;
- The concentration of any common laboratory contaminant in the blank exceeds the LOQ;
- If a method blank is contaminated as described above, then the laboratory shall reprocess affected samples in a subsequent preparation batch, except when sample results are below the LOD. If insufficient sample volume remains for reprocessing, the results shall be reported with appropriate data qualifiers.

4.20 Sporadic Marginal Exceedances are not allowed for target analytes (chemicals of concern as identified by a project) without project-specific approval. Target analytes are considered those few analytes that are critical for the success of a project (such as risk drivers) where sporadic marginal exceedances cannot be allowed. Laboratories should consult with clients whenever long lists of analytes are requested for analysis to determine if marginal exceedances will not be allowed.

4.21 DoD considers the same analyte exceeding the LCS control limit two (2) out of three (3) consecutive LCS to be indicative of non-random behavior, which requires corrective action and reanalysis of the LCS.

Table 3. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration (ICAL) for all analytes (including surrogates)	At instrument set-up and after ICV or CCV failure, prior to sample analysis.	ICAL must meet one of the three options below: **Option 1:** RSD for each analyte ≤ 20%; **Option 2:** linear least squares regression for each analyte: r2 ≥ 0.99; **Option 3:** non-linear least squares regression (quadratic) for each analyte: r2 ≥ 0.99.	Correct problem then repeat ICAL.	Flagging is not appropriate.	Minimum 5 levels for linear and 6 levels for quadratic. Quantitation for multicomponent analytes such as chlordane, toxaphene, and Aroclors must be performed using a 5-point calibration. Results may not be quantitated using a single point. No samples shall be analyzed until ICAL has passed.
Retention Time window position establishment	Once per ICAL and at the beginning of the analytical sequence.	Position shall be set using the midpoint standard of the ICAL curve when ICAL is performed. On days when ICAL is not performed, the initial CCV is used.	NA	NA	Calculated for each analyte and surrogate.
Retention Time (RT) window width	At method set-up and after major maintenance (e.g., column change).	RT width is ± 3 times standard deviation for each analyte RT from the 72-hour study or 0.03 minutes, whichever is greater.	NA	NA	Calculated for each analyte and surrogate. Only applicable if internal standard calibration is not used.

Table 3. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Initial Calibration Verification (ICV)	Once after each ICAL, analysis of a second source standard prior to sample analysis.	All reported analytes within established RT windows. All reported analytes within ± 20% of true value.	Correct problem, rerun ICV. If that fails, repeat ICAL.	Flagging is not appropriate.	No samples shall be analyzed until calibration has been verified with a second source.
Continuing Calibration Verification (CCV)	Before sample analysis, after every 10 field samples, and at the end of the analysis sequence with the exception of CCVs for Pesticides multi-component analytes (i.e., Toxaphene, Chlordane, and Aroclors other than 1016 and 1260), which are only required before sample analysis.	All reported analytes and surrogates within established RT windows. All reported analytes and surrogates within ± 20% of true value.	Immediately analyze two additional consecutive CCVs. If both pass, samples may be reported without reanalysis. If either fails or if two consecutive CCVs cannot be run, perform corrective action(s) and repeat CCV and all associated samples since the last successful CCV. Alternately, recalibrate if necessary; then reanalyze all associated samples since the last acceptable CCV.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since the last acceptable calibration verification.	Results may not be reported without a valid CCV. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Table 3. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Internal Standards (IS)	If employed, every field sample, standard, and QC sample.	Retention time within ± 0.06 RRT UNITS from retention time of the midpoint standard in the ICAL; Internal standard signal (area or height) within -50% to +100% of ICAL midpoint standard. On days when ICAL is not performed, the daily initial CCV can be used.	Inspect GC for malfunctions and correct problem. Reanalysis of samples analyzed while system was malfunctioning is mandatory.	If corrective action fails in field samples, data must be qualified and explained in the Case Narrative. Apply Q-flag to analytes associated with the non-compliant IS. Flagging is not appropriate for failed standards.	NA.
Method Blank (MB)	One per preparatory batch.	No analytes detected >1/2 LOQ or > 1/10 the amount measured in any sample or 1/10 the regulatory limit, whichever is greater.	Correct problem. If required, reprep and reanalyze MB and all samples processed with the contaminated blank.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid method blank. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Table 3. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Laboratory Control Sample (LCS)	One per preparatory batch.	Use in-house LCS limits (see the LIMS) if project limits are not specified.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available.	If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.
Matrix Spike (MS)	One per preparatory batch.	Use in-house LCS limits (see the LIMS) if project limits are not specified.	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	For matrix evaluation only. If MS results are outside the limits, the data shall be evaluated to determine the source(s) of difference, i.e., matrix effect or analytical error.
Matrix Spike Duplicate (MSD) or Matrix Duplicate (MD)	One per preparatory batch.	Use in-house LCS limits (see the LIMS) if project limits are not specified. RPD ≤ 30% (between MS and MSD or sample and MD).	Examine the project-specific requirements. Contact the client as to additional measures to be taken.	For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met and explain in the case narrative.	The data shall be evaluated to determine the source of difference. For Sample/MD: RPD criteria only apply to analytes whose concentration in the sample is greater than or equal to the LOQ.

Table 3. Quality Control Requirements – Organic Analysis by Gas Chromatography

QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action	Flagging Criteria	Comments
Surrogate Spike	All field and QC samples.	QC acceptance criteria specified by the project, if available; otherwise use in-house LCS limits (see the LIMS).	Correct problem, then reprep and reanalyze all failed samples for all surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference with surrogate is present, reanalysis may not be necessary, but the client must be notified prior to reporting data, and the failures must be discussed in the Case Narrative	Apply Q-flag to all associated analytes if acceptance criteria are not met and explain in the case narrative.	Alternative surrogates are recommended when there is obvious chromatographic interference.
Confirmation of positive results (second column)	All positive results must be confirmed (except for single column methods such as TPH by Method 8015 where confirmation is not an option or requirement).	Calibration and QC criteria for second column are the same as for initial or primary column analysis. Results between primary and secondary column RPD ≤ 40%.	NA	Apply J-flag if RPD >40%. Discuss in the case narrative.	Use project-specific reporting requirements if available; otherwise, use method requirements if available; otherwise report the result from the primary column.

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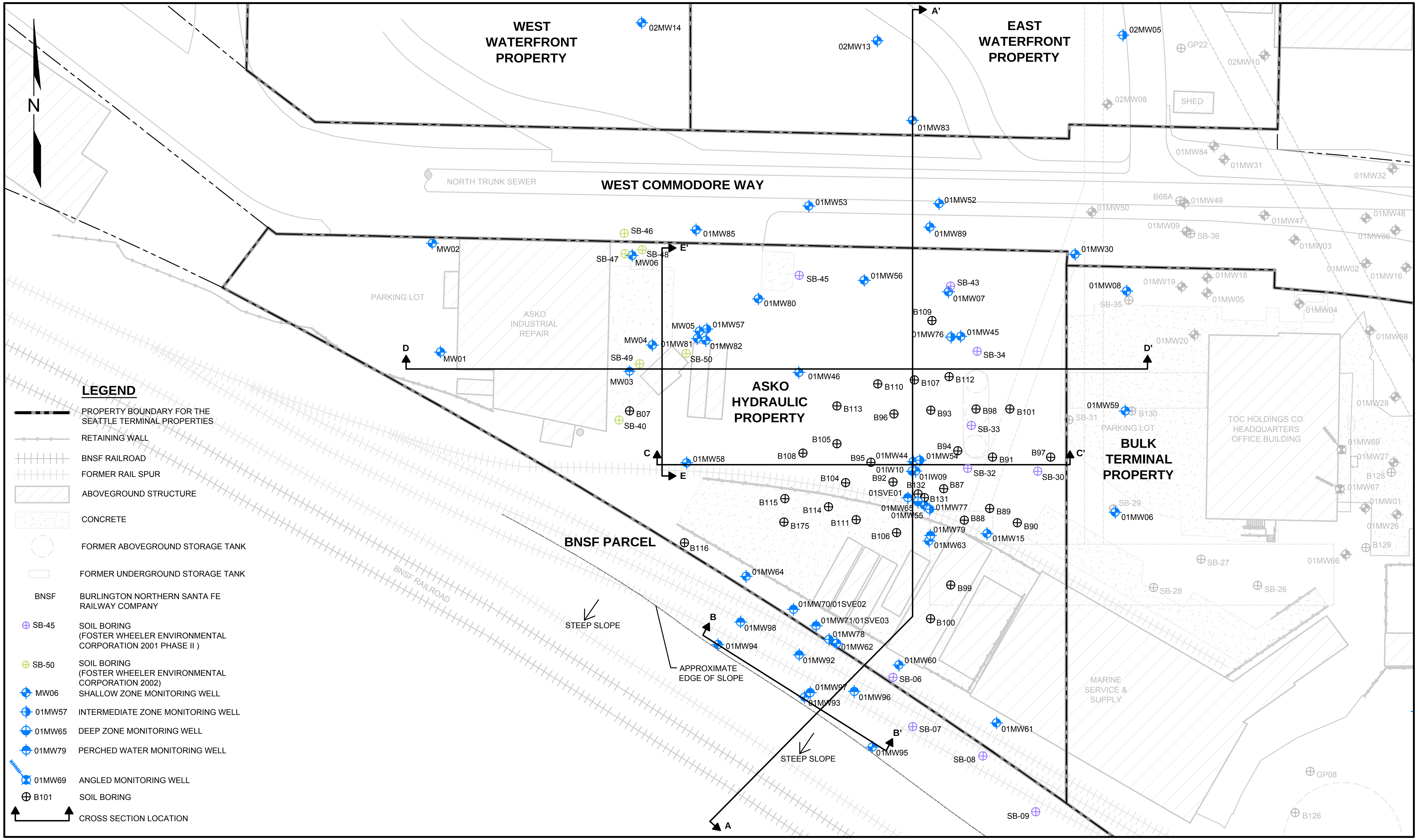
Appendix B

Geologic Cross-Sections



LEGEND

▬ ▪ ▬	PROPERTY BOUNDARY FOR THE SEATTLE TERMINAL PROPERTIES
-•-•-	RETAINING WALL
┼┼┼┼	BNSF RAILROAD
┼┼┼┼	FORMER RAIL SPUR
▨	ABOVEGROUND STRUCTURE
░	CONCRETE
○	FORMER ABOVEGROUND STORAGE TANK
▭	FORMER UNDERGROUND STORAGE TANK
BNSF	BURLINGTON NORTHERN SANTA FE RAILWAY COMPANY
⊕ SB-45	SOIL BORING (FOSTER WHEELER ENVIRONMENTAL CORPORATION 2001 PHASE II)
⊕ SB-50	SOIL BORING (FOSTER WHEELER ENVIRONMENTAL CORPORATION 2002)
⊕ MW06	SHALLOW ZONE MONITORING WELL
⊕ 01MW57	INTERMEDIATE ZONE MONITORING WELL
⊕ 01MW65	DEEP ZONE MONITORING WELL
⊕ 01MW79	PERCHED WATER MONITORING WELL
⊕ 01MW69	ANGLED MONITORING WELL
⊕ B101	SOIL BORING
▲―▲	CROSS SECTION LOCATION

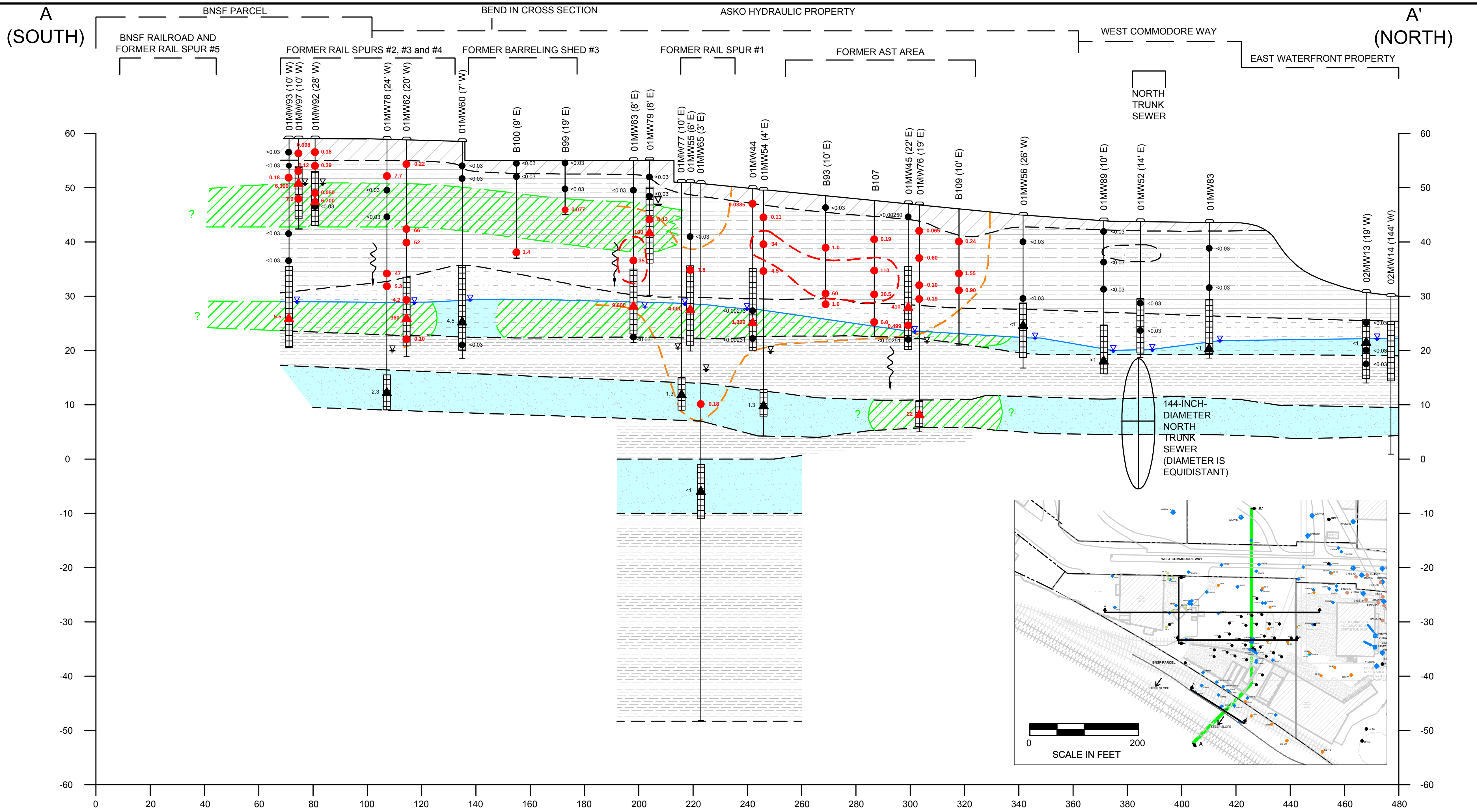
SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

DATE: 05/14/14
DRAWN BY: NAC/BLR
CHECKED BY: PJK/TSB
CAD FILE: 01-600_2013RI_BASE_ASKO

PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

FIGURE 5
EXPLORATION LOCATION PLAN

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\RI\01-600_2013RI_BASE_ASKO_F.DWG 5/14/2014



LEGEND

(6' W)	OFFSET 6' WEST FROM SECTION LINE
	MONITORING WELL
	SCREEN INTERVAL
▽	PERCHED WATER, INTERMEDIATE, OR DEEP ZONE GROUNDWATER LEVEL (MAY 2013)
▽	SHALLOW ZONE GROUNDWATER LEVEL (MAY 2013)

HISTORICAL CONCENTRATIONS OF TCE IN SOIL (mg/kg):

●	CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
●	CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

CONCENTRATIONS OF TCE IN GROUNDWATER IN SECOND QUARTER, 2013 (Õg/L):

▲	CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
▲	CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

⬚	TCE IN SOIL ABOVE MTCA METHOD A CLEANUP LEVEL
⬚	TCE IN SOIL ABOVE MTCA METHOD B CLEANUP LEVEL
▨	TCE CONTAMINATION IN GROUNDWATER
■	GROUNDWATER
↓	LEAKAGE THROUGH HETEROGENEOUS SOIL MATRIX OR THE SEMI-CONFINING UNIT

▨	SAND, SILTY SAND, AND GRAVEL (Hf)
⬚	SAND AND SILTY SAND (Hdf)
▤	SAND, SILT AND CLAY (Hdf)
▤	SILT AND CLAY (Qpf)
⬚	SAND AND SILTY SAND (Qpf)
— —	INFERRED CONTACT

AST	ABOVEGROUND STORAGE TANK
TCE	TRICHLOROETHENE
<	RESULT BELOW LABORATORY REPORTING LIMIT
mg/kg	MILLIGRAMS PER KILOGRAM
µg/L	MICROGRAMS PER LITER
MTCA	WASHINGTON STATE MODEL TOXICS CONTROL ACT

47	TCE
RED	DENOTES CONCENTRATION EXCEEDS MTCA METHOD A CLEANUP LEVEL
Hf	HOLOCENE FILL
Hdf	HOLOCENE DEPRESSION FILLINGS
Qpf	PRE-FRASER DEPOSITS

NOTE: ALL LOCATIONS ARE APPROXIMATE.

VERTICAL SCALE IN FEET
0
10
20

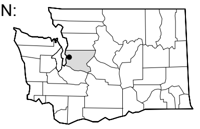
HORIZONTAL SCALE IN FEET
0
20
40

SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

DATE:	05/14/14
DRAWN BY:	NAC/BLR
CHECKED BY:	PJK/TSB
CAD FILE:	01-600_2013RI_XAA

PROJECT NAME:	TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER:	0440-004
STREET ADDRESS:	2805 WEST COMMODORE WAY
CITY, STATE:	SEATTLE, WASHINGTON

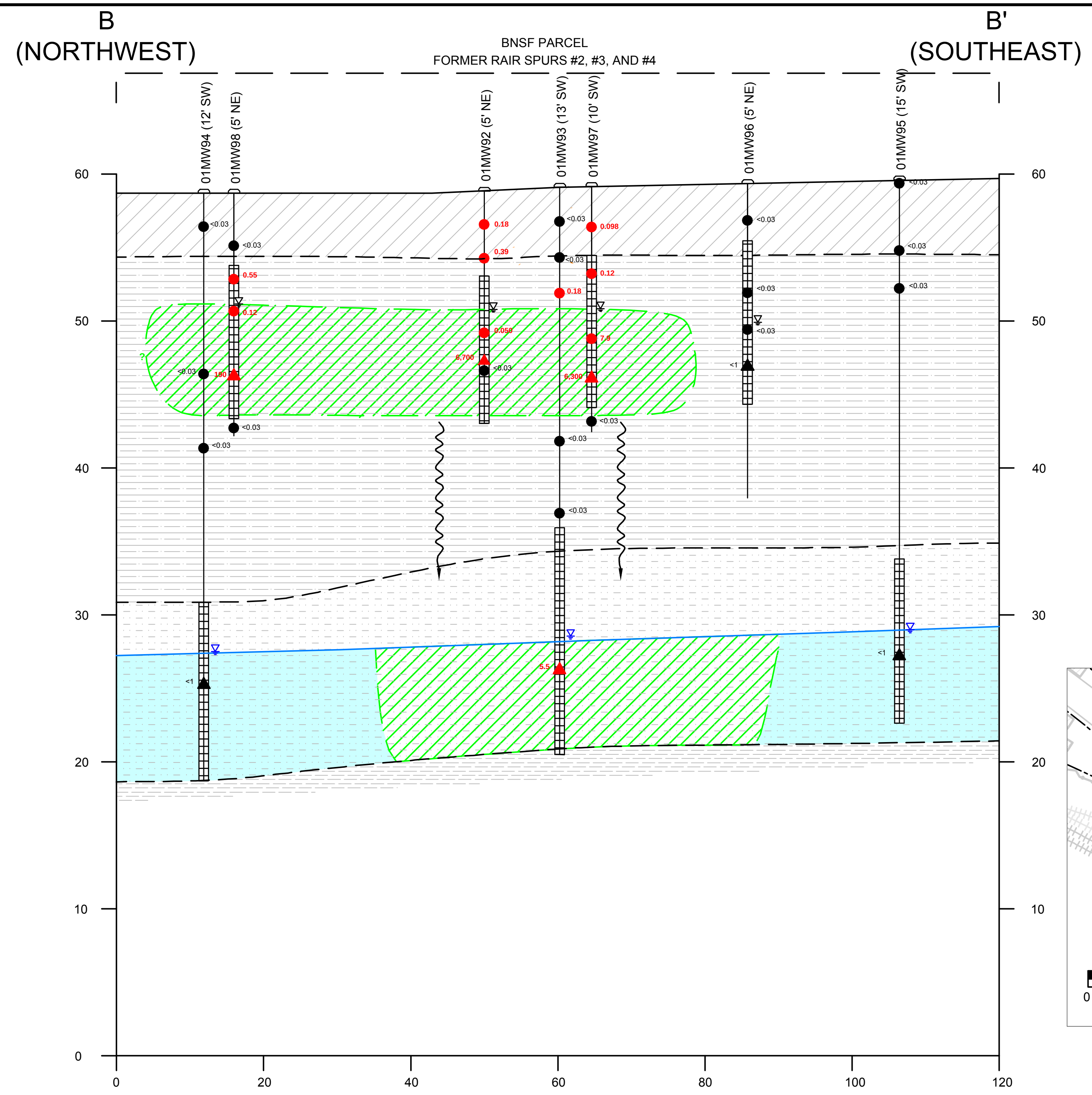
REGION:

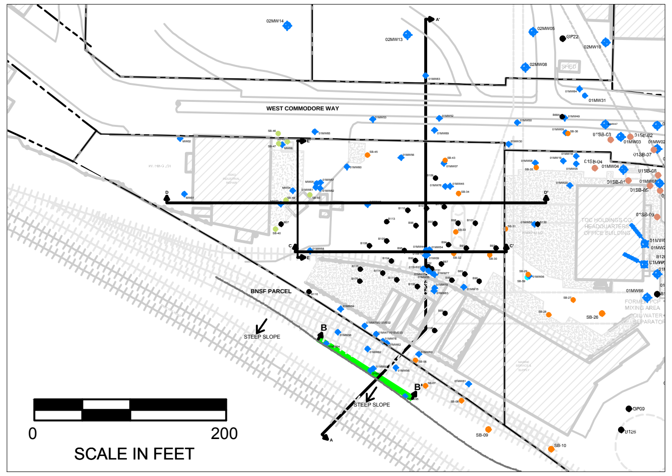


SCALE DEPICTED ABOVE

FIGURE 6
CROSS SECTION A-A'

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\RI\01-600_2013RI_XAA_F.DWG





LEGEND

(6' W) OFFSET 6' WEST FROM SECTION LINE
MONITORING WELL
SCREEN INTERVAL
PERCHED WATER, INTERMEDIATE, OR DEEP ZONE GROUNDWATER LEVEL (MAY 2013)
SHALLOW ZONE GROUNDWATER LEVEL (MAY 2013)

HISTORICAL CONCENTRATIONS OF TCE IN SOIL (mg/kg):

● CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL

● CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

CONCENTRATIONS OF TCE IN GROUNDWATER IN SECOND QUARTER, 2013 (Õg/L):

▲ CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL

▲ CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

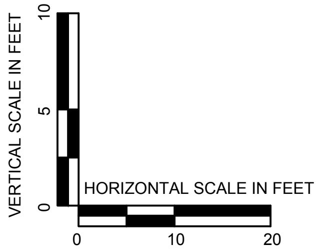
TCE IN SOIL ABOVE MTCA METHOD A CLEANUP LEVEL
🟩 TCE CONTAMINATION IN GROUNDWATER
GROUNDWATER
LEAKAGE THROUGH HETEROGENEOUS SOIL MATRIX OR THE SEMI-CONFINING UNIT

▨ SAND, SILTY SAND, AND GRAVEL (Hf)
SAND AND SILTY SAND (Hdf)
SAND, SILT AND CLAY (Hdf)
SILT AND CLAY (Qpf)
SAND AND SILTY SAND (Qpf)
— — INFERRED CONTACT

TCE	TRICHLOROETHENE
<	RESULT BELOW LABORATORY REPORTING LIMIT
mg/kg	MILLIGRAMS PER KILOGRAM
µg/L	MICROGRAMS PER LITER
MTCA	WASHINGTON STATE MODEL TOXICS CONTROL ACT
BNSF	BURLINGTON NORTHERN SANTA FE RAILWAY COMPANY

7.9	TCE
RED	DENOTES CONCENTRATION EXCEEDS MTCA METHOD A CLEANUP LEVEL
Hf	HOLOCENE FILL
Hdf	HOLOCENE DEPRESSION FILLINGS
Qpf	PRE-FRASER DEPOSITS

NOTE: ALL LOCATIONS ARE APPROXIMATE.



SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

DATE: 05/14/14
DRAWN BY: NAC/BLR
CHECKED BY: PJK/TSB
CAD FILE: 01-600_2013RI_XBB

PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
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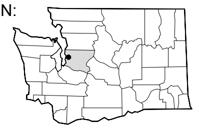
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:



SCALE DEPICTED ABOVE

FIGURE 7

CROSS SECTION B-B'

Appendix C

Health and Safety Plan

Site Specific Health and Safety Plan

Revision 19 b

Project Name: BNSF - Time Oil
2737 West Commodore Way
Seattle, Washington

Project Number: 30102090
Client Name: BNSF
Date: 1/27/2023
HASP Expires 1/27/2024
Revision:

Approvals:

HASP Developer: Dawn Moncio

Project Manager: Kyle Haslam

HASP Reviewer: Nicholas Monico
HASP Reviewer Name Typed

HASP Reviewer Signature (handwritten or digital signature)

Arcadis Culture of Caring

Arcadis is committed to a Culture of Caring that ensures each Arcadis employee, part time as needed employee (PTAN), temporary agency employee under Arcadis day to day control, Inexperienced Workers and contractor (cumulatively referred to here as "field staff") goes home at the end of the day free from injury or illness. I certify that the following has been performed with all Arcadis field staff on this project either in person or virtually through Teams:

- ☐ Reviewed the HASP including a discussion of hazard identification and controls.
  - ☐ If conducting activities deemed by Arcadis to be "High Risk", frontline management has reviewed applicable H&S standards (Job Safety Analysis [JSA] when authorized by H&S) for these activities with field staff.
  - ☐ If permit to work is required, frontline management has reviewed the permit(s) with field staff.
- ☐ Reviewed proactive H&S engagement expectations/injury prevention actions.
- ☐ Reviewed Stop Work Authority.
- ☐ Reviewed the incident reporting process and expectations including when WorkCare should be contacted by staff (WorkCare incident intervention for all minor, non-emergency injuries) and that the WorkCare phone number is programmed into field team cell phone.
- ☐ For Inexperienced Workers, a mentor has been assigned for the new task being performed.

For short service employees (SSEs), PTANS* and temporary agency employees* :

- ☐ Provided coaching and mentoring on Arcadis H&S expectations during project work. Reviewed in detail specific hazards and controls and provided a resource who can be contacted if individual has questions regarding planned or unplanned work tasks.

Mentor/Resource # ______________________ ______________________

Name Phone Number

Signed:

______________________ Associate Project Manager

* Upon hiring/contracting for the first time.

Emergency Information

Site Address:

BNSF - Time Oil
2737 West Commodore Way
Seattle, WA

Emergency Phone Numbers:

Emergency (fire, police, ambulance)		911
Emergency (facility specific, if applicable):		
Emergency Other (specify):		
Primary Client Contact:	Scott MacDonald	360-621-6419 (m) 206-625-6376 (o)
WorkCare (non-life-threatening injury/illness):		1-888-449-7787
Project H&S:	Kyle Haslam	206-413-6534
Task Manager:	Emily Zikmund	947-777-4721
Project Manager:	Kyle Haslam	206-413-6534
H&S Specialist:	Eve Crudup	713-953-4862
Area H&S Director:	Andrew McDonald	410-200-3752

Hospital Name and Address:

Swedish Hospital - Ballard
5350 Tallman Ave NW
Seattle, WA 98107

Hospital Phone Number: 206-781-6341

Supplemental Client Contact Information:

Other Important Phone Numbers:

Poison Control Center	1-800-222-1222
Nat. Response Ctr. (spills in reportable quantities)	1-800-424-8802
U.S. Coast Guard (spills to water)	1-800-424-8802

Incident Reporting Protocol Within Arcadis

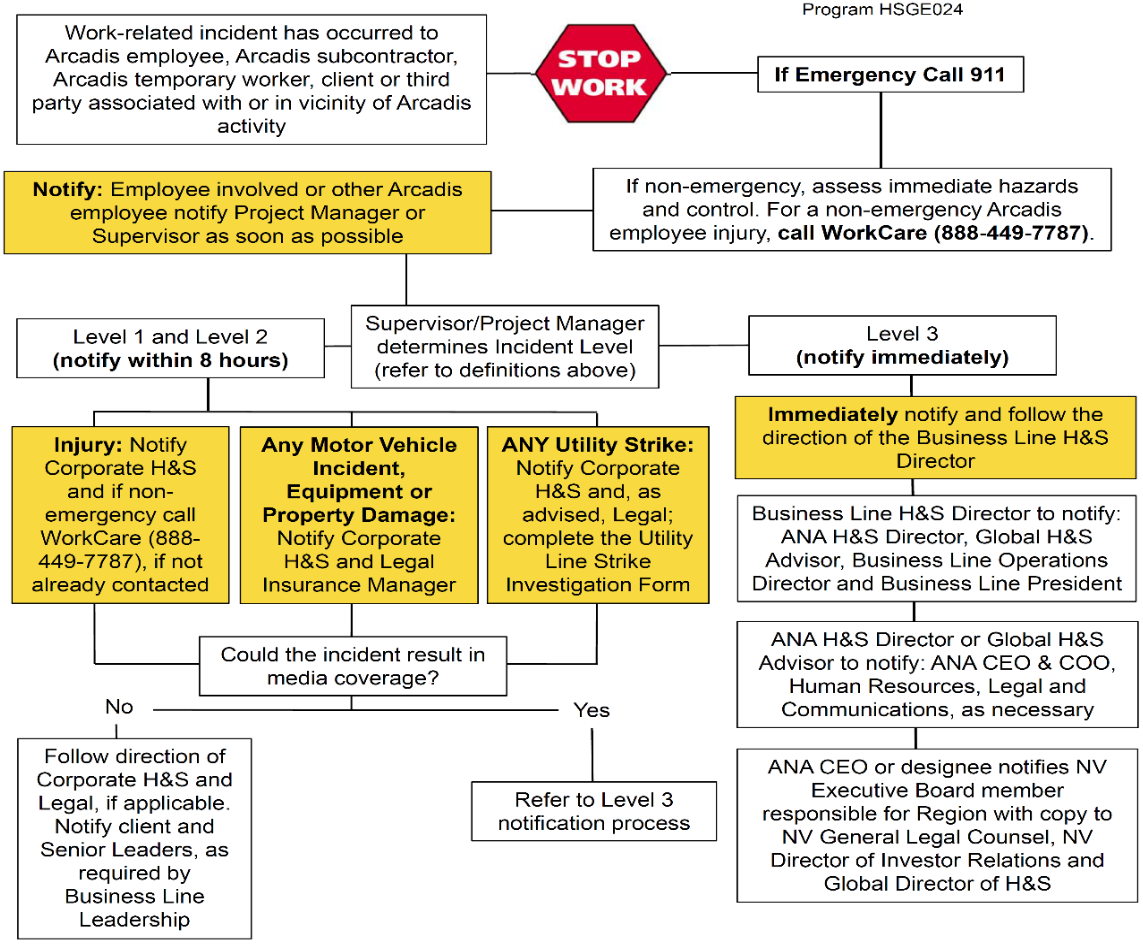
Incident Levels

Level 1: First aid/self-treated, work-related injury (contact WorkCare as soon as possible); minor property or equipment damage (less than or equal to $100); vehicle loss event* (no injuries, no third-party involvement or other vehicle involvement).

Level 2: Professional Medical Treatment (if non-emergency injury or illness, employee must contact WorkCare as soon as possible); moderate property or equipment damage (greater than $100 but less than or equal to $5,000); ANY utility strike incident, any motor vehicle accident* (including injury or third-party involvement).

Level 3: Immediately report fatality, severe or catastrophic injury and/or overnight hospitalization required; significant property or equipment damage (greater than $5,000); missing person or incident that generates media coverage.

* Refer to Motor Vehicle Safety Program HSGE024



Work-related incident has occurred to Arcadis employee, Arcadis subcontractor, Arcadis temporary worker, client or third party associated with or in vicinity of Arcadis activity

STOP WORK

If Emergency Call 911

If non-emergency, assess immediate hazards and control. For a non-emergency Arcadis employee injury, **call WorkCare (888-449-7787)**.

Notify: Employee involved or other Arcadis employee notify Project Manager or Supervisor as soon as possible

Supervisor/Project Manager determines Incident Level (refer to definitions above)

Level 1 and Level 2 **(notify within 8 hours)**

Level 3 **(notify immediately)**

Injury: Notify Corporate H&S and if non-emergency call WorkCare (888-449-7787), if not already contacted

Any Motor Vehicle Incident, Equipment or Property Damage: Notify Corporate H&S and Legal Insurance Manager

ANY Utility Strike: Notify Corporate H&S and, as advised, Legal; complete the Utility Line Strike Investigation Form

Could the incident result in media coverage?

Follow direction of Corporate H&S and Legal, if applicable. Notify client and Senior Leaders, as required by Business Line Leadership

Refer to Level 3 notification process

Immediately notify and follow the direction of the Business Line H&S Director

Business Line H&S Director to notify: ANA H&S Director, Global H&S Advisor, Business Line Operations Director and Business Line President

ANA H&S Director or Global H&S Advisor to notify: ANA CEO & COO, Human Resources, Legal and Communications, as necessary

ANA CEO or designee notifies NV Executive Board member responsible for Region with copy to NV General Legal Counsel, NV Director of Investor Relations and Global Director of H&S

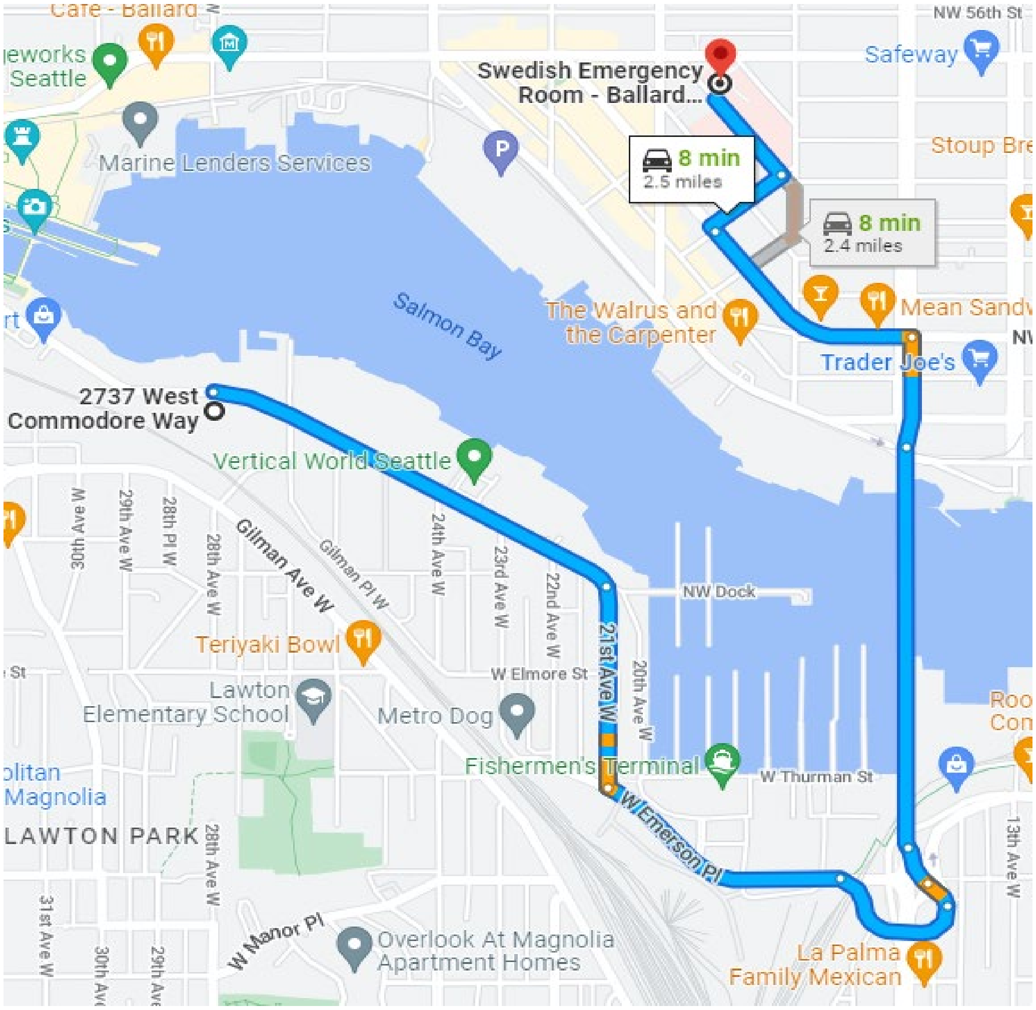
Client Incident Reporting Protocol

1. Dial 911/Facility Emergency Number/WorkCare as applicable.
2. Contact PM/Supervisor - Kyle Haslam (cell: 206-719-6991)
3. Contact Corporate H&S - Eve Crudup (cell: 713-953-4862)
4. Contact Client - Scott MacDonald (cell: 360-621-6419)

Route to the Hospital

SWEDISH HOSPITAL - BALLARD
2737 W Commodore Way
Seattle, WA 98199

Phone: 206-781-6341



Directions:
1. Head east on W Commodore Way toward 27th Ave W (travel 0.5 mi)
2. Continue onto 21 st Ave W (travel 0.2 mi)
3. Turn left onto W Emerson Pl/Emerson Street Bike Trail/S Ship Canal Trail (travel 0.3 mi)
4. Turn right onto W Nickerson St (signs for Ballard Bridge) (travel 0.2 mi)
5. Slight left to stay on W Nickerson St (travel 190 ft)
6. Continue straight (travel 272 ft)
7. Slight right onto 15th Ave W/Ballard Bridge (travel 0.5 mi)
8. Slight right onto 15 Ave NW (signs for Ballard) (travel 0.1 mi)
9. Turn left onto NW Leary Way (pass by Shelter Lounge Ballard on the right) (travel 0.3 mi)
10. Turn right onto NW Ione Pl (travel 0.1 mi)
11. Turn left onto Tallman Ave NW (detstination will be on the right) (travel 0.1 mi)

Travel Summary:
Travel Distance = 2.5 mi
Travel Time = 8 min

Site Type

The project site is an active facility with the following attributes:

Commercial
Railroad

For class I railroads, work within 25 ft of the rails is prohibited unless FRA On-Track Safety and railroad specific trained. For other railroads (i.e. short line railorads), the project or task manager will specify any special training needs. For all rail related work, field staff will have access to the Arcadis Railroad Safety Handbook and/or client rail safety handbook.

Surrounding Land Use and Topography

The site is located in a mixed industrial-residential area and is bounded by industial properties to the north and east, residential properties to the south, and another BNSF parcel to the west. The topography slopes downwards to the north, toward Salmon Bay.

Simultaneous Operations (SimOps)

SimOps is expected or will be conducted in proximity to Arcadis work activities on the project site. SimOps creates unique hazards that could affect Arcadis employees and subcontractors and SimOps hazards identified on site will be addressed in the JSA or similar governing document (i.e. permit) for affected Arcadis work tasks. If the SimOps work activities create a high hazard to Arcadis staff or subcontractors, Arcadis will utilize stop work until the SimOps activity is complete or will coordinate work activities with SimOps workers and/or client to ensure SimOps work hazards are mitigated.

Site Background

The site is located on Parcel #4237900240 and consists of a portion of the BNSF Railroad surrounded by heavily vegetated land. Cleanup on the site is under an Agreed Order with Washington Department of Ecology. Site COCs include petroluem and chlorinated solvents, which have impacted the groundwater.

Project Tasks

The following tasks are identified for this project:

1	Mobilization - Site set up and take down
2	Utilities - Clearance
3	Sampling - Soil sampling using sonic drilling technology
4	Monitor well - Well installation, development, or purging contractor oversight
5	Monitor well - Well sounding, water level or product measurements using probes, tapes or downhole water parameter measurements
6	Sampling - Well sampling using bladder and peristlatic pumps
7	Waste - Containment of IDW in small containment devices greater than 10 gallons but less than or equal to 119 gallons capacity
8	Waste - Solid and liquid waste sampling using manual methods
9	Biological- Vegetation maintenance clearing and/or removal using mechanized methods

The following documents and/or plans associated with the above task(s) are required and attached:

- Client specific H&S information.
- The Arcadis Utilities and Structures Checklist must be used for utility clearance activities.
- Silica Exposure Control Plan
- Washington Heat Illness Prevention Plan (HIPP).

☒ Required Checklists/Work Forms

Tailgate Safety Briefing Form
Vehicle Inspection Checklist
Utilities and Structures Checklist

☐ Required Permits

Not Applicable

☒ Required H&S Standards

Heat Stress Prevention_ARC HSIH013
Utility Location Procedures_ARC HSFS019

Short Service Employees (SSEs), Part Time As Needed Employees (PTANs) and Temporary Agency Employees

SSEs (employees who are employed with Arcadis for less than 1 year or are Inexperienced Workers) have the potential to work on this project. If SSEs are utilized, the project team working in conjunction with the SSE's administrative supervisor will ensure requirements of ARC HSGE019 "Short Service Employees" are completed. SSE's will be identified on the project Tailgate Safety Meeting Form.

Roles and Responsibilities

	Name	Role	Short Service Employee
1	Kyle Haslam	Project Manager (PM)	No
2	Emily Zikmund	Associate Project Manager (APM)	No
3	Emily Zikmund	Task Manager	No
4	Emily Zikmund	Field Technical Lead	No
5	Emily Zikmund	Site Safety Officer (SSO) (Non-HAZWOPER	No
6			
7			
8			
9			
10			

Training

All Arcadis employees are required to have the following training to be on site:

Hazwoper 40-Hour
Hazwoper 8-Hour Annual Refresher
H&S Program Orientation (non-certificate)
HAZCOM GHS/EAP (non-certificate)
Defensive Driving - Smith On-Line
First Aid/CPR
Fire Extinguisher (non-certificate)
Heat Stress
PPE (non-certificate)
Silica General Awareness
Railroad - Contractor Specific
Railroad - eRAILSAFE (non-CSX)
Railroad - FRA Roadway Worker
Client specific:
BNSF Contractor Safety
Other:

Selected Arcadis employees are required to have the following additional training:

	Names or Numbers from above
DOT HazMat #1	4 and/or 5
None	
None	
None	
None	
None	
None	
None	
None	
None	
None	
None	
None	
None	
None	
Other:	

The Arcadis Fundamental H&S Principles

Staff working on any of the task(s) listed above must utilize the six Arcadis Fundamental H&S Principles to ensure work is conducted safely. These principles include: 1) Use of TRACK, 2) H&S Planning, 3) Stop Work Authority, 4) "If Not Me Then Who", 5) Stewardship, and 6) Incident Reporting. Every project team member plays an important role in project health and safety. This is more than just having a HASP, training, or PPE. Proactive staff engagement with these principles is critical to a safe work environment.

General Task Hazard Assessment and Risk Control (HARC)

General: **Site-Wide**

The 12 hazard category HARC ratings are not available in this General THA. The mitigated and unmitigated ratings for the hazards presented are based on the Risk Assessment Matrix below. Modify hazards and ratings as necessary to meet project needs.

Risk Assessment Matrix		Likelihood Ratings			
Consequences Ratings		A	B	C	D
People	Property	0 Almost Impossible	1 Possible but Unlikely	2 Likely to Happen	3 Almost Certain to Happen
1-Slight or No Health Effect	Slight or No Damage	0-Low	1-Low	2-Low	3-Low
2-Minor Health Effect	Minor Damage	0-Low	2-Low	4-Medium	6-Medium
3-Major Health Effect	Local Damage	0-Low	3-Low	6-Medium	9-High
4-Fatalities	Major Damage	0-Low	4-Medium	8-High	12-High

Hazard #1

Driving - On road - Injury or vehicle damage from motor vehicle accident or incident

Suggested FHSHB Ref: 3.4
Overall Unmitigated Risk: HIGH
Mitigated Risk: MEDIUM

To mitigate this hazard, use TRACK and the following:
Smith System (on line)
JSAs

Comments: Use Smith System "5-Keys" when driving. See Driving JSA for details.

Hazard #2

Driving - Driver - Injury, death or property damage due to driver distraction, fatigue, etc.

Suggested FHSHB Ref: 3.4, 3.21
Overall Unmitigated Risk: HIGH
Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
Smith System (on line)
Driver awareness and use of stop work authority

Comments: Use route planning. Keep eyes moving while driving. See Driving JSA.

Hazard #3

Biological - skin/eye irritation or damage from poisonous plants

Suggested FHSHB Ref: 3.17.11
Overall Unmitigated Risk: MEDIUM
Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
See HASP Tick/Poisonous Plant Section
Job Briefing/Site Awareness

Comments: Use skin pre-treatment lotions when available.

Hazard #4

Biological - bites or stings from exposure to insects or arachnids

Suggested FHSHB Ref: 3.17: 2,3,7,8,9,10
Overall Unmitigated Risk: HIGH
Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
PPE (see HASP "PPE" section)
Job Briefing/Site Awareness

Comments: Do body check daily. For ticks see also HASP Tick/Poisonous Plant section

Hazard #5

Biological - cuts, scrapes, skin/eye puncture from exposure to physically damaging plants

Suggested FHSHB Ref: 3.17.11
Overall Unmitigated Risk: MEDIUM
Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
Job Briefing/Site Awareness
PPE (see HASP "PPE" section)

Comments:

General Task HARC (continued)

Hazard #6		
Environmental - Thermal stress - Injury or illness from heat or cold		
Suggested FHSHB Ref:	3.16	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Field H&S Handbook (see ref. above)
Mitigated Risk:	LOW	JSAs
Comments:	Use job rotation or rest breaks. Stay hydrated and eat regularly.	
Hazard #7		
Environmental - Inclement weather -Injury or equipment damage from inclement weather		
Suggested FHSHB Ref:	3.12	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Weather Monitoring
Mitigated Risk:	LOW	Cont./Emerg. Planning
Comments:	Use 30/30 rule for lightning. See FHSHB for details.	
Hazard #8		
Motion - Musculoskeletal - Injury from lifting, twisting , stooping, or awkward body positions		
Suggested FHSHB Ref:	3.29.1	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Engineering Controls (specify in comments)
Mitigated Risk:	LOW	Admin. Controls (specify in comments)
Comments:	Use proper lifting techniques. Use job rotation when applicable. See FHSHB for details.	
Hazard #9		
Motion - Musculoskeletal - Injury from repeated work activity or body motion		
Suggested FHSHB Ref:	3.29.2	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Engineering Controls (specify in comments)
Mitigated Risk:	LOW	Admin. Controls (specify in comments)
Comments:	Use proper lifting techniques. Use job rotation when applicable. See FHSHB for details.	
Hazard #10		
Gravity - Falls - Injury due to slips and trips		
Suggested FHSHB Ref:	3.26.4, 4.11	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	Housekeeping
Comments:	Use footwear appropriate for site conditions, plan routes and do not hurry while walking.	

Task Specific HARC

Task 1:	**Mobilization - Site set up and take down**

HARC Unmitigated Hazard Types (H-High, M-Medium, L-Low): FHSHB Ref: 3.9

Biological*	-	Chemical	L	Driving*	-	Electrical	L
Environmental*	L	Gravity*	M	Mechanical	L	Motion*	M
Personal Safety	L	Pressure	L	Radiation	L	Sound	L

* *Hazard rating, if present, excludes General THA hazards in this category.*

Hazard #1

Motion - Struck by - Bodily injury from impact with moving object

Suggested FHSHB Ref: 2.5, 3.22
Overall Unmitigated Risk: MEDIUM
Mitigated Risk: LOW
Comments: Stay clear of railroad tracks; wear Class II safety vest. When working in vegetated areas, examine trees loose or dead branches in danger of falling, do not work under branches if avoidable; wear hard hat.

To mitigate this hazard, use TRACK and the following:
Site Awareness
PPE (see HASP "PPE" section)

Hazard #2

Gravity - Struck by - Injury from falling object

Suggested FHSHB Ref: 3.26.2
Overall Unmitigated Risk: MEDIUM
Mitigated Risk: LOW
Comments: Open vehicle doors slowly as equipment may have shifted during travel; wear safety-toed boots.

To mitigate this hazard, use TRACK and the following:
Job Briefing/Site Awareness
PPE (see HASP "PPE" section)

Hazard #3

Mechanical - Pinch point - Injury by pinching of body part in mechanical process

Suggested FHSHB Ref: 3.27.4
Overall Unmitigated Risk: MEDIUM
Mitigated Risk: LOW
Comments: Keep hands/fingers away from pinch points (vehicle doors, equipment cases, etc.); wear work gloves.

To mitigate this hazard, use TRACK and the following:
Site Awareness
PPE (see HASP "PPE" section)

Hazard #4

Motion - Cuts and scrapes - Injury from moving object impacting skin or eye

Suggested FHSHB Ref: 2.5, 3.22
Overall Unmitigated Risk: MEDIUM
Mitigated Risk: LOW
Comments: Do not rush to unload or load vehicle as this may lead to injuries. Identify equipment that may have sharp edges prior to setting up and taking down work area; wear safety glasses and work gloves.

To mitigate this hazard, use TRACK and the following:
Site Awareness
PPE (see HASP "PPE" section)

Task Specific HARC (continued)

Task 2:	Utilities - Clearance

HARC Unmitigated Hazard Types (H-High, M-Medium, L-Low): FHSHB Ref: 3.36

Biological*	L	Chemical	L	Driving*	-	Electrical	M
Environmental*	L	Gravity*	L	Mechanical	M	Motion*	M
Personal Safety	L	Pressure	L	Radiation	-	Sound	L

Hazard #1

Motion - Struck by - Bodily injury from impact with moving object

Suggested FHSHB Ref:	2.5, 3.22	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Stay clear of railroad tracks; wear Class II safety vest. When working in vegetated areas, examine trees loose or dead branches in danger of falling, do not work under branches if avoidable; wear hard hat. When air-knifing, be aware of process and make eye contact with operator prior to approaching; wear hard hat and Class II safety vest.

Hazard #2

Mechanical - Pinch point - Injury by pinching of body part in mechanical process

Suggested FHSHB Ref:	3.27.4	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Identify pinch points prior to starting task; keep fingers/hands away from pinch points; wear work gloves.

Hazard #3

Electrical - Housekeeping - Injury or property damage due to frayed wiring, improperly mounted wiring, missing or damaged warning labels, etc.

Suggested FHSHB Ref:	3.25	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Inspections
Mitigated Risk:	LOW	Housekeeping

Comments: Inspect equipment with electrical components prior to use; do not use equipment with electrical components that are damaged or showing excessive wear.

Task Specific HARC (continued)

Task 3:	**Sampling - Soil sampling using sonic drilling technology**

HARC Unmitigated Hazard Types (H-High, M-Medium, L-Low): FHSHB Ref: 3.9

Biological*	L	Chemical	L	Driving*	-	Electrical	M
Environmental*	L	Gravity*	M	Mechanical	M	Motion*	M
Personal Safety	L	Pressure	L	Radiation	-	Sound	H

Hazard #1

Motion - Struck by - Bodily injury from impact with moving object

Suggested FHSHB Ref:	2.5, 3.22	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Stay clear of railroad tracks; wear Class II safety vest. When working in vegetated areas, examine trees loose or dead branches in danger of falling, do not work under branches if avoidable; wear hard hat. Be aware of the drilling process and make eye contact with operator prior to approaching; wear hard hat and Class II safety vest.

Hazard #2

Chemical - solids/particulates, skin or eye irritation/damage/allergy

Suggested FHSHB Ref:	3.9, 3.22, 3.30, 3.33	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Job Briefing/Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Be aware of site contaminants; wear nitrile gloves and safety glasses.

Hazard #3

Chemical - liquids, skin or eye irritation/damage/allergy

Suggested FHSHB Ref:	3.9, 3.22, 3.30, 3.33	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Job Briefing/Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Be aware of sample bottle preservatives; wear nitrile gloves and safety glasses.

Hazard #4

Motion - Cuts and scrapes - Injury from moving object impacting skin or eye

Suggested FHSHB Ref:	2.5, 3.22	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Wear cut-resistant gloves under nitrile gloves when removing soil from liner; cut edges of liner are sharp. Do not overtighten lids on glass bottleware as this may cause breakage; wear cut-resistant gloves under nitrile gloves.

Hazard #5

Environmental - Utilities - Injury or property damage from utility strike/damage

Suggested FHSHB Ref:	3.36	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	HIGH	Specialized Checklist/Forms
Mitigated Risk:	MEDIUM	Inspections

Comments: Use three-lines of evidence to clear for utilities; complete the Utilities Checklist prior to drilling. Keep 5 feet off of all identified utilities.

Task Specific HARC (continued)

Task 4:	**Monitor well - Well installation, development, or purging contractor oversight**

HARC Unmitigated Hazard Types (H-High, M-Medium, L-Low): FHSHB Ref: 3.9

Biological*	L	Chemical	L	Driving*	-	Electrical	-
Environmental*	L	Gravity*	M	Mechanical	L	Motion*	L
Personal Safety	-	Pressure	L	Radiation	-	Sound	M

Hazard #1

Motion - Struck by - Bodily injury from impact with moving object

Suggested FHSHB Ref: 2.5, 3.22

Overall Unmitigated Risk: MEDIUM

Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:

Site Awareness

PPE (see HASP "PPE" section)

Comments: Stay clear of railroad tracks; wear Class II safety vest. When working in vegetated areas, examine trees loose or dead branches in danger of falling, do not work under branches if avoidable; wear hard hat. Be aware of the process and make eye contact with rig operator prior to approaching; wear hard hat and Class II safety vest.

Hazard #2

Chemical - liquids, skin or eye irritation/damage/allergy

Suggested FHSHB Ref: 3.9, 3.22, 3.30, 3.33

Overall Unmitigated Risk: MEDIUM

Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:

Job Briefing/Site Awareness

PPE (see HASP "PPE" section)

Comments: Be aware of site contaminants; wear nitrile gloves and safety glasses.

Hazard #3

Motion - Cuts and scrapes - Injury from moving object impacting skin or eye

Suggested FHSHB Ref: 2.5, 3.22

Overall Unmitigated Risk: MEDIUM

Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:

Site Awareness

PPE (see HASP "PPE" section)

Comments: Be aware of process; do not approach rig while in operation; communicate with operator prior to approaching; wear hard hat and safety glasses.

Task Specific HARC (continued)

Task 5:	**Monitor well - Well sounding, water level or product measurements using probes, tapes or downhole water parameter measurements**

HARC Unmitigated Hazard Types (H-High, M-Medium, L-Low): FHSHB Ref: 3.9

Biological*	L	Chemical	L	Driving*	-	Electrical	-
Environmental*	L	Gravity*	M	Mechanical	-	Motion*	L
Personal Safety	-	Pressure	L	Radiation	-	Sound	L

Hazard #1

Motion - Struck by - Bodily injury from impact with moving object

Suggested FHSHB Ref:	2.5, 3.22	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Stay clear of railroad tracks; wear Class II safety vest. When working in vegetated areas, examine trees loose or dead branches in danger of falling, do not work under branches if avoidable; wear hard hat.

Hazard #2

Chemical - liquids, skin or eye irritation/damage/allergy

Suggested FHSHB Ref:	3.9, 3.22, 3.30, 3.33	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Job Briefing/Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Be aware of site contaminants; wear nitrile gloves and safety glasses.

Hazard #3

Chemical - liquids - injury or illness from vapor inhalation

Suggested FHSHB Ref:	3.2, 3.22, 3.30, 3.33	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Job Briefing/Site Awareness
Mitigated Risk:	LOW	JSAs

Comments: Be aware of site contaminants that may cause vapors to build up inside well; stand up wind of open well; do not hold head/face over open well.

Hazard #4

Motion - Cuts and scrapes - Injury from moving object impacting skin or eye

Suggested FHSHB Ref:	2.5, 3.22	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Use caution when opening well lids/vaults; use hand tools in the manner intended by the manufacturer; protect knuckles from scraping on pavement when opening flush-mount wells; wear work gloves.

Hazard #5

Mechanical - Pinch point - Injury by pinching of body part in mechanical process

Suggested FHSHB Ref:	3.27.4	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Use caution when closing well lid/vault as fingers may become pinches; wear work gloves.

Task Specific HARC (continued)

Task 6:	**Sampling - Well sampling using bladder and peristlatic pumps**

HARC Unmitigated Hazard Types (H-High, M-Medium, L-Low): FHSHB Ref: 3.9

Biological*	L	Chemical	M	Driving*	-	Electrical	L
Environmental*	M	Gravity*	M	Mechanical	L	Motion*	M
Personal Safety	L	Pressure	L	Radiation	-	Sound	M

Hazard #1

Motion - Struck by - Bodily injury from impact with moving object

Suggested FHSHB Ref: 2.5, 3.22

Overall Unmitigated Risk: MEDIUM

Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
Site Awareness
PPE (see HASP "PPE" section)

Comments: Stay clear of railroad tracks; wear Class II safety vest. When working in vegetated areas, examine trees loose or dead branches in danger of falling, do not work under branches if avoidable; wear hard hat.

Hazard #2

Chemical - liquids, skin or eye irritation/damage/allergy

Suggested FHSHB Ref: 3.9, 3.22, 3.30, 3.33

Overall Unmitigated Risk: MEDIUM

Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
Job Briefing/Site Awareness
PPE (see HASP "PPE" section)

Comments: Be aware of site contaminants; wear nitrile gloves and safety glasses.

Hazard #3

Chemical - liquids - injury or illness from vapor inhalation

Suggested FHSHB Ref: 3.2, 3.22, 3.30, 3.33

Overall Unmitigated Risk: MEDIUM

Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
Job Briefing/Site Awareness
PPE (see HASP "PPE" section)

Comments: Be aware of site contaminants that may cause vapors to build up inside well; stand up wind from open well; do not hold head/face over open well.

Hazard #4

Mechanical - Pinch point - Injury by pinching of body part in mechanical process

Suggested FHSHB Ref: 3.27.4

Overall Unmitigated Risk: MEDIUM

Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
Site Awareness
PPE (see HASP "PPE" section)

Comments: Use caution when closing well lid/vault as fingers may become pinches; wear work gloves.

Hazard #5

Motion - Cuts and scrapes - Injury from moving object impacting skin or eye

Suggested FHSHB Ref: 2.5, 3.22

Overall Unmitigated Risk: MEDIUM

Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
Site Awareness
PPE (see HASP "PPE" section)

Comments: Use caution when opening well lids/vaults; protect knuckles from scraping on pavement when opening flush-mount wells; wear work gloves. Do not overtighten lids on glass bottlware as this may cause breakage; cut-resistant gloves. Do not used fixed-blade cutters when sizing tubing; wear cut-resistant gloves.

Hazard #6

Electrical - Housekeeping - Injury or property damage due to frayed wiring, improperly mounted wiring, missing or damaged warning labels, etc.

Suggested FHSHB Ref: 3.25

Overall Unmitigated Risk: MEDIUM

Mitigated Risk: LOW

To mitigate this hazard, use TRACK and the following:
Inspections
Housekeeping

Comments: Inspect equipment with electrical components daily; do not use equipment with damaged or exposed wires or components showing excessive wear.

Task Specific HARC (continued)

Task 7:	**Waste - Containment of IDW in small containment devices greater than 10 gallons but less than or equal to 119 gallons capacity**

HARC Unmitigated Hazard Types (H-High, M-Medium, L-Low): FHSHB Ref: 3.3

Biological*	L	Chemical	M	Driving*	-	Electrical	-
Environmental*	M	Gravity*	M	Mechanical	L	Motion*	M
Personal Safety	L	Pressure	L	Radiation	-	Sound	L

Hazard #1

Motion - Struck by - Bodily injury from impact with moving object

Suggested FHSHB Ref:	2.5, 3.22	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	Site Awareness

Comments: Stay clear of railroad tracks; wear Class II safety vest. When working in vegetated areas, examine trees loose or dead branches in danger of falling, do not work under branches if avoidable; wear hard hat.

Hazard #2

Chemical - liquids, skin or eye irritation/damage/allergy

Suggested FHSHB Ref:	3.9, 3.22, 3.30, 3.33	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Job Briefing/Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Be aware of site contaminants; wear nitrile gloves and safety glasses.

Hazard #3

Chemical - solids/particulates, skin or eye irritation/damage/allergy

Suggested FHSHB Ref:	3.9, 3.22, 3.30, 3.33	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Job Briefing/Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Be aware of site contaminants; wear nitrile gloves and safety glasses.

Hazard #4

Mechanical - Pinch point - Injury by pinching of body part in mechanical process

Suggested FHSHB Ref:	3.27.4	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Use caution when opening/closing drums; skin can easily become pinched between drum and lid; use hand tools in the manner intended by the manufacturer; wear work gloves.

Hazard #5

Motion - Cuts and scrapes - Injury from moving object impacting skin or eye

Suggested FHSHB Ref:	2.5, 3.22	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Use caution when opening drums, specially drum with rusty or overtightened bolts; use hand tools in the manner intended by the manufacturer; wear work gloves.

Task Specific HARC (continued)

Task 8:	Waste - Solid and liquid waste sampling using manual methods

HARC Unmitigated Hazard Types (H-High, M-Medium, L-Low): FHSHB Ref: 3.31

Biological*	L	Chemical	L	Driving*	-	Electrical	-
Environmental*	M	Gravity*	M	Mechanical	-	Motion*	M
Personal Safety	L	Pressure	L	Radiation	-	Sound	L

Hazard #1

Chemical- liquids - injury or illness from skin absorption

Suggested FHSHB Ref: 3.9, 3.22, 3.30, 3.33 To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk: MEDIUM Site Awareness
Mitigated Risk: LOW PPE (see HASP "PPE" section)
Comments: Be aware of site contaminants and sample preservatives; wear nitrile gloves and safety glasses.

Hazard #2

Chemical - liquids - injury or illness from vapor inhalation

Suggested FHSHB Ref: 3.2, 3.22, 3.30, 3.33 To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk: MEDIUM Site Awareness
Mitigated Risk: LOW PPE (see HASP "PPE" section)
Comments: Be aware of site contaminants that may cause vapors to build up inside drum; stand up wind from open drum; do not hold head/face over open drum.

Hazard #3

Chemical - solids/particulates, skin or eye irritation/damage/allergy

Suggested FHSHB Ref: 3.9, 3.22, 3.30, 3.33 To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk: MEDIUM Site Awareness
Mitigated Risk: LOW PPE (see HASP "PPE" section)
Comments: Be aware of site contaminants and sample preservatives; wear nitrile gloves and safety glasses.

Hazard #4

Chemical - solids/particulates, injury or illness from inhalation

Suggested FHSHB Ref: 3.2, 3.22, 3.30, 3.33 To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk: MEDIUM Site Awareness
Mitigated Risk: LOW PPE (see HASP "PPE" section)
Comments: Be aware of site contaminants that may cause vapors to build up inside drum; stand up wind from open drum; do not hold head/face over open drum.

Hazard #5

Mechanical - Pinch point - Injury by pinching of body part in mechanical process

Suggested FHSHB Ref: 3.27.4 To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk: MEDIUM Site Awareness
Mitigated Risk: LOW PPE (see HASP "PPE" section)
Comments: Use caution when opening/closing drums; skin can easily become pinched between drum and lid; use hand tools in the manner intended by the manufacturer; wear work gloves.

Hazard #6

Motion - Cuts and scrapes - Injury from moving object impacting skin or eye

Suggested FHSHB Ref: 2.5, 3.22 To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk: MEDIUM Site Awareness
Mitigated Risk: LOW PPE (see HASP "PPE" section)
Comments: Use caution when opening drums, specially drum with rusty or overtightened bolts; use hand tools in the manner intended by the manufacturer; wear work gloves.

Task Specific HARC (continued)

Task 9:	Biological- Vegetation maintenance clearing and/or removal using mechanized methods

HARC Unmitigated Hazard Types (H-High, M-Medium, L-Low): FHSHB Ref: 3.28

Biological*	M	Chemical	-	Driving*	-	Electrical	-
Environmental*	L	Gravity*	L	Mechanical	M	Motion*	M
Personal Safety	-	Pressure	L	Radiation	-	Sound	M

Hazard #1

Motion - Struck by - Bodily injury from impact with moving object

Suggested FHSHB Ref:	2.5, 3.22	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	Select

Comments: Stay clear of railroad tracks; wear Class II safety vest. When working in vegetated areas, examine trees loose or dead branches in danger of falling, do not work under branches if avoidable; wear hard hat. Be aware of possible flying debris when using a string trimmer; wear hard hat and safety glasses.

Hazard #2

Motion - Cuts and scrapes - Injury from moving object impacting skin or eye

Suggested FHSHB Ref:	2.5, 3.22	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Site Awareness
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Identify sharp edges/blades on equipment prior to use; keep body away from equipment blades; wear cut-resistant gloves.

Hazard #3

Chemical - liquids, skin or eye irritation/damage/allergy

Suggested FHSHB Ref:	3.9, 3.22, 3.30, 3.33	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	JSAs
Mitigated Risk:	LOW	PPE (see HASP "PPE" section)

Comments: Wear nitrile gloves and safety glasses when refueling equipment

Hazard #4

Electrical - Housekeeping - Injury or property damage due to frayed wiring, improperly mounted wiring,

Suggested FHSHB Ref:	3.25	To mitigate this hazard, use TRACK and the following:
Overall Unmitigated Risk:	MEDIUM	Inspections
Mitigated Risk:	LOW	Housekeeping

Comments: Inspect equipment with electrical components daily; do not use equipment with damaged or exposed wires or components showing excessive wear.

Hazard Communication (HAZCOM)/Global Harmonization System (GHS)

☐ HAZCOM/GHS for this project is managed by the client or general contractor

List the chemicals anticipated to be used by Arcadis on this project per HAZCOM/GHS requirements.
(Modify quantities as needed)

	Preservatives	Qty
☐	Not applicable	
☒	Hydrochloric acid	<500 ml
☒	Nitric acid	<500 ml
☒	Sulfuric acid	<500 ml
☐	Sodium hydroxide	<500 ml
☐	Zinc acetate	<500 ml
☐	Ascorbic acid	<500 ml
☐	Acetic acid	<500 ml
☐	Isopropyl alcohol	< 4 gal.
☐	Formalin (<10%)	< 4 gal.
☒	Methanol	<500 ml
☐	Sodium bisulfate	<500 ml

	Decontamination	Qty
☐	Not applicable	
☒	Alconox	≤ 5 lbs
☒	Liquinox	≤ 1 gal
☐	Acetone	≤ 1 gal
☐	Methanol	≤ 1 gal
☐	Hexane	≤ 1 gal
☐	Isopropyl alcohol	≤ 4 gal
☐	Nitric acid	≤ 1 L
☐	Other:	

	Calibration	Qty.
☐	Not applicable	
☒	Isobutylene/air	1 cyl
☐	Methane/air	1 cyl
☐	Pentane/air	1 cyl
☐	Hydrogen/air	1 cyl
☐	Propane/air	1 cyl
☐	Hydrogen sulfide/air	1 cyl
☐	Carbon monoxide/air	1 cyl
☒	pH standards (4,7,10)	≤ 1 gal
☐	Conductivity standards	≤ 1 gal
☐	Other:	

	Fuels	Qty.
☒	Not applicable	
☐	Gasoline	≤ 5 gal
☐	Diesel	≤ 5 gal
☐	Kerosene	≤ 5 gal
☐	Propane	1 cyl
☐	Other:	

	Kits		Qty.
☒	Not applicable		
☐	Hach (specify):		1 kit
☐	DTECH (specify):		1 kit
☐	Other:		1 kit

	Remediation	Qty.
☒	Not applicable	
☐		
☐		
☐		
☐		
☐		

	Other:	Qty.
☐	Not applicable	
☒	Spray paint	≤ 6 cans
☐	WD-40	≤ 1 can
☐	Pipe cement	≤ 1 can
☐	Pipe primer	≤ 1 can
☐	Mineral spirits	≤ 1 gal

	DOT(1):	Qty.
☐	MOT eligible soils	
☐	MOT eligible water	
☐	MOT eligible solids	
☐	MOT eligible liquids	
☐		
☐		
☐		

(1) Attach applicable Materials of Trade (MOT) Quick Form to shipping determination or this HASP. SDS not generally applicable to this category.

SDSs for this project will be available in printed form in the company vehicle. All project workers will be notified of the SDS location in their initial safety briefing.

Contractor SDSs will be submitted to Arcadis in advance of work and will be filed with Arcadis SDSs as indicated above.

This project will not be utilizing materials subject to the HAZCOM Standard in bulk storage. In this HASP, bulk storage means any material stored on the project site in a bulk packaging >119 gallons (> 450 L) liquid capacity or a palletized quantity of a material in packagings ≤119 gallons (≤450 L) liquid capacity.

Air Monitoring

☐ There are no atmospheric chemical, radiological, or particulate hazards on this project requiring air monitoring.
☐ Air monitoring is the responsibility of the client or subcontractor.

Constituents of Interest:

Time Weighted Averages (TWAs) are ACGIH 8-Hr Threshold Limit Values (TLVs) unless noted.

TCE			
TWA	10 ppm	LEL/UEL (%):	8/10.5
STEL	25 ppm	VD (Air = 1):	NA
IDLH	1000 ppm, NIOSH	VP (mmHg):	58

Diesel — Anticipated Breathing Zone Concentration <= 3 mg/m3

Diesel			
TWA	100 mg/m3, skin, (15 ppm Arcadis limit-see PID warning)	LEL/UEL (%):	NA
STEL	NA	VD (Air = 1):	NA
IDLH	NA	VP (mmHg):	NA

Gasoline			
TWA	30 ppm, Arcadis administrative limit	LEL/UEL (%):	1.4/7.6
STEL	500 ppm	VD (Air = 1):	NA
IDLH	NA	VP (mmHg):	38-300

TWA - Time Weighted Average (ACGIH TLV unless noted)	LEL/UEL - Lower /Upper Explosive Limit
STEL - Short Term Exposure Limit	RGD - Relative Gas Density
IDLH - Immediately Dangerous to Life and Health	VP - Vapor Pressure

Notes:

One or more constituents above is listed with a skin notation. Avoid conditions where dusts, mists, or aerosols are created. Avoid skin contact with impacted media.

Required Monitoring Instruments, Action Levels and Monitoring Frequency

Gray fields below are not automated. Make necessary selections from drop down menus.

Photoionization Detector Select Lamp: 10.6 eV

Diesel/Fuel Oil: The 15 ppm Arcadis recommended exposure limit for diesel/fuel oil is not included in the computation below. Manual action level adjustment may be required. The PID may provide a slow response to diesel fuel/fuel oil.

Computed action levels (PID units) (1):	☐	Computed action levels have been manually adjusted.
<	11.1	Continue working
	11.1 - 22.2	Levels sustained > 5 minutes, monitor continuously and review engineering controls and PPE. Proceed with caution.
>	22.2000	Stop work and contact SSO

(1) Computed action levels are for PIDs which have not been programmed to correct TLVs for specific constituents or mixtures.

Particulate/aerosol monitoring is not required. Re-evaluate if visible dusts or aerosols cannot be controlled.

Action levels are in mg/m3	☐	Computed action levels have been manually adjusted.
<	NA	Continue working
	NA	Levels sustained > 5 minutes, monitor continuously and review engineering controls and PPE. Proceed with caution.
>	NA	Stop work and contact SSO

Breathing zone air monitoring using the above instruments will be performed at the following frequency:

Hourly

If manually logging air monitoring results, all results must be documented, including non-detects.

Multigas (including LEL/O2 and Hg vapor) monitoring is not required.

LEL/O2 Meter	0-5% LEL	Continue work
LEL/O2 Monitoring Not Required	>5-10% LEL	Continually monitor, review engineering controls, proceed with caution
	>10% LEL	Stop work, evacuate, contact SSO
	19.5%-23.5% O2	Normal, continue work
	<19.5% O2	O2 deficient, stop work, evacuate, contact SSO
	>23.5% O2	O2 enriched, stop work, evacuate, contact SSO

Additional Gas/Vapor Monitoring is Not Required

		1/2 TLV	Stop Work Action Level	Comments
☐	Ammonia	12.5 ppm	25 ppm	
☐	Carbon dioxide	2500 ppm	5000 ppm	
☐	Carbon monoxide	12.5 ppm	25 ppm	
☐	Chlorine	0.05 ppm	0.1 ppm	
☐	Hydrogen cyanide	2.35 ppm (skin)	4.7 ppm* (skin)	
☐	Hydrogen sulfide	0.5 ppm	1 ppm	
☐	Methane	Simple Asphyxiant		
☐	Nitrogen dioxide	0.1 ppm	0.2 ppm	
☐	Phosphine	0.025 ppm	0.05 ppm	
☐	Sulfur dioxide	0.125 ppm	0.25* ppm	
☐	Mercury vapor	0.0125 mg/m3	0.025 mg/m3	

* Ceiling or STEL value

All air-monitoring instruments must be calibration checked daily, if used, per manufacturer's instructions. Calibration checks, including calibration gases used, must be documented.

Compound specific monitoring using indicator tubes or chips is not required.

Indicator:	≤TWA	Continue work
☐ Tube ☐ Chip	>TWA	Stop work, review engineering controls and PPE, contact SSO
Compound(s):		

Indicator tube/chip monitoring frequency:

Tick and Poisonous Plant Hazards

For all projects with outdoor work, biological hazards must be addressed in the tailgate safety meeting each day. The following controls must be used to mitigate biological hazards while working and must also be discussed in the tailgate safety meeting.

Controlling Tick Hazards

Risk Guide for Ticks:

Low	Paved areas; parking lots; well manicured lawns and fields; no work taking place within 15 feet of vegetated areas; work in REGIONS with no tick populations; sub-freezing temperatures, snow or ice cover on ground.*
Medium	Brush hogged fields, wetlands, and grasslands; forested areas with little undergrowth; weeds less than knee height; moderately dense foliage; sporadic or moderately vegetated shaded areas; average leaf accumulation and decaying material on the ground; work taking place in fields after application of insecticide; work in REGIONS with a recognized moderate tick populations; outdoor work during spring, summer and fall months.*
High	Uncut fields, wetlands, forested areas, and grasslands; weeds taller than knee height; heavy dense foliage; heavily vegetated shaded areas; excessive accumulations of leaves and decaying material on the ground; work in REGIONS with recognized heavy tick populations; areas with posted tick hazard warnings; outdoor work during spring, summer and fall months.*

*Cold weather does not eliminate risk of exposure to deer ticks as they may be active all year in areas that experience subfreezing temperatures.

Ticks are ranked as a **High** risk for this project

Care should be taken to avoid walking through or working in tall grasses, overgrown or bushy vegetation to the extent reasonable and practical. No single control is effective against ticks.

Select required controls below:

Engineering Controls

- ☐ Mowing of work area
- ☒ Clearing overgrown vegetation
- ☐ Pesticide application
- ☐ Other:

Administrative Controls

- ☒ Complete tick check morning/evening
- ☐ Scheduled tick check:
- ☒ Inspect backpacks, equipment cases, etc. daily
- ☒ Vehicle cab - maintain good housekeeping
- ☐ Other:

Personal Protective Equipment

- ☒ Light colored clothing
- ☒ Light colored hat/hardhat
- ☒ Pants tucked in boots
- ☒ Shirt tucked into pants
- ☒ Long sleeved shirt and long pants
- ☐ White Tyvek pants
- ☐ White coveralls/Tyvek
- ☐ Taped cuffs/pant legs
- ☐ Tick gators
- ☐ Double sided tape/duct tape sticky side out
- ☐ Insect mesh/netting for face/head or whole body suit
- ☐ Other:

Heat stress signs/symptoms and controls to also be addressed in tailgate safety meeting if temperatures >80°F

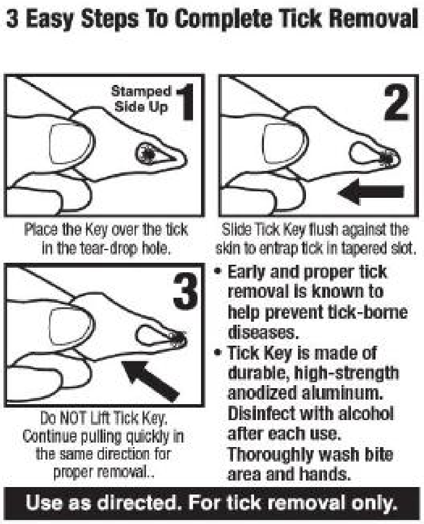
Repellents

- ☐ Repellents will not be used
- ☒ Permethrin impregnated clothing (purchased)
- ☐ Permethrin (0.5% self applied/treated to clothing)
- ☐ Deet 20-40% applied to skin
- ☐ Other:

Tick Removal and First Aid

Ticks removed within 24 hours of embedment represent <u>a very low risk</u> for adverse outcomes. Perform tick checks as directed above. To properly remove a tick:

Using a Tick Removal Tool



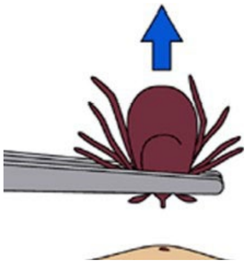
3 Easy Steps To Complete Tick Removal

1. Place the Key over the tick in the tear-drop hole.
2. Slide Tick Key flush against the skin to entrap tick in tapered slot.
3. Do NOT Lift Tick Key. Continue pulling quickly in the same direction for proper removal..

- Early and proper tick removal is known to help prevent tick-borne diseases.
- Tick Key is made of durable, high-strength anodized aluminum. Disinfect with alcohol after each use. Thoroughly wash bite area and hands.

Use as directed. For tick removal only.

Using Tweezers



1) Use point tip tweezers, if available, to reduce potential of crushing the ticks body
2) Grasp the tick as close to skin as possible
3) Pull upward with even pressure.

Do not crush tick with fingers

After removal, wash affected area with alcohol or iodine. Wash hands thoroughly after removal.
Document date/time of the removal in field notes, field form or H&S app.
If rash or fever develops, call WorkCare

Poisonous Plants (Poison Ivy, Poison Oak, Poison Sumac)

All work outdoors, regardless of time of year, must address poisonous plant hazards and controls in the tailgate safety meeting.

Controlling Exposure to Poisonous Plants

Poisonous Plants are ranked as a **Medium** risk on this project

Select required controls below:

Engineering Controls

☒ Not applicable
☐ Mowing of work area
☐ Clearing overgrown vegetation
☐ Herbicide application
☐ Other: ____________________

Administrative Controls

☒ Identify and avoid (see ID Quick Guide below)
☒ Watch for signs or symptoms of exposure
☒ Vehicle cab - maintain good housekeeping
☐ Other: ____________________________________

Personal Protective Equipment

☒ Gloves
☐ Hat/hardhat/head covering
☒ Pants tucked in boots
☒ Shirt tucked into pants
☐ Long sleeved shirt and long pants

☐ White coveralls/Tyvek
☐ Taped cuffs/pant legs
☐ Dust mask (during burning activities, etc.)
☐ Other: ____________________________________

Repellents

☐ Repellents will not be used
☒ Barrier creams
☐ Other: ____________________

Skin Decontamination

☒ Wash with post-exposure soap and water
☒ Wash with soap and water (use hot water if available)
☐ Hot shower at end of day
☐ Other: ______________________________________

Equipment Decontamination

Due to the medium risk associated with poisonous plants on this project, portable equipment and tools have a potential to be contaminated with urushiol (the oil that causes allergic reactions and dermatitis in poisonous plants covered by this plan). Decontaminate by using post-exposure soap and water or alcohol spray if safe to do so for the equipment/tool being cleaned. Larger equipment should be decontaminated prior to performing maintenance by pressure washing or spraying with alcohol spray in area of maintenance (i.e. tires, etc.).

Clothing Decontamination

Wash work clothing in hot water separate from other clothing. Since the project has a medium risk for poisonous plants, work boots should be considered contaminated with urushiol. Decontaminate with post-exposure soap and water or hot soap and water. If safe for the boot, consider spraying with alcohol spray if post-exposure soap is not available. Place disposable outer clothing (coveralls, Tyvek, etc.) and disposable gloves in plastic bag for disposal. Wear gloves while removing disposable outer clothing.

First Aid

If skin irritation or other signs of allergic reaction develops contact WorkCare for assistance. Document date and time of exposure, if known, in field notes, field form or H&S app.

Identification Quick Guide

Ticks:

American Dog Tick

Blacklegged (Deer) Tick

Brown Dog Tick

Groundhog Tick

Gulf Coast Tick

Lone Star Tick

Rocky Mountain Wood Tick

Soft Tick

Poison Ivy:

Poison Oak:

Poison Sumac:

For other biological hazards, address the hazards and controls in the JSA for the work task.

Personal Protective Equipment (PPE)

See JSA or Permit for the task being performed for required PPE. If work is not conducted under a JSA or Permit, refer to the governing document for PPE requirements. At a minimum, the following checked PPE is required for all tasks during field work (outside of field office trailers and vehicles) not covered by a JSA or Permit on this project:

Minimum PPE required to be worn by all staff on project:

			Specify Type:
☒ Hard hat	☐ Snake chaps/guards	☐ Coveralls:	
☒ Safety glasses	☐ Briar chaps	☐ Apron:	
☐ Safety goggles	☐ Chainsaw chaps	☐ Chem. resistant gloves:	
☐ Face shield	☐ Sturdy boot	☐ Gloves other:	
☐ Hearing protection	☒ Steel or comp. toe boot	☐ Chemical boot:	
☐ Rain suit	☐ Metatarsal boot	☐ Boot other:	
☐ Other:		☒ Traffic vest, shirt or coat:	Class II
		☐ Life vest:	

Task specific PPE: Nitrile Gloves, Work Gloves, Cut-Resistant Gloves, Hearing Protection

Comments:

See Tick and Poisonous Plant Hazards section for addtional PPE information.

Task-specific PPE will be worn when the associated hazards are present and in accordance with applicable JSAs

Medical Surveillance

All project workers will be required to be participants in HAZWOPER medical surveillance except employees and/or subcontractors listed below.

Client and DOT mandated drug and alcohol testing is not required for this project and will not be performed.

Specify Companies: Utility Locators

Hazardous Materials Shipping and Transportation

A shipping determination package has been prepared, reviewed and provided to Arcadis field staff for this project.

Traffic Safety and Traffic Safety Plans (TSPs)

The scope of work on this project will not expose Arcadis workers or subcontractors to vehicular traffic. A traffic safety plan will not be required.

Arcadis Commercial Motor Vehicles (CMVs)

CMVs operated by Arcadis employees on public roadways will not be utilized on this project. Arcadis defines a CMV as any single vehicle with a gross vehicle weight rating (GVWR) ≥10,001 pounds or a truck and trailer combination with a combined GVWR ≥10,001 pounds (GVWR of truck + GVWR of trailer = ≥10,001 pounds).

Site Control

Site control requirements are addressed in the applicable task JSA for this project. JSAs requiring site control are attached to this HASP.

Decontamination

Decontamination protocols are addressed in the applicable task JSA(s) for this project. The applicable JSAs are attached to this HASP.

Sanitation

The project scope is a mobile work operation. The project field team will have reasonable access to restroom facilities within 10 minutes of the work area where the mobile work activity is actively taking place. Potable water will be carried by the field team in the vehicle used for the project. Unless alternate requirements are stipulated in a plan supplement (i.e. Heat Injury and Illness Prevention Plan), permit or JSA, bottled or water coolers with potable water will be provided to project workers at 1 gallon/worker/day.

Safety Briefings

Arcadis will lead all safety briefings on this project and will document the safety briefing on a Tailgate Safety Briefing form or logbook. Safety briefings will be conducted once at the beginning of each work day unless the Site Safety Officer deems more frequent safety briefings will be required based on work being conducted. All project workers, including Arcadis subcontractors, will be required to attend the safety briefing. Site visitors and project workers not on duty during the morning safety briefing will receive the safety briefing upon their arrival onto the project site for the day.

Employee Health and Safety Engagement

The CPM or APM is responsible for reviewing and establishing H&S engagement goals for the project. These goals are summarized below.

Hazard Observations (via H&S App or TIP) required at the following frequency on this project:

1 per person

Close Call reporting (via H&S app) goals for this project:

1 per event

Other (specify):

Safety Equipment and Supplies

Safety equipment/supply requirements are addressed in the JSA or Permit for the task being performed. If work is not performed under a JSA or Permit, the following safety equipment is required to be present on site in good condition unless otherwise noted (Check all that apply):

- ☒ First aid kit
- ☐ Bloodborne pathogens kit
- ☒ Fire extinguisher
- ☐ Eyewash (ANSI compliant)
- ☒ Eyewash (bottle)
- ☒ Drinking water
- ☐ Other:

- ☐ Insect repellent:
- ☒ Sunscreen
- ☐ Air horn
- ☒ Traffic cones
- ☐ 2-way radios
- ☐ Heat stress monitor
- ☐ See Tick and Poisonous Plant Hazards section for addtional equipment/supply information.

International Travel

International travel is not required for this project.

Spill Control and Containment

Spill control and containment protocols, including required equipment and supplies, are located in a JSA prepared by Arcadis. Implementation of the JSA requirements are the responsiblity of Arcadis.

Use of Electronic Devices in Areas of Increased Safety Risk

The intent of this section is to ensure use of standard computer tablets, laptops, or cell phones (collectively referred to in this HASP as a digital device) is performed in a manner that is effective in preventing or mitigating injury to the user of the digital device.

Use of electronic devices within 25 ft of a railroad track requires approval of the railroad owning or operating on the track. Railroad On-Track Safety rules for use of electronic devices must be followed without exception even if not under contract to the railroad (Arcadis policy). Refer to the Arcadis Railroad Safety Handbook for more information.

Electronic device use and distractions to be discussed and documented in the job briefing/safety briefing.

Signatures

I have read, understand and agree to abide by the requirements presented in this health and safety plan. I understand that I have the absolute right to stop work if I recognize an unsafe condition affecting my work until corrected.

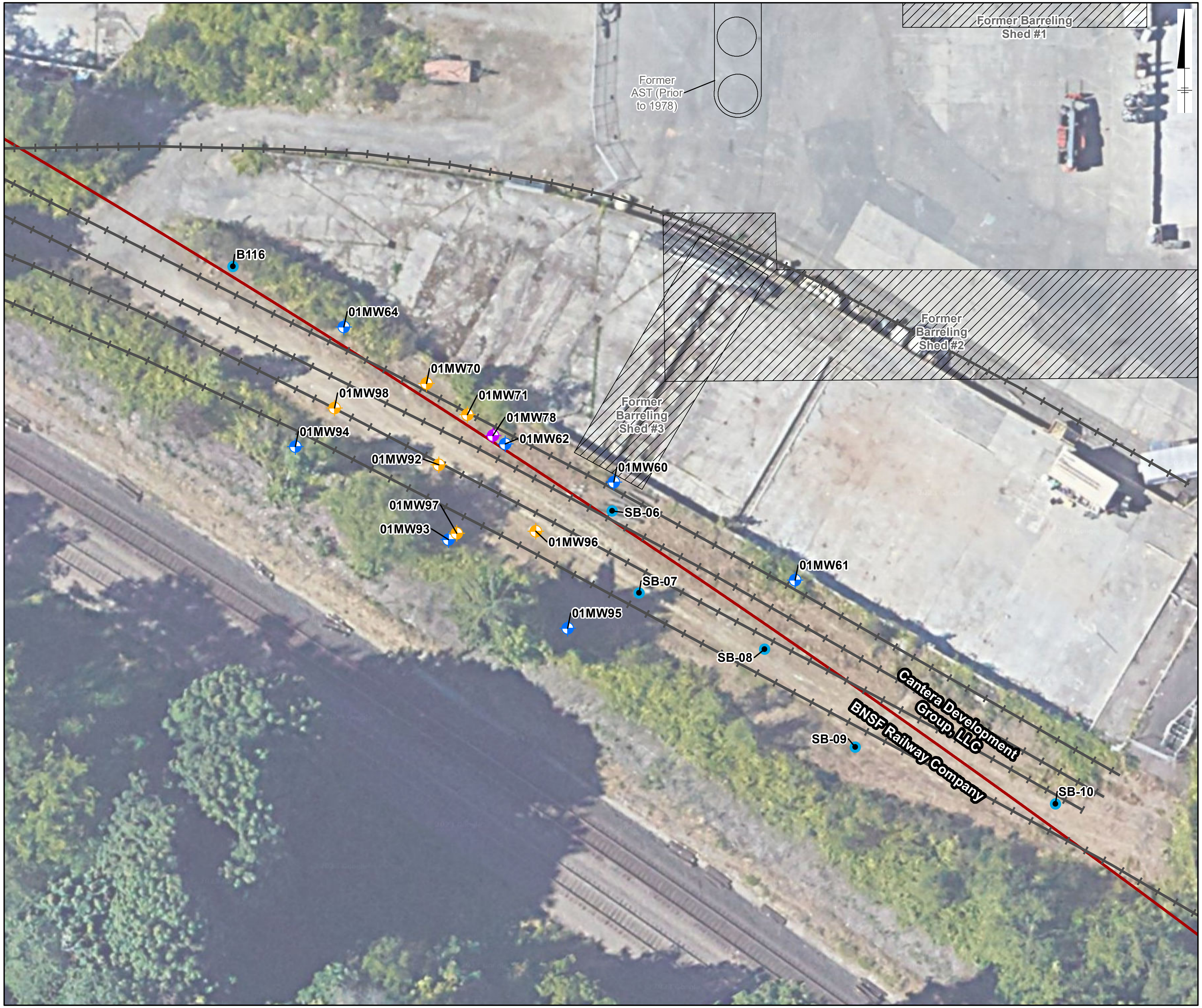
Printed Name	Signature	Date

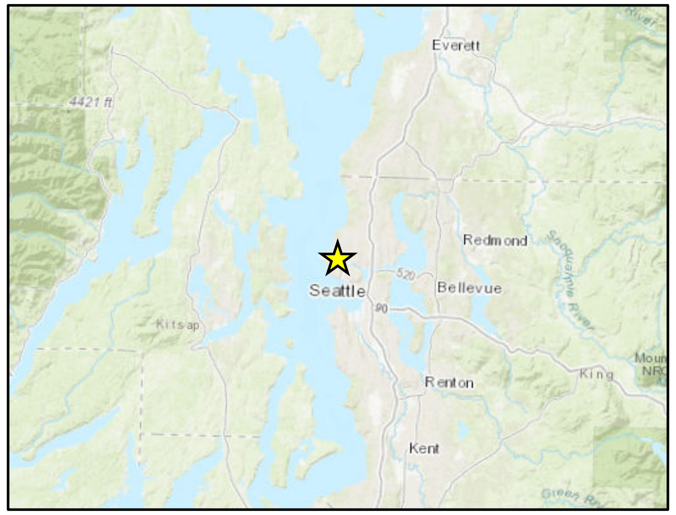
Add additional sheets if necessary

You have an absolute right to STOP WORK if unsafe conditions exist!

Attachment A

Site Map





LEGEND:

- ☆ SITE
- ⊕ PERCHED MONITORING WELL
- ⊕ SHALLOW MONITORING WELL
- ⊕ INTERMEDIATE MONITORING WELL
- ● SOIL BORING
- — PROPERTY BOUNDARY
- ┼ HISTORICAL RAIL SPUR (APPROXIMATE LOCATION)
- ▨ HISTORICAL BARRELING SHED (APPROXIMATE LOCATION)

0 30 60 Feet

NOTE:
1. AERIAL IMAGERY OBTAINED FROM GOOGLE EARTH PRO. IMAGERY DATE: 08/14/2020.
2. PROPERTY BOUNDARY SURVEY COMPLETED BY TRUE NORTH LAND SURVEYING, INC. ON JANUARY 08, 2021.

BNSF RAILWAY COMPANY
TIME OIL BULK TERMINAL - BNSF PROPERTY
SEATTLE, WASHINGTON
REMEDIAL INVESTIGATION WORK PLAN

SITE MAP

ARCADIS

FIGURE
3

Last Saved By: dholmes
T:_ENV\BNSF\BNSF_FormerTimeOil_WA\MXD\2023_RI_WorkPlan\F3_SiteMap.mxd 1/29/2023 9:35:35 AM

Attachment B
Silica Plan
Heat Illness Protection Plan
Lone Worker Plan
Smoke Protection Plan

Silica Exposure Control Plan

Project Name: BNSF - Time Oil2737 West Commodore WaySeattle, Washington
Project Number: 30102090
Date:

Task Description:
The scope of work includes groundwater and soil sampling, and installation of groundwater monitoring wells.

1) *Arcadis Silica Competent Person:* N/A *Phone:*

The above individual will ensure requirements stipulated in this plan are implemented and has the authority to take corrective measures and/or revise this plan to ensure employee, contractor and/or public exposure to silica dust remains below the respirable inhalation time weighted average action level of 25 µg/m3 over an 8-hour period.

2) *What material will the team be working with on this project?*

Grout

3) *The following work activity will be performed on this project which have a potential for silica dust exposure:*

Mixing/pouring

The following controls will be utilized to mitigate exposure to silica dust hazards:
Based on the activity entered above, the following OSHA/Arcadis activity category is:
Arcadis regulated activity

4) *The controls to be utilized include:*

Reasonable care will be taken to control visible dusts and wetting will be the preferred method to control dusts. If wetting cannot be utilized, the Arcadis competent person will design and implement engineering and administrative controls to mitigate the dust hazard prior to directing use of respiratory protection.

4a) *Respiratory Protection:*

	≤4 HRS	>4HRS		≤4 HRS	>4HRS
Indoors or Enclosed Area:	None	None	Outdoors:	None	None

The Arcadis competent person may require 10 APF respiratory protection based on data and observations available.

Additional Housekeeping Requirements:
Arcadis prohibits dry sweeping or dry brushing where such activity could contribute to employee exposure to respirable crystalline silica unless wet sweeping, HEPA-filtered vacuuming or other methods that minimize the likelihood of exposure are not feasible.

Arcadis prohibits use of compressed air to clean clothing or surfaces where such activity could contribute to employee exposure to respirable crystalline silica unless:
The compressed air is used in conjunction with a ventilation system that effectively captures the dust cloud created by the compressed air; or
No alternative method is feasible (requires concurrence with a CIH).

5) Air Monitoring Requirements for Activities with an Assigned Respirator APF Listed in Section 4a.

☒ Real-time air monitoring for silica is not required for this project.

☐ Real-time air monitoring will be conducted during work activities where employees or contractors are exposed to or have the reasonable probability to be exposed to silica dust hazards. Silica air monitoring will include use of an aerosol monitor equipped with a Dorr-Oliver cyclone kit for respirable dust evaluation. Although not permitted to be the sole method of determining employee exposure, real-time air monitoring for silica will be performed in the employee breathing zone (personal air monitoring) and also performed at the perimeter of the work area (exclusion zone boundary). The results will be documented and submitted to Corporate H&S upon completion of the project. Air samples for laboratory analysis will also be required unless excepted from collection by a CIH.

Aerosol monitor selected for use on this project: ____________________
Frequency of air sample collection for laboratory analysis: ____________________
Air samples will be submitted to the following laboratory: ____________________

6) Medical Surveillance

Employees performing work activities where exposure to silica dust is known to be or has a reasonable probability to be above the OSHA 8-Hr TWA action level of 25 µg/m3 will participate in silica medical surveillance in conjunction with their annual HAZWOPER physical. New entrants into the silica medical surveillance program at times when the HAZWOPER physical is not due will coordinate the required surveillance with WorkCare and then maintain the surveillance with their HAZWOPER physical going forward.

7) Additional Instructions

This silica exposure control plan was prepared to document that the tasks included in the current scope of work, which may expose workers to respirable crystalline silica, present no airborne hazard requiring monitoring nor a silica competent person be on site. If the scope of work changes from these current tasks, this plan will be re-evaluated to assess new hazards.

Signatures:

Dawn Monico
Preparer Name Printed

1/27/2023
Date

Dawn J Monico
Preparer Signature

Arcadis Heat Illness Prevention Plan (HIPP)
HASP Supplement

Purpose and Scope **Date Completed** 1/27/2023

The purpose of this document is to serve as a planning tool and implementation guide to assist the project team, onsite personnel, and the Site Safety Officer (SSO) or other designated responsible party to comply with the requirements set forth by **Cal/OSHA Title 8 CCR 3395 Heat Illness Prevention Standard** and the **Washington State Outdoor Heat Exposure Regulations 296-62-09510 thru 09560**.

NOTE: This HASP Supplement is required to be used in California and Washington states. The Arcadis Health and Safety Standards ARC HSIH013 Heat Stress Prevention, and ARC HSGE008 Injury and Illness Prevention Program (IIPP) must accompany this HASP Supplement. To completely address the regulatory requirements for work in CA and WA states these standards are required to be used in association with the project-specific HASP and this supplement.

The scope of this HIPP applies to Arcadis projects which include, but are not limited to: outdoor operations such as contractor oversight, construction, refining, oil and gas extraction, asbestos removal, and hazardous waste site activities and interior work particularly tasks which require employees to wear PPE which can increase the risk for heat stress for the wearer. This HIPP provides guidance to prevent or reduce the risk of work-related heat illness. This HASP Supplement provides site specific instructions for actions to be completed at the project site.

Project sites in other states and provinces are expected to use this HASP Supplement as a Best Management Practice to prevent heat related illness injuries.

Project Site Name BNSF - Time Oil

Authority and Implementation

The following designated individuals have authority and responsibility for implementing the provisions of this program at the project work site indicated above.

Project Manager Kyle Haslam
Site Safety Officer (SSO) Emily Zikmund
SSO Designated Alternate Emily Zikmund

Acclimatization of Personnel for Heat Stress Prevention

The degree to which personnel have been able to physiologically adjust or acclimatize to working under hot conditions affects ability to safely do work. Acclimatized individuals generally have lower heart rates and body temperatures than unacclimated individuals, and sweat sooner and more profusely. This enables them to maintain lower skin and body temperatures at a given level of environmental heat and work loads than unacclimated workers. Acclimatization can occur after a few days of exposure to the hot work environment. OSHA/NIOSH suggests an acclimatization period of 2-3 days for fit personnel. One the 1st day personnel should spend 50% of the day exposed to / working in the hot environment and increasing the amount of work 10-20% based on personnel response to the hot environment and work load.

Procedures for Provisions for Potable Water

The SSO or designee will be responsible for implementing the following when conditions at the site are anticipated to exceed 80 degrees (°) Fahrenheit (F) / 26.6° Celsius (C)

1. Proper hydration is critical to preventing heat related illness and injury. Project sites will maintain an adequate supply of suitably cool, fresh and pure potable water on site/readily accessible to allow each employee to consume 1 quart (1 L) of water per hour, ideally at a rate of four 8-oz (250 mL)

each employee to consume 1 quart (1 L) of water per hour, ideally at a rate of four 8-oz (250 mL) cups per hour.
NOTE: Fresh and pure water is defined as being "odor free and suitably cool". Where suitably cool means water being cooler than the ambient temperature but not so cold as to cause discomfort or prevent drinking.
NOTE: Electrolyte replacement drinks or “Sports Drinks” should be used to replace essential minerals lost during sweating. Sports drinks should supplement water intake e.g. one “sport drink” to every three bottles of water (3 waters : 1 sport drink)

2. During the Tailgate Safety Meeting and site briefings identify and communicate the type and location of the water source. The water source must provide suitably cool, fresh, and pure water in sufficient quantity for all employees at the site. Water shall be provided free of charge or expenses will be reimbursed for employees. If the source is potable plumbed water do not complete Item 6 of this Section.

3. Communicate to staff whether all water for the day will be provided at the start of the shift (e.g., 2 gallons / 8 L per employee for an 8-hour shift), or how and when water will be replenished.

NOTE: A sufficient quantity of water must always be present and readily accessible to allow every employee to consume at least 1 quart (1L) of water per hour. It is suggested to have a minimum of three hours supply of water per employee on hand.

4. Water supplies must be positioned as close as reasonable possible to site workers. Placing water only in shaded areas or by toilet facilities is not sufficient, particularly at large work sites or at multi-story construction sites. Drinking water sources need to be close enough to workers to allow for routine consumption per the rate noted above.

5. Inspect the coolers / water dispensers for cleanliness and replenishment of water and cooling ice routinely based on temperatures and staff size. Cooling ice will be stored in clean coolers if added directly to water dispensers.
NOTE: If the site temperature exceeds 90° F / 32° C the frequency of the cooler inspection will increase to verify water remains cool and the water supply is maintained.

6. Oversee the daily inspection and maintenance of coolers to ensure they are kept clean and in good condition.

Potable Water Source & Location

☐	Potable plumbed source	Location:	
☒	Bottled water in chilled cooler	Location:	Field Vehicle
☐	Drinking water dispenser & cups	Location:	

Procedures for Provisions for Potable Water Continued

Check which applies. Must check at least one box, or provide additional detail.

☒ Ice will be purchased at the start of each day.
☐ Ice will be provided by an onsite source or vendor service. Ice to be potable
☐ Alternative potable ice source:
☐ Food safe cleaning product for water cooler.

☐ Sufficient amount of drinking water cups for each employee per dispenser.
☐ Other items needed: ____________________

Access to Shade

The SSO or designee is responsible for implementing the following for how shade will be coordinated and provided **when temperatures exceed 80° F / 26° C**.

1. Access to shade must be allowed at all times. Before the start of work, the location of the shade areas, the importance of taking shade breaks, recognizing the signs and symptoms of heat illness, the schedule of shade breaks, and the location of shade break locations (if not portable) will be addressed during each Tailgate Safety Meeting and site briefing.

NOTE: Where required by regulation, shade breaks will be taken at a minimum rate of 10 minutes of shade for every two hour work period. As temperature increases shade breaks will increase in frequency. See the Heat Index table below for Heat Index specific Action Levels defining shade break frequency and duration.

2. The amount of shaded area must be able to accommodate all employees taking a recovery or rest break including employees on meal breaks. The shaded area(s) don't need to provide shade to accommodate **all employees** on a site or working a shift at the same time. An example includes rotating routine breaks among employees. Also, additional portable shade structures can be erected on an “as-needed” basis.

Employees must have enough shaded space so they can sit in a normal posture fully in the shade with enough space to allow for sitting without being in physical contact with each other. Employees who desire access to shade must not be deprived of it due to lack of space.

3. Employees who take a preventative cool-down rest;

(1) shall be monitored and asked if they are experiencing symptoms of heat related illness. (2) shall be encouraged to remain in the shade. (3) shall not be ordered back to work until signs or symptoms of heat illness have abated, but in no event less than 5 minutes in addition to the time needed to access the shade.

If an employee exhibits signs or symptoms of heat illness while taking a preventative cool-down rest the SSO will provide appropriate support (e.g. additional hydration and/or call to WorkCare) or emergency response support as needed based on symptoms.

4. Shade structures will be relocated to follow the crew for moving tasks. Shade structures will be placed within 50 feet of the work area, if practical. Shade structures must be no further than a short walk away (e.g. 2-3 minutes) from the work area. This consideration becomes more critical as the temperature rises above 80° F (26 C).

Access to Shade Continued

5. In situations where it is not safe or feasible to provide shade, the SSO will document in the HASP Supplement the unsafe or unfeasible conditions, and include the steps taken to provide alternative cooling measures equivalent to shade.

Unsafe/unfeasible conditions: ____________________

Alternative Cooling Measures Implemented:

- ☒ Provide vehicles with working air conditioner to all employees for rest breaks / recovery breaks / meal breaks.
- ☐ Provide temporary or mobile shade structure(s) that are either ventilated or open to air movement (Secure against wind.)
- ☐ Provide a building / permanent structure(s) in close proximity to the work area with a cooling environment via mechanical ventilation or open to air movement which will be used for shade. (Job trailer, pavilion, manufacturing building, etc.)
- ☐ Other:

Monitoring of Weather and Heat Index Table

1. The SSO or designee must check the extended weather forecast in advance of the upcoming work on a weekly basis. Work schedules will be adjusted in advance, taking into consideration whether high temperatures or a heat wave is expected.
Accepted weather forecasting resources include webpages "NOAA.gov" or "weather.com" or see the NIOSH Heat Tool (formerly the OSHA Heat Tool app)

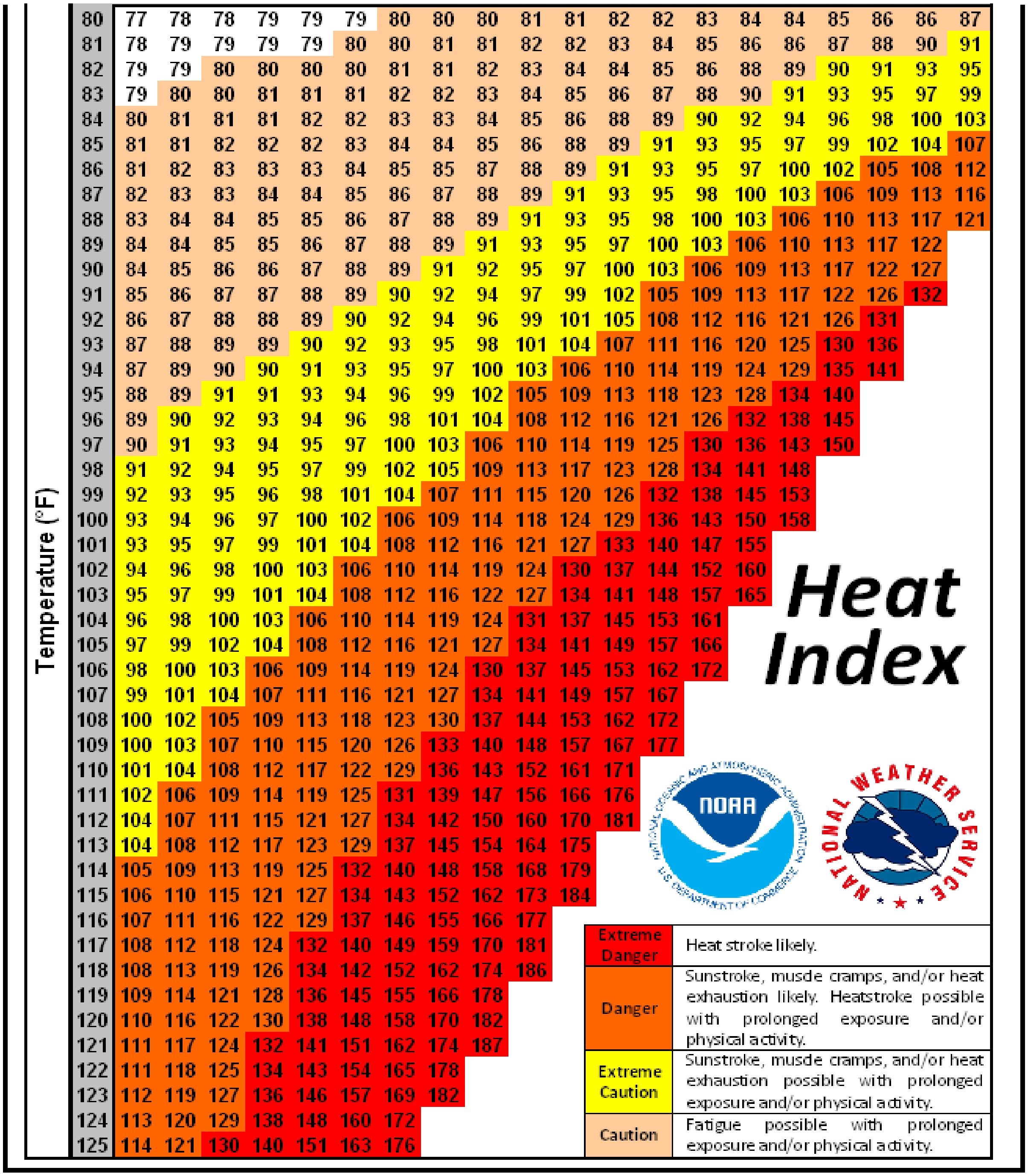
https://www.cdc.gov/niosh/topics/heatstress/heatapp.html

2. Before work starts for the day or shift, the SSO will review the forecasted temperature and humidity for the (exterior) work site and compare conditions against the National Weather Service Heat Index (below) to evaluate the risk level for heat illness. Determination will be made of whether or not workers will be exposed to a combination of temperature and humidity characterized as "Caution", “Extreme Caution”, "Danger" or “Extreme Danger” for heat illnesses.
NOTE: It is important to know the temperature at which these warnings occur. When working outdoors see the Heat Index Table in this supplement for Action Level specific instructions for hazard controls.

3. Where state regulations indicate a thermometer or similar on-site monitoring device will be used at the job site to monitor for sudden increases in temperature. The SSO will be responsible for obtaining a thermometer/weather station prior to the start of work and make it readily visible / accessible where it can easily be monitored throughout the course of the day.
NOTE: If the temperature is **> 80°F (26 C)** shade structures will be opened and made available to workers. If temperature is **≥ 95° F (35 C)** additional preventive measures will be implemented.

Monitoring of Weather and Heat Index Table Continued

	Relative Humidity (%)																			
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100



Temperature (°F)																				
80	77	78	78	79	79	79	80	80	80	81	81	82	82	83	84	84	85	86	86	87
81	78	79	79	79	79	80	80	81	81	82	82	83	84	85	86	86	87	88	90	91
82	79	79	80	80	80	80	81	81	82	83	84	84	85	86	88	89	90	91	93	95
83	79	80	80	81	81	81	82	82	83	84	85	86	87	88	90	91	93	95	97	99
84	80	81	81	81	82	82	83	83	84	85	86	88	89	90	92	94	96	98	100	103
85	81	81	82	82	82	83	84	84	85	86	88	89	91	93	95	97	99	102	104	107
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87	82	83	83	84	84	85	86	87	88	89	91	93	95	98	100	103	106	109	113	116
88	83	84	84	85	85	86	87	88	89	91	93	95	98	100	103	106	110	113	117	121
89	84	84	85	85	86	87	88	89	91	93	95	97	100	103	106	110	113	117	122	
90	84	85	86	86	87	88	89	91	92	95	97	100	103	106	109	113	117	122	127	
91	85	86	87	87	88	89	90	92	94	97	99	102	105	109	113	117	122	126	132	
92	86	87	88	88	89	90	92	94	96	99	101	105	108	112	116	121	126	131		
93	87	88	89	89	90	92	93	95	98	101	104	107	111	116	120	125	130	136		
94	87	89	90	90	91	93	95	97	100	103	106	110	114	119	124	129	135	141		
95	88	89	91	91	93	94	96	99	102	105	109	113	118	123	128	134	140			
96	89	90	92	93	94	96	98	101	104	108	112	116	121	126	132	138	145			
97	90	91	93	94	95	97	100	103	106	110	114	119	125	130	136	143	150			
98	91	92	94	95	97	99	102	105	109	113	117	123	128	134	141	148				
99	92	93	95	96	98	101	104	107	111	115	120	126	132	138	145	153				
100	93	94	96	97	100	102	106	109	114	118	124	129	136	143	150	158				
101	93	95	97	99	101	104	108	112	116	121	127	133	140	147	155					
102	94	96	98	100	103	106	110	114	119	124	130	137	144	152	160					
103	95	97	99	101	104	108	112	116	122	127	134	141	148	157	165					
104	96	98	100	103	106	110	114	119	124	131	137	145	153	161						
105	97	99	102	104	108	112	116	121	127	134	141	149	157	166						
106	98	100	103	106	109	114	119	124	130	137	145	153	162	172						
107	99	101	104	107	111	116	121	127	134	141	149	157	167							
108	100	102	105	109	113	118	123	130	137	144	153	162	172							
109	100	103	107	110	115	120	126	133	140	148	157	167	177							
110	101	104	108	112	117	122	129	136	143	152	161	171								
111	102	106	109	114	119	125	131	139	147	156	166	176								
112	104	107	111	115	121	127	134	142	150	160	170	181								
113	104	108	112	117	123	129	137	145	154	164	175									
114	105	109	113	119	125	132	140	148	158	168	179									
115	106	110	115	121	127	134	143	152	162	173	184									
116	107	111	116	122	129	137	146	155	166	177										
117	108	112	118	124	132	140	149	159	170	181										
118	108	113	119	126	134	142	152	162	174	186										
119	109	114	121	128	136	145	155	166	178											
120	110	116	122	130	138	148	158	170	182											
121	111	117	124	132	141	151	162	174	187											
122	111	118	125	134	143	154	165	178												
123	112	119	127	136	146	157	169	182												
124	113	120	129	138	148	160	172													
125	114	121	130	140	151	163	176													

Extreme Danger	Heat stroke likely.
Danger	Sunstroke, muscle cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	Fatigue possible with prolonged exposure and/or physical activity.

Note: The Heat Index table was developed with an expectation of partial shade & light wind conditions present. Work conducted in direct / full sunlight (e.g. no partial shade) and no wind adds up to 15° F (8° C) to the Heat Index evaluation.

Monitoring of Weather and Heat Index Table Continued

Heat Index Action Levels. Below are recommended additional controls. Each level of additional controls is additive as the temperature increases.

CAUTION 80° - 90° F (26° - 32° C). Implement one or more of the following measures: Provide and direct hydration, schedule breaks, ensure lightweight clothing is worn, provide break areas with shade / ventilation / air conditioning.

EXTREME CAUTION 90° - 105° F (32° - 40.5° C). Implement all the previous and add one or more of the following: Provide light duty PPE, cooled break areas, shaded work areas.
NOTE: “Light Duty PPE” includes hard hat sun shades, sun hats, dry or wet evaporative cooling vests, microfiber cooling towels / scarves / headbands / hard hat suspension inserts or sweatbands, hard hat neck shades.

DANGER 105 ° - 130 ° F (40.5° - 54.4° C). Implement all the previous and add one or more of the following: cooled work areas, modified work schedule, heavy duty PPE, and personnel physiological monitoring.
NOTE: “Heavy Duty PPE” phase-change cooling vests, gel pack or ice pack equipped cooling vests. Consider engineering controls such as forced ventilation.

EXTREME DANGER ≥ 130° F (≥ 54.4° C). If working at this temperature or greater Stop Work until conditions change or hazards are effectively controlled via the items listed above. At this range of temperatures it is critical to implement personnel vital sign monitoring for determining the appropriate frequency and duration of Work / Rest cycles.

Work / Rest Cycle Duration and Frequency Process

All workers, regardless if they are wearing permeable or impermeable clothing, should be monitored when conditions warrant e.g., when temperatures exceed 80°F / 26.6°C. If impermeable clothing is worn (e.g., not standard cotton/synthetic work clothes), it is a best practice to begin monitoring workers when temps are > 70°F in the work area. Prioritize workers completing strenuous tasks. Prioritization should also apply to work conducted indoors, for strenuous tasks, and/or if additional PPE is worn (such as Level C respiratory protection or(CPC). If impermeable clothing, Level C, or CPC is not worn, follow the Heat Index table instructions and evaluate personnel monitoring as part of the high heat measures. Details provided below for appropriate work/rest cycle development with the default rest cycle being a 15-minute interval for every hour when temperatures exceed 90°F.

NOTE: *Warning signs include: When a person’s sustained (e.g., several minutes) heart rate exceeds 180 beats per minute (bpm) minus their age (e.g., 180 - age = X) for individuals with normal cardiac performance per their physician; or a body core temperature exceeds 101.3°F / 38.5°C for acclimatized workers or 100°F / 38°C for unacclimated workers; a recovery heart rate at 1 minute after a peak work effort is greater than 120 bpm; or there are symptoms of sudden and severe fatigue, nausea, dizziness, or lightheadedness.*

Suggested Frequency and Duration of Work / Rest Cycles Applying Physiological Monitoring of Acclimatized Personnel

Adjusted Temp. (1)	Permeable PPE (2)	Impermeable PPE (3)
≥ 90° F / 32° C	After ea. 45 mins. of work	After ea. 15 mins. working
87.5-90° F / 30.8-32.2° C	After ea. 60 mins. of work	After ea. 30 mins. Working
82.5-87.5° F / 28.1-30.8° C	After ea. 90 mins. of work	After ea. 60 mins. Working
77.5-82.5° F / 25.3-28.1° C	After ea.120 mins. of work	After ea. 90 mins. Working
72.5-77.5° F / 22.5-25.3° C	After ea.150 mins. of work	After ea. 120 mins. Working

NOTES:

(1) Adjusted air temp (ta adj) calculation: ta adj F = ta F + (13 x % sunshine). Measure the air temperature (ta) with a thermometer (shielded from radiant heat). Estimate the percent sunshine by judging what percent time the sun is not covered by clouds
that are thick enough to produce a shadow. (100 percent sunshine = no cloud cover and a sharp, distinct shadow; 0 percent sunshine = no shadows.)

(2) Permeable PPE consists of cotton clothing with long sleeves and pants or breathable coveralls.

(3) Add 1.8 °F for Tyvek coveralls; add 5.4 °F for heavy clothing; add 19.8 °F for impermeable/semi-impermeable PPE - Level A/B suits)

Heart Rate Monitoring

When conducting heart rate monitoring, first record a resting heart rate to establish the individuals daily baseline heart rate. Count the radial pulse (located on the inside of the wrist below the thumb) during a 30 second interval before the start of work to establish a baseline heart rate. During rest cycles count the heart rate as early as possible at the beginning of the rest cycle and again 3-5 minutes later. The heart rate should fall and soon approach the individuals baseline heart rate.

- If the heart rate exceeds 110 beats per minute at the beginning of the rest period, shorten the next work cycle by one-third and keep the rest period the same.
- If the heart rate still exceeds 110 beats per minute at the next rest period, shorten the following work cycle by one-third.

Body Temperature Monitoring

Use an oral, inner ear, or an infrared type thermometer to measure the body temperature at the end of the work period (If using an oral thermometer record temperature before drinking liquids).

- If oral temperature exceeds 99.6°F (37.6°C), shorten the next work cycle by one-third without changing the rest period.
- If oral temperature still exceeds 99.6°F (37.6°C) at the beginning of the next rest period, shorten the following work cycle by one-third.
- Do not permit a worker to wear a semi-permeable or impermeable garment when his/her oral temperature exceeds 100.6 °F (38.1 °C).

Procedures for High Heat Conditions and Heat Waves

These procedures are additional preventative measures to be implemented when the temperature is > 95° F (35° C). The SSO or designee is responsible for ensuring effective observation and monitoring of employees during periods of high heat by implementing one or more of the following procedures:

1. SSO or designee will supervise 20 or fewer employees.
2. The “Buddy System” is mandatory. Conduct routine checks for early signs of Heat Illness. Set and verify routine consumption of water & sports drinks in a 3:1 ratio.
3. Maintain regular communication between Project Manager or SSO / designee and field staff (e.g. via mobile phone, radio or another effective means) for observation of early signs of heat illness.
4. Designate one or more employees as authorized to contact emergency medical services and communicating that if no designate is identified and the SSO is unavailable that any employee can call for emergency medical assistance.
5. Modify work schedule to avoid hottest parts of the day (e.g. start work earlier in the AM, stop work for the hottest hours of the day, conduct work during the evening).

Additionally, tailgate Safety Meetings will include a review the high heat procedures, encourage employees to drink plenty of water, and remind employees of the importance to take a preventative or recovery cool-down rest when necessary.

Employees will be observed for alertness and signs and symptoms of heat illness at regular intervals to be documented in the field book or field log.

The “Buddy System” must be implemented. Particular attention needs to be paid to new employees or employees who have yet to acclimate to high heat conditions. Additionally, frequent communication will be maintained with employees working by themselves (via cell phone or two-way radio), to evaluate early warning signs and symptoms of heat illness.

When the SSO is not available, an alternate responsible person must be assigned to look for signs and symptoms of heat illness. Such a designated observer will be trained and know what steps to take if heat illness occurs.

"Heat Wave" Procedures

A “heat wave” as defined by NOAA, is a period of abnormally and uncomfortably hot and unusually humid weather.” Typically, a heat wave lasts 2 or more days. A "Heat Wave" as defined for the purposes of this Standard is when temperatures are sustained above 80° F / 26° C.
During a heat wave or if site conditions indicate the potential for “Extreme Caution”, "Danger" or “Extreme Danger” per the NOAA Heat Index Table the following steps will be taken:

Work schedules will be modified to protect workers from heat illnesses. The SSO or designee in coordination with the project team, will use their Stop Work Authority and evaluate the following actions and document the action in the daily field log

1. Modify work hours to exclude the hottest parts of the day.

2. Reschedule work or specific tasks that require strenuous exertion or Stop Work.

If schedule modifications are not possible, the Heat Illness Prevention Plan will be reviewed before work resumes. At a minimum, procedures for heat illness prevention, the provisions of the high heat procedures, the weather forecast and emergency response protocols will be reviewed.

Employees will be provided with additional water and rest breaks and will be observed more frequently. During work activities and rest breaks, employees will be observed for signs and symptoms of heat illness.

All employees will maintain frequent communication with the SSO or designee, who will be monitoring workers for possible symptoms of heat illness. In the event of large project sites where the SSO may be unable to be near the workers (to directly observe or communicate with them), then communication via a cell phone or radio may be used for this purpose provided reception in the area is reliable.

Procedure for Emergency Response

Emergency procedures include recognizing the symptoms of heat related illness. A critical step also involves ensuring that effective communication is established either through voice, direct observation or electronic means such as via mobile phones or 2-way radios. In an emergency situation it is critical that employees understand the process and contact information for requesting emergency medical support. The reception coverage for the site must be evaluated and understood to ensure adequate communication is in place across the project site. During a heat wave or hot temperatures, workers will be reminded and encouraged to immediately report to the SSO any signs or symptoms of the onset of heat stress they are experiencing.

Procedure for Emergency Response Continued

The SSO or designee is responsible for implementing the following procedures for emergency response. These procedures include, but are not limited to, the following:

1. Prior to assigning staff to a particular work site, during the Tailgate H&S Safety Meeting all site workers will review the HASP along with the identified Hospital precise directions (such as streets or road names, distinguishing features, and distances to major roads), to avoid a delay of emergency medical services.

2. Prior to work, efforts will be made to ensure that a qualified, appropriately trained and equipped personnel are consistently available to render first aid.

3. Prior to the morning Tailgate Safety Meeting, an evaluation of whether or not a language barrier is present at the site for understanding the necessary preventative measures and emergency notifications procedures can be completed. Necessary steps will be taken (such as assigning the responsibility to call emergency medical services to the SSO or an English speaking worker) to ensure that emergency medical services can be immediately called in the event of an emergency.

4. All SSOs and supervisors will carry cell phones or other means of communication to ensure that emergency medical services can be called. Routine checks will be made to ensure the devices are allowed on site, have adequate reception across the site, and are functional prior to each shift.

5. When an employee reports symptoms, or displaying symptoms of possible heat illness, steps will be taken immediately to keep the affected employee cool and comfortable. Evaluate whether 1st aid is to be administered or emergency services are to be contacted or the employee is to be taken to an emergency facility for care.

Procedure for Handling a Sick Employee

Signs of Heat Stress: Excessive fatigue, heavy sweating, headaches, abdominal and/or upper thigh cramps, mild dizziness, elevated pulse.
Signs of Heat Exhaustion: Cool, moist, pale or flushed skin, nausea or vomiting, disorientation or confusion.
Signs of Heat Stroke: Hot, red skin which can feel dry to the touch, or moist from overexertion, changes in consciousness, rapid or weak pulse, shallow rapid breathing.

The SSO or designee is responsible for implementing the following procedures for evaluating and providing care for a sick employee:

1. When an employee displays signs or symptoms consistent with the heat related illness, the SSO or designee will check the sick employee and determine whether resting in the shade and drinking cool water will suffice or if emergency service providers will need to be called.

Procedure for Handling a Sick Employee Continued

If determined to be **a non-emergency** (e.g. heat cramps or heat stress) the SSO will contact **WorkCare Injury Assistance Hotline 1-888-449-7787** for 1st aid medical assistance. In the event of the injury being an emergency, or potentially (e.g. Heat Exhaustion or Heat Stroke) contact emergency support services.

2. When an employee displays possible signs or symptoms of heat illness and no trained first aid worker or supervisor is available at the site, emergency service providers will be called.

3. Emergency service providers will be called immediately if an employee displays signs or symptoms of advanced stage heat related illness like Heat Exhaustion or Heat Stroke (loss of consciousness, incoherent speech, convulsions, red and hot face) or does not get better after drinking cool water in intervals of 8 ounces every 15 minutes and resting in the shade. While the ambulance is in route, assign a person to care for the injured, first aid will be administered (cool the worker by placing them in the shade, remove excess layers of clothing, place ice pack in the armpits and groin area and fan the person). A worker determined to be suffering an advanced stage of heat related illness will not be allowed to leave the site except under medical care, or as directed by a medical professional.

4. If an employee displays signs or symptoms of advanced stage heat related illness (loss of consciousness, incoherent speech, convulsions, red and hot face), and the work site is located more than 20 minutes away from a hospital, call emergency service providers, communicate the signs and symptoms of the victim, and request an Air Ambulance if necessary.

Revisions, notes, amendments, and clarifications specific to this plan will be detailed in the space below:

(For international travel/work, use the Travel Safety and Security Plan template in lieu of this template)

Project Name: BNSF - Time Oil2737 West Commodore WaySeattle, Washington

Project Number: 30102090

Date: 1/27/2023

Revision:

General Information (select all that apply):

☒ Worker will be alone
☐ Buddy system will be used
☐ Area is within cell phone service range
☐ Cell phone service is limited or out of range
☐ Worker will be performing high risk activity (Lone Worker is not permitted)
☐ Work will be performed outside normal operating hours (nights or weekends)
☐ Wilderness work
☐ Site is not accessible to standard emergency services
☐ Other unique site conditions that may hinder employee's ability to get help, if required.
Explain:

Communication Plan

Frequency of Communication: HOURLY

Planned Start Time: Planned End Time: 12:00:00 PM

Contact Information:
Field Worker Name:
Field Worker Phone Number:
Vehicle Make/Model/ Plate:
Office Contact Name:
Office Contact Phone Number:

Method of Communication:

☒ Cell Phone (including text notification)
☐ Landline
☐ 2-way Radio
☐ Satellite Phone
☐ GPS
☐ Transponder
☐ App:
☐ Other:

Contingency Plan (if the Field Worker cannot be reached, describe actions the Office Contact will take)

Notification Log

Time	Field Worker Notification	Office Receipt of Notification
12:00:00 AM		
1:00:00 AM		
2:00:00 AM		
4:00:00 AM		
5:00:00 AM		
6:00:00 AM		
7:00:00 AM		
8:00:00 AM		
9:00:00 AM		
10:00:00 AM		
11:00:00 AM		
12:00:00 PM		

Smoke Respiratory Protection Plan

ARCADIS

Project Name: BNSF - Time Oil2737 West Commodore WaySeattle, Washington
Project Number: 30102090
Date:

Introduction:

This Smoke Respiratory Protection Plan (Plan) has been prepared for use by employees working on projects or project sites in wildfire smoke impacted areas where there is known, forecasted or anticipated smoke concentrations in the breathing zone greater than or equal to a current Air Quality Index (AQI) of 151 for PM2.5 (See definitions below). This plan is designed to meet Cal OSHA regulatory requirements but may be used outside of California as a best practice on project sites with breathing zone smoke issues.

Task Description:

The scope of work includes groundwater and soil sampling, and installation of groundwater monitoring wells.

Definitions:

Current Air Quality Index (AQI). The method used by the U.S. Environmental Protection Agency (U.S. EPA) to report air quality on a real-time basis. Current AQI is also referred to as the "NowCast," and represents data collected over time periods of varying length in order to reflect present conditions as accurately as possible. The AQI data can be used to assess conditions at the work site if site specific data is unavailable.

PM2.5. Solid particles and liquid droplets suspended in air, known as particulate matter, with an aerodynamic diameter of 2.5 micrometers or smaller

Filtering facepiece respirator (FFR). An FFR is an N95 or similar type respirator AKA as "dust ask". Unlike FFRs, reusable respirators described as "tight-fitting facepieces" or "elastomeric respirators" even when used in a "voluntary use" capacity still have requirements which at a minuimum includes a medical evaluation.

The current AQI is divided into six categories as shown in the table below, adapted from Table 2 of Title 40 Code of Federal Regulations, Part 58, Appendix G.

Air Quality Index (AQI) Categories for PM2.5	PM2.5 in Microgram per Cubic Meter (µg/m3)	Levels of Health Concern
0 to 50	0 to 12	Good
51 to 100	12.1 to 35.4	Moderate
101 to 150	35.5 to 55.4	Unhealthy for Sensitive Groups
151 to 200	55.5 to 150.4	Unhealthy
201 to 300	150.5 to 250.4	Very Unhealthy
301 to 500	**250.4 to 500.4**	**Hazardous**

If Site Specific Air Monitoring Equipment is Used:

☒ Project team will rely on AQI data from AirNow.gov instead of using air monitoring devices.

When using a direct-reading particulate monitor to determine PM2.5 levels described above:
(1) Must not underestimate employee exposures to wildfire smoke; or
(2) May underestimate wildfire smoke exposures, but the project team has obtained information on the possible error of the monitor from the manufacturer or other published literature and has accounted for the error of the monitor when determining exposures to PM2.5 to ensure that employee exposure levels are not underestimated.

The monitor selected shall be designed and manufactured to measure the concentration of airborne particle sizes ranging from an aerodynamic diameter of 0.1 micrometers up to and including 2.5 micrometers. If the monitor measures a particle size range beyond these limits, the project team must treat the results as the PM2.5 levels.

The project team shall ensure that the monitor used is calibrated, maintained, and used, including the use of necessary accessories, in accordance with the manufacturer's instructions for accurately measuring PM2.5 concentrations.

Smoke Inhalation Hazard Controls:
Consistent with Arcadis policy, engineering controls will first be considered and implemented to the extent practical to control PM2.5 levels of smoke in the atmosphere. These controls include, but are not limited to performing work such as preparing paperwork, calibrating instruments, preparing equipment, etc. inside buildings or vehicles with filtered air ventilation systems to the extent possible.

If engineering controls fail to mitigate smoke to less than current AQI 151 for PM2.5 levels in the breathing zone, administrative controls will be considered. These controls may include, but are not limited to, adjusting work schedules for affected employees, use of job rotation, implementing work/rest periods, etc. to mitigate the exposure.

If engineering and administrative controls fail to mitigate a current AQI151 for PM2.5 exposure, personal protective equipment in the form of respiratory protection will be provided as follows:

a) Where the current AQI for PM2.5 is equal to or greater than 151, but does not exceed 500, respirators will be provided to all employees for voluntary use and employees are encouraged to use the respirators provided. Respirators selected shall be NIOSH-approved and effectively protect the wearers from inhalation of PM2.5, such as N95 filtering facepiece respirators. Respirators shall be cleaned, stored, maintained, and replaced so that they do not present a health hazard to users. Additionally:

1) The project team shall provide each respirator wearer a copy of Attachment A to this Plan as training in the proper voluntary use of respirators on the project.
2) Since the filtering facepiece respirator use is voluntary, regulatory and Arcadis requirements regarding fit testing and medical evaluations are not mandatory.

b) Where the current AQI for PM2.5 exceeds 500, respirator use is required in accordance with all requirements in the Arcadis Respiratory Protection Health and Safety Standard. The assigned protection factor for the respirator used will ensure the PM2.5 levels inside the respirator correspond to an AQI less than 151. If wildfire smoke is the only respiratory hazard of concern on the project,

Site Specific Controls:
Arcadis will monitor AQI and if the AQI gets above safe work levels will call a stop work and monitor the situation until it is safe to begin working again.

Respirator Change Out:
In most situations, the NIOSH approved N-95 respirator to be issued for voluntary use will be in the form of a "dust mask". When used in voluntary situations, the dust mask will be replaced:

a) At the end of each work shift; or
b) When visibly soiled or discolored from smoke, dirt or debris; or
c) When breathing becomes difficult or labored while wearing the dust mask.

Voluntary use of other types of respirators meeting NIOSH N-95 protection, such as tight-fitting half-facepiece or full facepiece air purifying respirators equipped with particulate cartridges, the cartridges will be changed out using the same criteria above for dust masks or will be changed out in accordance with manufacturer's end of service life (ESLI) recommendations.

Respirator Decontamination and Disinfection:

Disposable dust masks will not be decontaminated or disinfected and will be disposed after use. For other types of respirators, the following cleaning and disinfecting procedure will be used:

1) Remove cartridges/canisters/filters. Disassemble facepiece by removing speaking diaphragm, demand and pressure-demand valve assemblies, hoses, or any components recommended by the manufacturer.
2) Wash components with warm (<110° F) water with a mild detergent or with a cleaner approved by the manufacturer. A soft, non-wire bristle brush may be used to facilitate dirt removal.
3) Rinse with warm (<110° F) clean water, preferably running water.
4) If the cleaner used does not contain a disinfecting agent, respirator components should be immersed in one of the following for two minutes:

a) Hypochlorite solution (50 ppm chlorine) made by adding approximately 1 milliliter of laundry bleach to 1 liter of water at 110° F; or
b) Aqueous solution of iodine (50 ppm iodine) made by adding approximately 0.8 milliliters of tincture of iodine [6-8 grams ammonium and/or potassium iodide/100 cubic centimeters (cc) of 45 percent alcohol] to one liter of water at 110° F; or
c) Other commercially available cleansers of equivalent disinfectant quality, when used as directed by the manufacturer, and are approved for use by the respirator manufacturer.

5) Thoroughly rinse the respirator components in clean, warm, (<110° F) running water.
6) Components should be hand dried with a soft lint free cloth or allowed to air dry.
7) Reassemble the facepiece and restore cartridges/canisters/filters as necessary.
8) Test the respirator for proper working condition.

Communications:

The Site Safety Officer will update employees on current AQI for PM2.5 verbally during safety briefings and throughout the day by:

☐ Two-way radio communications
☒ Cell or satellite phone via voice or text
☐ Other method: ______________________

Utilization of WorkCare for Smoke Inhalation Questions or Concerns:

Employees experiencing diffculty breathing due to wildfire smoke exposure (regardless of the AQI) or through voluntary use of a respirator are expected, as a matter of Arcadis policy, to contact WorkCare (1-888-449-7787) for medical evaluation and guidance.

Signatures:

Prepared by: Dawn Moncio Date: 1/0/1900

Reviewed by: Nicholas Monico Date: 1/0/1900

Attachment A

Protection from Wildfire Smoke Information to Be Provided to Employees (California Mandatory per Appendix B to Title 8 Section 5141.1. All Other States Distribution Recommended)

(a) The health effects of wildfire smoke.

Although there are many hazardous chemicals in wildfire smoke, the main harmful pollutant for people who are not very close to the fire is "particulate matter," the tiny particles suspended in the air. Particulate matter can irritate the lungs and cause persistent coughing, phlegm, wheezing, or difficulty breathing. Particulate matter can also cause more serious problems, such as reduced lung function, bronchitis, worsening of asthma, heart failure, and early death. People over 65 and people who already have heart and lung problems are the most likely to suffer from serious health effects. The smallest-and usually the most harmful-particulate matter is called PM2.5 because it has a diameter of 2.5 micrometers or smaller.

(b) The right to obtain medical treatment without fear of reprisal.

Employers shall allow employees who show signs of injury or illness due to wildfire smoke exposure to seek medical treatment, and may not punish affected employees for seeking such treatment. Employers shall also have effective provisions made in advance for prompt medical treatment of employees in the event of serious injury or illness caused by wildfire smoke exposure.

(c) How employees can obtain the current Air Quality Index (AQI) for PM2.5.

Various government agencies monitor the air at locations throughout California and report the current AQI for those places. The AQI is a measurement of how polluted the air is. An AQI over 100 is unhealthy for sensitive people and an AQI over 150 is unhealthy for everyone. Although there are AQIs for several pollutants, Title 8, section 5141.1 about wildfire smoke only uses the AQI for PM2.5.

The easiest way to find the current and forecasted AQI for PM2.5 is to go to www.AirNow.gov and enter the zip code of the location where you will be working. The current AQI is also available from the U.S. Forest Service at https://tools.airfire.orgl or a local air district, which can be located at www:arb.ca.gov/capcoa/dismap.htm. Employees who do not have access to the internet can contact their employer for the current AQL. The EPA website www.enviroflash.info can transmit daily and forecasted AQIs by text or email for particular cities or zip codes.

(d) The requirements in Title 8, section 5141.1 about wildfire smoke.

If employees may be exposed to wildfire smoke, then the employer is required to find out the current AQI applicable to the worksite. If the current AQI for PM2.5 is 151 or more, the employer is required to:

(1) Check the current AQI before and periodically during each shift.
(2) Provide training to employees.
(3) Lower employee exposures.
(4) Provide respirators and encourage their use.

(e) The employer's two-way communication system.

Employers shall alert employees when the air quality is harmful and what protective measures are available to employees. Employers shall encourage employees to inform their employers if they notice the air quality is getting worse, or if they are suffering from any symptoms due to the air

The employer communication system is:

The Site Safety Officer will update employees on current AQI for PM2.5 verbally during safety briefings and throughout the day by:

☐ Two-way radio communications
☒ Cell or satellite phone via voice or text
☐ Other methoc NA

f) The employer's methods to protect employees from wildfire smoke.

Employers shall take action to protect employees from PM2.5 when the current AQI for PM2.5 is 151 or greater. Examples of protective methods include:

(1) Locating work in enclosed structures or vehicles where the air is filtered.
(2) Changing procedures such as moving workers to a place with a lower current AQI for PM2.5.
(3) Reducing work time in areas with unfiltered air.
(4) Increasing rest time and frequency, and providing a rest area with filtered air.
(5) Reducing the physical intensity of the work to help lower the breathing and heart rates.

The employer's control system at this worksite is:
Arcadis will monitor AQI and if the AQI gets above safe work levels will call a stop work and monitor the situation until it is safe to begin working again.

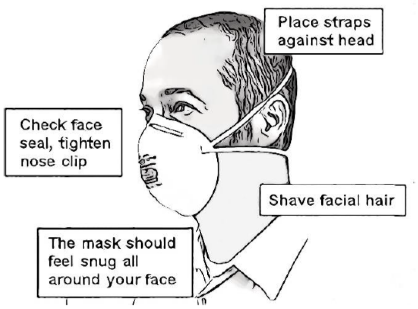
(g) The importance, limitations, and benefits of using a respirator when exposed to wildfire smoke.

Respirators can be an effective way to protect employee health by reducing exposure to wildfire smoke, when they are properly selected and worn. Respirator use can be beneficial even when the AQI for PM2.5 is less than 151, to provide additional protection.□
When the current AQI for PM2.5 is151 or greater, employers shall provide their workers with proper respirators for voluntary use. If the current AQI is greater than 500, respirator use is required in accoradance with all applicable regulatory and Arcadis Respiratory Protection Program requirements.

A respirator should be used properly and kept clean. The following precautions shall be taken:
(1) Employers shall select respirators certified for protection against the specific air contaminants at the workplace. NIOSH, the National Institute for Occupational Safety and Health of the U.S. Center for Disease Control and Prevention, certifies respirators. A label or statement of certification should appear on the respirator or respirator packaging. It will list what the respirator is designed for (particulates, for example). Surgical masks or items worn over the nose and mouth such as scarves, T-shirts, and · bandannas will not provide protection against wildfire smoke. An N95 filtering facepiece respirator, shown in the image below, is the minimum level of protection for wildfire smoke.
(2) Read and follow the manufacturer's instructions on the respirator's use, maintenance, cleaning and care, along with any warnings regarding the respirator's limitations. The manufacturer's instructions for medical evaluations, fit testing, and shaving should also be followed, although doing so is not required by Title 8, section 5141.1 for voluntary use of filtering facepiece respirators.
(3) Do not wear respirators in areas where the air contains contaminants for which the respirator is not designed. A respirator designed to filter particles will not protect employees against gases or vapors, and it will not supply oxygen.

(4) Employees should keep track of their respirator so that they do not mistakenly use someone else's respirator.
(5) Employees who have a heart or lung problem should ask their doctor before using a respirator.

(h) How to properly put on, use, and maintain the respirators provided by the employer.
To get the most protection from a respirator, there must be a tight seal around the face. A respirator will provide much less protection if facial hair interferes with the seal. Loose-fitting powered air purifying respirators may be worn by people with facial hair since they do not have seals that are affected by facial hair.
The proper way to put on a respirator depends on the type and model of the respirator. For those who use an N95 or other filtering facepiece respirator mask that is made of filter material:
(1) Place the mask over the nose and under the chin, with one strap placed below the ears and one strap above.
(2) Pinch the metal part (if there is one) of the respirator over the top of the nose so it fits securely.



Drawing Showing Proper Fitting of a Filtering Facepiece Respirator
(shaving is not required for voluntary respirator use)

For a respirator that relies on a tight seal to the face, check how well it seals to the face by following the manufacturer's instructions for user seal checks. Adjust the respirator if air leaks between the seal and the face. The more air leaks under the seal, the less protection the user receives.

Respirator filters should be replaced if they get damaged, deformed, dirty, or difficult to breathe through. Filtering facepiece respirators are disposable respirators that cannot be cleaned or disinfected. A best practice is to replace filtering facepiece respirators at the beginning of each shift.
If you have symptoms such as difficulty breathing, dizziness, or nausea, go to an area with cleaner air, take off the respirator, and get medical help.

NOTE: Authority cited: Section 142.3, Labor Code. Reference: Sections 142.3 and 144.6, Labor Code.

Attachment C

Field Checklists and Forms

Arcadis Weekly Vehicle Inspection Form

ARCADIS

Vehicle # / License Plate #

Lease Plan # / Last 6 of Vin #

	Inspection Date												
	Odometer reading												
	Driver / Inspector Name												
	Check the appropriate box and enter repair date for identified repairs:	OK	Needs Repair	Repair Date	OK	Needs Repair	Repair Date	OK	Needs Repair	Repair Date	OK	Needs Repair	Repair Date
Interior	Horn operational												
	Door Locks operational												
	Seat Belts in good repair												
	Seats and Seating Controls												
	Steering Wheel - No Excessive Play												
	Interior Lights and Light Controls												
	Instrument Panel/Gauges												
	Wiper Controls operational												
	Heat/Defrost/Air Conditioning working												
	Rear View Mirror present												
	Backup Camera/Sensors working												
	Jack and Lug Wrench present												
Exterior[1]	Lights and Signals operational												
	ires properly inflated/good tread depth												
	Spare Tire properly inflated												
	Doors operational												
	Windows Not Cracked/Damaged												
	Side View Mirrors												
	Body Panels and Bumpers												
Engine & Brakes	Engine Start & Running Smoothly												
	Fluid Levels, No Noticeable Leaks												
	Belts tight, no cracks												
	Brakes operational, no squeaking												
Emergency Equipment[2]	First Aid Kit, inspected weekly												
	Fire Extinguisher properly secured												
	Fire Extinguisher inspected weekly												
	range/Yellow emergency warning light												
	Roadside Assistance Information												
	Recommend spotter cones available												
Cargo	Cargo Secure and Properly Distributed												
	Securing Devices in Good Condition												
Registration	License Plate /Tags												
	Registration and Insurance												
	City/State Inspection Decal												
	Lease Plan information/Fuel Card												

[1] **Note all damages to the vehicle on the back of this page**

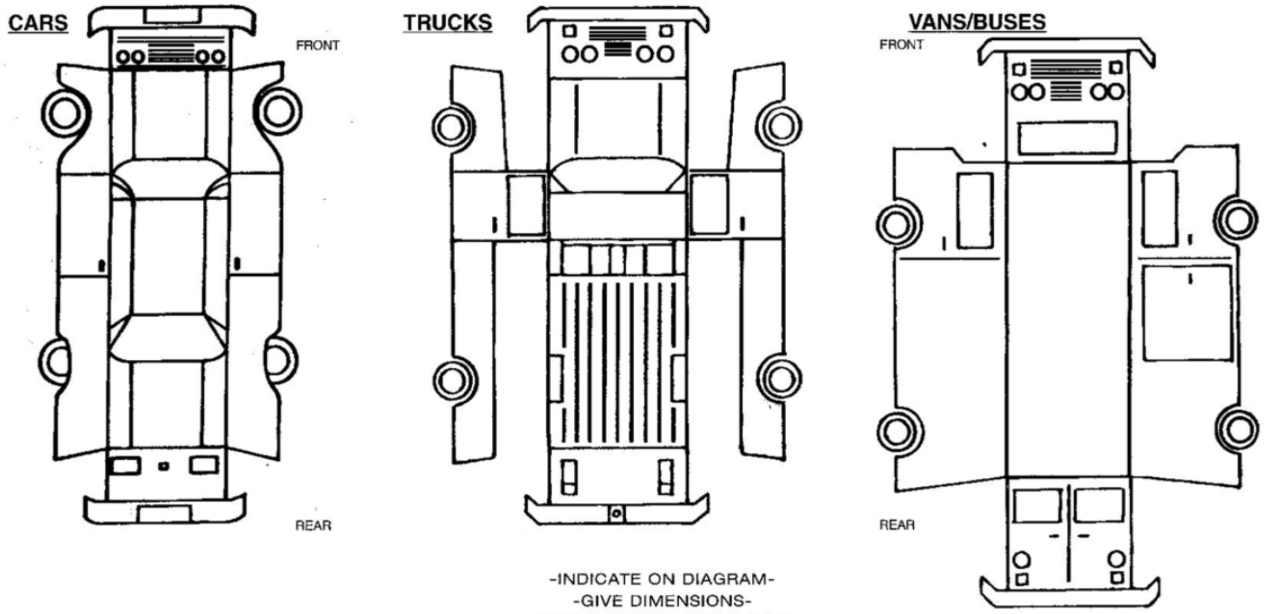
[2] **Emergency Equipment required per Motor Vehicle Standard ARC HSGE024**

Note All Vehicle Damage Below

All Vehicle Damage must be reported to Sue Berndt (Corporate Legal), Andrew McDonald (Corporate H&S), and Roger Elliot (Corporate Fleet Manger)

CODES:

B-BENT
BR-BROKEN
BU-BULGE
C-CHAFED
CH-CHIPPED
CPM-COVERED WITH PROTECTIVE MATERIAL-UNABLE TO DETERMINE DEFECTS IF ANY
CSA-CHAFED AND SCRATCHED ALL OVER
CR-CRACKED
D-DENTED
DMC-DUST AND MUD COVERED UNABLE TO DETERMINE OTHER DEFECTS IF ANY
G-GOUGED OR CUT
GC-GLASS CRACKED
HS-HAIRLINE SCRATCH
M-MISSING
P-PUNCTURED
R-RUSTY
S-SCRATCHED
SC-SCRAPED
SM-SMASHED
ST-STAINED AND/OR SOILED
T-TORN



-INDICATE ON DIAGRAM-
-GIVE DIMENSIONS-
-CIRCLE WHERE APPLICABLE-

Notes:

Tread guide: If a tread gauge is not available coins may be used to determine remaining tread. 2/32” is the minimum by law in most states (top of Lincoln’s head on penny), 4/32” is minimum recommended for wet surfaces (top of Washington’s head on quarter), 6/32” is minimum recommended for snowy surfaces (top of Lincoln Memorial on penny).Vehicle tires should be replaced if the tread depth is less than 6/32”.

2/32” remaining 4/32” remaining 6/32” remaining

Reference JSA 10907 For Weekly Vehicle Inspection

Control Number: TSM- 30102090

TSM + project number plus date as follows: xxxxxxxx.xxxx.xxxxx - dd/mm/year

ARCADIS

TAILGATE HEALTH & SAFETY MEETING FORM

Project Name:			**Project Location:**
Date:	**Time:**	**Conducted by:**	**Signature/Title:**

Issues or concerns from previous day's activities:

Task anticipated to be performed today:

☐ Additional permits/checklists attached

USE TRACK! Evaluate the hazards (h) for the tasks being performed today and rank as Low (L), Medium (M) or High (H). Use relevant JSAs, FHSHB, permit or other work standard to communicate controls (c) to be used to eliminate or mitigate identified hazards.

☐ Gravity (i.e., ladder, trips) (L M H) h: c:	☐ Motion (i.e., traffic, machinery) (L M H) h: c:	☐ Mechanical (i.e., augers, motors) (L M H) h: c:
☐ Electrical (i.e., utilities) (L M H) h: c:	☐ Pressure (i.e., gas cyl., wells) (L M H) h: c:	☐ Environment (i.e., heat, cold) (L M H) h: c:
☐ Chemical (i.e., fuel, acid, paint) (L M H) h: c:	☐ Biological (i.e., ticks, poison ivy) (L M H) h: c:	☐ Radiation (i.e., alpha, sun, laser) (L M H) h: c:
☐ Sound (i.e., machinery) (L M H) h: c:	☐ Personal (i.e. alone, night) (L M H) h: c:	☐ Driving (i.e. car, ATV, boat) (L M H) h: c:

☐ Refer to the attached Hazard Analysis Sheet(s) or JSA

Comments:

Signature and Certification: I have read and understand the project specific HASP for this project.

Non-Life Threatening Injury or Illness
Call WorkCare 1-888-449-7787

SSE Employee*	Printed Name/Signature/Company	Sign In Time	Sign Out Time

***Short Service Employee (SSE) working for Arcadis <1 year.**

I will STOP the job any time anyone is concerned or uncertain about health & safety or if anyone identifies a hazard or additional mitigation not recorded in the site, project, job or task hazard assessment.

I will be alert to any changes in personnel, conditions at the work site or hazards not covered by the original hazard assessments.

If it is necessary to **STOP THE JOB,** I will perform **TRACK**; and then amend the hazard assessments or the HASP as needed.

I will not assist a subcontractor or other party with their work unless it is absolutely necessary and then only after I have done TRACK and I have thoroughly controlled the hazard.

All site staff should arrive fit for work. If not, they should report to the supervisor any restrictions or concerns.

In the event of an injury, employees will call **WorkCare at 1.888.449-7787** and then notify the field supervisor.

Utility strike, motor vehicle accident or 3rd party property damage - field supervisor will immediately notify the Project or Task Manager

THIS FORM MUST BE ENTIRELY COMPLETED PRIOR TO BEGINNING ANY INTRUSIVE WORK

Project Name: BNSF - Time Oil2737 West Commodore Start Date: ____________

Project #: 30102090 End Date: ____________

Utility markings valid for 15 days. Initiate clearance renewal 5 days prior to expiration for ongoing work

PRE-FIELD WORK REQUIREMENTS

DigSafe 811 notified 48-72 hrs. in advance of work? ☐ DigSafe Ticket #: ____________

Ticket Expiration Date: ____________ State Utility Laws: www.commongroundalliance.com/map

Ticket(s) Attached(Y/N)? ☐ List utility owners notified via DigSafe 811 & response status:

List addt'l. utilities requiring notification not included in DigSafe811 Notice:

Review task details w/ private utility location subcontractor. ID work areas, clearance equipment needed, depth of clearance needed, types of features, utilities, anticipated/known/unknown. Verify DigSafe 811 markings to confirm public utility clearance.

Private Utility Locator Name, if used: AUS onsite meeting (Y/N)? ☐

FIELD WORK REQUIREMENTS

This portion of the checklist must be completed on site. AUS staff must have a minimum of one year of field experience in identifying utilities to complete the checklist. Field staff will review the completed checklist with PM or designee prior to beginning intrusive work.

Heavy equipment/mechanized intrusive work w/in the Arcadis Tolerance Zone (utility or structure present within 30-in. of point of work) REQUIRES pre-approval by Corporate H&S prior to working at all such locations. STOP WORK if the Arcadis Tolerance Zone work has not been approved.

List work type & locations for utility location and clearance as applicable to this checklist:

3 Reliable Lines of Evidence are REQUIRED for EACH INTRUSIVE LOCATION prior to starting any subsurface intrusive work. Check corresponding boxes below to document utility clearance efforts.

☐ OneCall/DigSafe 811 Public Utility Locate (required by State law for subsurface work)

811 is only reliable as a Line of Evidence when working in/adjacent to a public ROW or easement.

Marking type: ☐ Paint ☐ Pin Flags/Stakes ☐ Other: ____________ ☐ None

☐ Client provided maps/drawings (Y/N)? ☐ Maps/drawings not provided (Y/N)?

☐ Client Clearance (Y/N)? Name(s)/Affiliation(s): ____________

☐ Interviews (Y/N)? Name(s)/Affiliation(s): ____________

☐ Specific subsurface feature types and depths provided by person interviewed (Y/N)?

Details provided: ____________

☐ Site Inspected (Y/N)? (document on Pg. 2.) Photo Document Marked Utilities & Structures

☐ Public records/Client Dwgs/As-Builts (Y/N)? Type:

List private locator tools used: ☐ Radio Freq. Detection ☐ Electromagnetic ☐ GPR

☐ Metal Detector ☐ Acoustic Pipe Locator ☐ Downhole sonde Other:

☐ Soft Dig Methods used (Y/N)? ☐ Hand auger ☐ Probing ☐ Hand tools (shovel/rake)

☐ Air knife ☐ Hydro Knife ☐ Potholing/Vacuum extraction

☐ Other soft dig tools used (Y/N)? If Yes, list here:

ALL BOXES BELOW MUST BE COMPLETED BEFORE PROCEEDING

Site inspection also requires investigating vicinity outside of the work area for structures and utilities. Noting "YES" requires addt'l. investigation. Utilities must be field marked prior to intrusive work.

Is the utility present (Y/N)?		Utility Color Code
☐	Utilities entering/exiting structures?	**No Color**
☐	Intrusive work area marked out?	**White**
☐	Structural features above or below?	**White**
☐	Public natural gas line or meter?	**Yellow**
☐	Private natural gas laterals/feeders?	**Yellow**
☐	Public electrical service?	**Red**
☐	Conduit from meter or on wall?	**Red**
☐	Conduit from poles into ground?	**Red**
☐	Poles/devices w/ no visible lines?	**Red**
☐	Overhead electrical lines?	**Red**
☐	Solar arrays or wind turbines?	**Red**
☐	Public water line(s)?	**Blue**
☐	Private water line(s) or lateral(s)?	**Blue**
☐	Water meter onsite?	**Blue**
☐	Fire hydrants/post indicator valves?	**Blue**
☐	Irrigation system control box/valve?	**Blue**
☐	Sprinkler heads, drip lines, vaults?	**Blue**
☐	Water dispensers, fill stations?	**Blue**
☐	Telecomm. overhead or buried?	**Orange**
☐	Telecomm. ground box or relays?	**Orange**
☐	Telecomm./security CCTV devices?	**Orange**
☐	Public sanitary sewer pipes?	**Green**
☐	Combined sanitary/storm pipes?	**Green**
☐	Private sanitary laterals/clean outs?	**Green**
☐	Restrooms, kitchens, wash bays?	**Green**

Is the utility present (Y/N)?		Utility Color Code
☐	Evidence of stormwater network?	**Green**
☐	Curb drains/catch basins/manholes?	**Green**
☐	Stormwater culverts, outfalls?	**Green**

ABOVEGROUND Features Present?

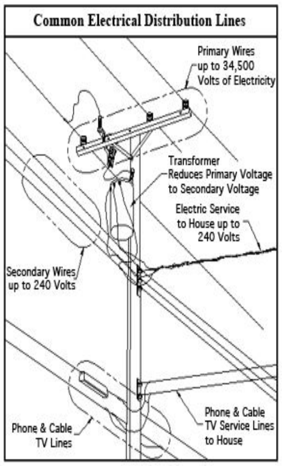
☐	Transportation tunnels/structures/markers present?	
☐	Overhead electrical lines?	**Red**
☐	< 50 kV w/in 10 ft of work area?	**Red**
☐	>50-200 kV w/in 15 ft of work area?	**Red**
☐	>200-350 kV w/in 20 ft of work area?	**Red**
☐	>350-500 kV w/in 25 ft of work area?	**Red**
☐	>500-750 kV w/in 35 ft of work area?	**Red**
☐	>750-1000 kV w/in 45 ft of work area?	**Red**
☐	Aboveground fire suppression?	**Blue**
☐	Aboveground communications?	**Orange**
☐	Aboveground chases/racks/trays?	**Orange**
☐	Private/Remediation system lines?	**Various**
☐	Unclassed utilities/anomalies?	**Pink**
☐	Warning signs/stakes/markers present?	
☐	Heavy Equipment: Mark travel route for overhead, next to route, and/or under route (e.g. crush risk) utilities.	

Signs of other utilities/ground disturbance

☐	Signs of asphalt or concrete disturbance/repair?	
☐	Any ground subsidence or change in vegetation?	
☐	Unknown manholes or valve covers in work area?	

Tips for Thorough Utility Location (HSS Section 5.6):

1. Don't forget to look up for utilities
2. Be on-site with Private Utility Locators.
3. Ask Private Locators to "confirm" other's markings.
4. Also clear alternate/backup locations
5. Mark all known utilities.
6. No hammering, no pickaxes, no digging bars, no shortcutting.
7. No excessive turning or downward force of hand tools, especially hand augers.
8. Utilities may run in or directly under asphalt/concrete
9. Heavy equipment may damage shallow utilities. Especially during clearing and grubbing.
10. Use spotter for heavy equipment near aboveground utilities?



☐ Utilities & Structures Checklist reviewed by the PM or Designee (Y/N)? *If no, STOP WORK call PM*

PM or Designee Name: ____

Name and Signature of person completing the checklist ______________________________

Date of checklist review / update: ______________________________

ALL SUSPECT UTILITY STRIKES REQUIRE CORPORATE H&S NOTIFICATION WITHIN 24 hrs. OF KNOWLEDGE OF STRIKE WITH A CONFIRMED RESPONSE FROM CORPORATE H&S.

PID Calibration Log

ARCADIS

Zero Gas Source: ____________________ Instrument Type: ____________________ PAGE ____ of ____
Lot Number/Expiration Date: ____________________ Serial Number: ____________________
Calibration Gas Source: ____________________ Instrument Type: ____________________
Lot Number/Expiration Date: ____________________ Serial Number: ____________________
Concentration: ____________________ ____________________

Instrument Number	Date	Time	Zero Cal. OK (Y/N)	Calibration Gas Reading	Comments	Calibration w/in 2% (Y/N)?	Alarms Set (Yes/No)?	User Initials

Air Monitoring Documentation Form

ARCADIS

PID Model: ____________________ Monitor Frequency: ____________________

LEL/O_2 Model: ____________________

CIT Model: ____________________

Dust Mon. Model: ____________________

Air Monitoring Results

Date	Time	PID (units)	O_2 (%)	LEL (% LEL)	CIT (ppm)	Dusts (mg/m^3)	Location

CIT = Colorimetric Indicator Tube

LEL = Lower Explosive Limit

mg/m3 = Milligram per cubic meter

O2 = Oxygen

ppm = Part per million

% = Percent

PID = Photoionization Detector

Task Improvement Process

General

Observed Company:

Observation Type:

TIP Form: H&S Field Multi-Task (General)

Task Observed:

Observee Name:

Observer Name:

Observation Date:

Project Number: 30102090

Project Name: BNSF - Time Oil2737 West Commodore WaySeattle, Washington

Supervisor:

Equipment On Site:

Pertinent Information:

Observation

Task	Correct	Questionable	Comments
General			
PPE worn according to HASP/JLA specifications and inspected before use?			
STOP work authority used where appropriate?			
Body Use/Positioning			
Proper lifting/pushing/pulling techniques used (no awkward positions/posture; no twisting or excessive reaching; no straining; no excessive weight; load under control/stable; etc.)?			
Body parts away from pinch points (clear or protected from being caught between objects/equipment or from contacting sharp objects/edges, etc.)?			
Body parts not in the Line of Fire (protected from being struck by traffic, equipment, falling/flying objects, etc.)?			
Work Procedures/Environment			
Correct type and number of barricades/warning devices/cones?			

Communication with others when necessary (hand signals, flags, etc.)?			
Right tools and equipment selected for the job and inspected before use?			
Tools and equipment used properly?			
Housekeeping performed (work areas and pathways clear of hazards, uneven surfaces addressed, etc.)?			
Slip/trip/fall hazards addressed (path selected and cleared, eyes on path, speed footing, etc.)?			
Proper energy control (electrical systems grounded, lock out/tag out performed, isolated, cords/fixtures in good condition, GFCI inspected and utilized when appropriate and used properly, etc.)?			
Protected from overhead/underground utilities (proper clearance, properly marked, spotters as necessary, etc.)?			
Safe work on/near water (appropriate flotation device, appropriate boat for body of water and operation of boat, etc.)?			
Chemical/Radiation protection (decontamination zones set up properly, air monitoring, completed, and logged, etc.)?			
Fall from elevated height prevention (maintains 3-points of contact, appropriate ladder, mounting/dismounting vehicle/equipment, fall arrest system, etc.)?			
Any additional safety issues identified:			

Tip Summary **Enter details of the TIP and follow up discussion provide details on how any questionable items were resolved.**

Discussion following the TIP led by: ______________________________

Date of follow-up discussion: ______________________________

Positive Comments:

Discussion Summary Completed:

☐ Supervisor Led
☐ Peer to Peer
☐ Arcadis Employee to Subcontractor

Summary of Questionable Items

Action Items (Optional)

Assign appropriate action items based on the observations made. You can add more than one action item if needed.

Item #	Action Item	Responsible Person	Due Date	Comp. Date
1				
2				
3				

Standard Review

Reviews to be performed after entry of this TIP into 4-Sight.

Quality Review

Quality Reviews to be performed after entry of this TIP into 4-Sight.

Field Validation and Verification

Use the 4-Sight generated copy of this TIP to perform field V&V activities.

Arcadis Visitor Acknowledgement and Acceptance of HASP Signature Form

By signing below, I waive, release, and discharge the owner of the site and Arcadis and their employees from any future claims for bodily and personal injuries which may result from my presence at, entering, or leaving the site and in any way arising from or related to any and all known and unknown conditions on the site.

Printed Name	Signature	Company	Date/Time On Site	Date/Time Off Site

Attachment D

JSAs

Job Safety Analysis

ARCADIS

JSA Description: Air Knife Hand Clearing	**Date of JSA Development: 1/30/2023**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)

Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	Vacuum Truck / Air compressor

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
☑ Long pants
☑ Long-sleeved shirts
☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
☑ Hard hat that complies with ANSI Z89.1

TASK SPECIFIC: Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

☒ Impact Goggles
☐ Flexible goggles
☐ Welding goggles/helmet or face shield. Tinted lenses required
☐ Laser safety glasses

Head Protection

☐ Type E Hardhat (Electrical)
☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

☒ Photoionization Detector (PID)
☐ Flame Ionization Detector (FID)
☐ Dust Monitor
☐ LEL / O_2 Meter
☐ H_2S Meter

Hearing Protection

☒ Ear Plugs (noise 80 db)
☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

☐ Chemical resistant clothing recommended on SDS
☐ Chain saw chaps
☐ Snake chaps or boots marketed as "snake proof"[3]
☐ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
☐ ANSI/ISEA 107-2010 Class 2 or 3 ***BREAKAWAY*** vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
☐ Sunscreen lotion >= SPF30
☐ Flying insect control: DEET (primary), permethrin (secondary)
☐ Tick control: Permethrin (primary), DEET (secondary)
☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

☐ Chemical protective goggles that comply with ANSI Z87.1
☒ Face Shield over safety glasses

Respiratory Protection

☐ Half-face Air Purifying Respirator
☐ Full-face Air Purifying respirator
☐ SCBA or Supplied Air

Fall Protection

☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

☐ Chemical resistant gloves per SDS
☒ Cut-resistant gloves or liners
☐ Leather/Work gloves
☐ Welding gloves
☒ Leather gloves, insulated
☒ Nitrile gloves
☐ Impact resistant gloves

Foot Protection

☐ Safety shoes or boots with metatarsal guards
☒ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
☐ Rubber-sole boots or grips
☐ Chemical resistant boot covers
☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

☐ Cooling vest
☐ Flame resistant clothing (FRC)

***If an item is checked, it is relevant for all job steps. If an item is specific to a particular job step it must be noted in the Critical Action(s) column in the JSA.**

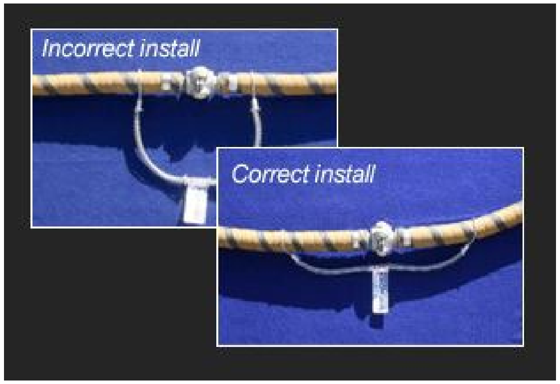
JSA Description: Air Knife Hand Clearing	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
1. Establish exclusion zone with cones, flags, caution tape, and/or barriers at the proposed air knife location.	MOTION - Injury or death from being struck by motor vehicle	- Utilize **buddy system**. One person must focus on establishing work zone while the second person must focus on establishing eye contact with approaching motor vehicle drivers and alerting other workers to potential imminent hazards. - Wear **DOT Class II or higher hi-visibility traffic vests** to make personnel more visible to on and off site traffic.	
	MECHANICAL - Pinch and cuts to hands when carrying barricades	- Identify **pinch points** with tape or high visibility marking ink to increase awareness. - Wear minimum Level 2 **cut-resistant gloves** to reduce potential for soft tissue injuries - If blast barricades are required to protect vehicles/buildings/equipment, utilize team lift for carrying frames/panels.	
	GRAVITY - Slip, trip and fall hazards associated with debris, fixed obstacles, uneven or slippery surfaces resulting in personal bodily injury	- Scan proposed work zone for **debris, fix obstacles, uneven and slippery surfaces.** - Remove all debris from work zone and mark fixed obstacles with cones or high visibility marking ink - If a cover plates are used to cover an open borehole, **put cover plate away** in a designated place outside of work area when not in use to prevent tripping hazard.	
2. Air knife location and recover loosened soil using vacuum extraction equipment	MECHANICAL – Insufficient maintenance could lead to downtime, or leaks from the equipment	- Verify that the subcontractor has inspected the equipment before use and provides a paper copy of the inspection documentation. - If leaks are observed, or a component of the equipment is damaged/malfunctioning – **STOP WORK** and replace or repair equipment before proceeding - Go over emergency equipment stops and their location as part of the daily tailgate – if equipped. Test emergency stops daily to confirm functionality.	

JSA Description: Air Knife Hand Clearing	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
3. Air knife location and recover loosened soil using vacuum extraction equipment	PRESSURE - Personal bodily injury resulting from the separation of the pressured air line connection. PRESSURE - Personal bodily injury resulting from the separation of the pressured air line connection.	• Prior to start of air knife operation ensure that all **air line hoses are in working condition** and have whip checks in place. Prior to heavy equipment operation, inspect and document condition of equipment using an equipment checklist. • **Establish eye contact** with the air knife operator before entering the exclusion zone. • Always point the **air knife lance away from your body** and other people/equipment even if the air knife is not operating. • All workers within the exclusion zone must wear a **face shield** in addition to **safety glasses & hearing protection** when the air knife is operating.  	
	ELECTRICAL - Physical injury or property damage from encountering an underground utility.	• Prior to start of air knife operation confirm that a public and private utility markout has been conducted. Follow ARCADIS Utility Clearance guidance and verify ARCADIS utility clearance procedures. • Follow the Subsurface Clearance Procedure Checklist to minimize potential for encountering an underground utility.	

JSA Description: **Air Knife Hand Clearing**	**Site ID:**

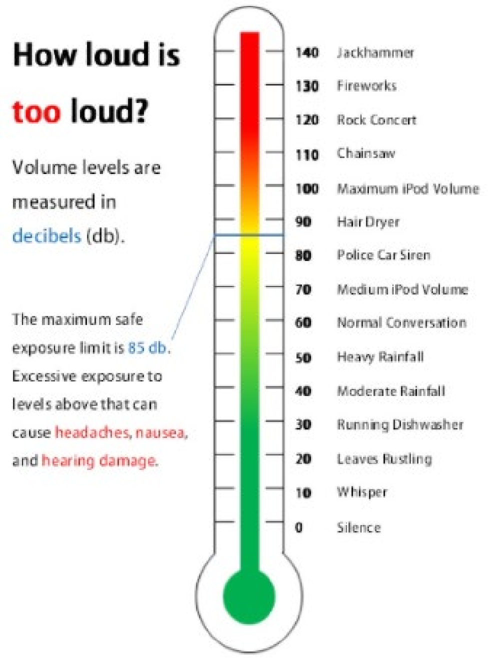
BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
3. Air knife location and recover loosened soil using vacuum extraction equipment	ELECTRICAL - Physical injury or property damage from encountering an underground utility.	If a utility is encountered, immediately **STOP WORK** and call the Project Team and Manager to inform. ELECTRIC GAS-OIL COMMUNICATION WATER SEWER TEMPORARY SURVEY MAKER RECLAIMED WATER-IRRIGATION PROPOSED EXCAVATION	
	SOUND - Hearing loss due to excessive noise from air knife and vacuum extraction operation.	• **Keep nonessential workers** at a safe working distance of **10 feet from established work zone** to distance themselves from high noise levels and disturbed soil blown into the air. • **All team members must wear hearing protection** if inside exclusion zone.	

Job Safety Analysis

JSA Description: **Air Knife Hand Clearing**	**Site ID:**

BIOLOGICAL | CHEMICAL | ELECTRICAL | GRAVITY | HUMAN PERFORMANCE | MECHANICAL | MOTION | PRESSURE | RADIATION | SOUND | TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
3. Air knife location and recover loosened soil using vacuum extraction equipment	SOUND - Hearing loss due to excessive noise from air knife and vacuum extraction operation.		

JSA Description: Air Knife Hand Clearing	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
3. Air knife location and recover loosened soil using vacuum extraction equipment	PRESSURE - Injury to the eyes from soils disturbed during air knife activities.	• **Work upwind** of air knife activities • **Wear safety glasses** to prevent soils or dust getting into eyes. Upgrade to spoggles if winds are above 20 mph. • **Team members actively air knifing or assisting must wear face shields.**	
	PRESSURE - Physical injury resulting due to the air stream from the air lance.	• Never point the air lance towards personnel or equipment. • Wear minimum Level **2 cut-resistant gloves** to reduce potential for soft tissue injuries	
	TEMPERATURE – Dermal damage from extensive air lance handling.	• Wear task required gloves to minimize thermal exposure to lance. • If staff must cease operations to allow lance to cool down, stage the air lance in a manner which does not create additional hazards.	
	CHEMICAL - Inhalation of chemical vapors from disturbed soil.	• Monitor breathing zone per HASP monitoring section using instruments indicated. If action level is approached, **STOP WORK and evaluate engineering controls. Contact H&S for further guidance.**	

JSA Description: Air Knife Hand Clearing	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
4. Backfilling soil from the vacuum truck back into the location	MECHANICAL - Pinch and cuts to hands when truck is hydraulically lifting	• **Identify pinch points** with tape or high visibility marking ink to increase awareness. • **Communicate truck movements to staff within the exclusion zone.** • **Stay clear** of any moving parts in the truck that is being lifted. Keep track of other workers in the area	

JSA Acknowledgement

"I have read this JSA, and I understand the hazards and safe work practices associated with the task.
If conditions change or an additional hazard is recognized, I will Stop Work and notify the Site H&S Officer immediately:"

This JSA must be acknowledged by affected workers every shift.

Name	Signature	Initials Used on Form	Date	Date	Date	Date	Date	Date

Verification of Critical Actions – Undersigned verifies that critical actions are in place, or have been evaluated based on availability, effectiveness and understood by the crew prior to work starting.

Name of Verifier	Signature	Date	Date	Date

End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

JSA Description: Air Monitoring	**Date of JSA Development: 01/31/2022**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)

Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	Constituent Specific Air Monitoring Device

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- ☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☑ Long pants
- ☑ Long-sleeved shirts
- ☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
- ☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
- ☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
- ☑ Hard hat that complies with ANSI Z89.1

<u>TASK SPECIFIC:</u> Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

- ☐ Impact Goggles
- ☐ Flexible goggles
- ☐ Welding goggles/helmet or face shield. Tinted lenses required
- ☐ Laser safety glasses

Head Protection

- ☐ Type E Hardhat (Electrical)
- ☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

- ☐ Photoionization Detector (PID)
- ☐ Flame Ionization Detector (FID)
- ☐ Dust Monitor
- ☐ LEL / O_2 Meter
- ☐ H_2S Meter

Hearing Protection

- ☐ Ear Plugs (noise 80 db)
- ☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

- ☐ Chemical resistant clothing recommended on SDS
- ☐ Chain saw chaps
- ☐ Snake chaps or boots marketed as "snake proof"[3]
- ☐ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
- ☐ ANSI/ISEA 107-2010 Class 2 or 3 <u>*BREAKAWAY*</u> vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☒ Sunscreen lotion >= SPF30
- ☒ Flying insect control: DEET (primary), permethrin (secondary)
- ☐ Tick control: Permethrin (primary), DEET (secondary)
- ☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

- ☐ Chemical protective goggles that comply with ANSI Z87.1
- ☐ Face Shield over safety glasses

Respiratory Protection

- ☐ Half-face Air Purifying Respirator
- ☐ Full-face Air Purifying respirator
- ☐ SCBA or Supplied Air

Fall Protection

- ☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

- ☐ Chemical resistant gloves per SDS
- ☒ Cut-resistant gloves or liners
- ☐ Leather/Work gloves
- ☐ Welding gloves
- ☐ Leather gloves, insulated
- ☒ Nitrile gloves
- ☐ Impact resistant gloves

Foot Protection

- ☐ Safety shoes or boots with metatarsal guards
- ☐ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
- ☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
- ☐ Rubber-sole boots or grips
- ☐ Chemical resistant boot covers
- ☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

- ☐ Cooling vest
- ☐ Flame resistant clothing (FRC)

***If an item is checked, it is relevant for all job steps. If an item is specific to a particular job step it must be noted in the Critical Action(s) column in the JSA.**

Job Safety Analysis

JSA Description: Air Monitoring	**Site ID:**

BIOLOGICAL | CHEMICAL | ELECTRICAL | GRAVITY | HUMAN PERFORMANCE | MECHANICAL | MOTION | PRESSURE | RADIATION | SOUND | TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)	**Critical Action(s)** (Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)	**Responsible Person(s) – Initials**
1. Calibration of air monitoring equipment	MECHANICAL - Pinch Points to hand and fingers from equipment cases	• Keep fingers 6 inches from opening and closing edges on equipment cases.	
	GRAVITY - Broken bones, lacerations or sprains from slip, trip, and falls due to site hazards or equipment on the ground	• Maintain good housekeeping practices in instrument room. • Visually check for hazards on ground. Identify and remove trip hazards if possible. If hazard cannot be removed, mark with high-visibility paint or flagging, and notify others. • Designate equipment storage area within work area to prevent clutter and reduce trip hazards. • Evaluate need to wear steel toe boots with puncture resistant soles to mitigate any debris puncturing the foot and to prevent from any tools being dropped (Required for all OE sites)	
	CHEMICAL - Hazardous atmosphere and respiratory irritation from calibration gas	• Remove nozzle from calibration gas after completing calibration to prevent accidental release. • Keep SDS onsite for calibration gases.	
	MOTION - Laceration to hands from equipment lamps	• Do not remove PID lamps that are stuck in the lamp housing. Reference equipment manuals for PID maintenance. • Wear type II cut resistant gloves to protect hands from lacerations.	
	CHEMICAL - Chemical skin irritation from equipment cleaning material	• Slowly pour cleaning chemicals on areas of the equipment that require regular cleaning. • Pour the cleaning materials over a containment pan or bucket to prevent release/spillage. • Wear nitrile gloves and safety glasses to prevent exposure to cleaning chemicals, review and understand MSDS.	
2. Cleaning sensors	CHEMICAL – Skin irritation from splash hazard from cleaners	• If pouring cleaners, pour slow so no splash occurs. • Wear safety glasses to protect eyes from splashes and use prongs when placing and removing sensors from cleaning solution.	

JSA Description: Air Monitoring

Site ID:

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		• Wear long sleeve shirts to protect against any splashes that may occur.	
	MOTION - Lacerations from equipment sensors	• Do not grasp sensor tightly to prevent breaking glass when removing sensors from cleaning solution.	
3. Transport instrument to or from support vehicle	GRAVITY - Broken bones, lacerations or sprains from slips, trips and falls from uneven terrain	• Use route planning. Identify hazards along walking path prior to transporting equipment. • Place ice melt on steps during winter conditions.	
	MOTION - Personal injury or death from being struck by or against vehicles or equipment	• Plan work to stay out of active traffic areas and complete during low-traffic times, if possible. • Park support vehicle between active traffic and workers to protect workers from traffic. • Use traffic control measures (barricades and/or cones) to direct traffic around a designated work area. • Wear hi-visibility vest/shirt to increase visibility to drivers.	
4. Setting up instruments at field sampling locations	GRAVITY - Broken bones, lacerations, or sprains from slips, trips and falls from uneven terrain	• Select even and stable travel routes when walking to the instrument locations. Avoid iced over areas.	
	BIOLOGICAL - Biological hazards (flying insects, ticks, poisonous snakes)	• Observe for wasps and bees nest in the instrument stands before placing instruments on the stand. • Survey the vegetation and identify poison ivy, oak or sumac and avoid these areas. Survey walking areas for snakes or varmints. • Avoid wild animal encounter by staying out of wooded or hidden areas.	
	BIOLOGICAL - Heat and Cold Stress	• Cover exposed skin during cold weather conditions to prevent frost bite. • Drink fluids to hydrate body during hot weather. • Use of sunscreen is recommended to prevent sunburn.	

JSA Description: Air Monitoring	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

<table>
<tr><th>Job Steps
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<tr><td></td><td></td><td><table><tr><td>Temperature (°F)</td><td>Maximum Allowable Work Time</td><td>Minimum Mandatory Rest Time</td></tr><tr><td>95+</td><td>8 minutes</td><td>15 minutes</td></tr><tr><td>85-95</td><td>13 minutes</td><td>10 minutes</td></tr><tr><td>75-85</td><td>20 minutes</td><td>10 minutes</td></tr></table>•</td><td></td></tr>
<tr><td></td><td>ELECTRICAL - Serious injury or death from electrical shock from lightning</td><td>• If lightening is observed, stop work immediately and discontinue work for 30 minutes after the last lightning strike.
• Do not pick up instruments during lightning storms.
• Pick up instruments 30 minutes after last lightning strike is observed.</td><td></td></tr>
<tr><td></td><td>CHEMICAL - Skin and respiratory exposure and irritation to contaminants</td><td>• Use open air environments to allow exposure levels to dissipate prior to sampling.
• Utilize STOP WORK and communicate exceedances of any PEL in a timely manner to site Health and Safety Manager and project team.
• Follow proper employee decon JSA when donning/doffing PPE.
• Don air purifying respirator if exposure level merits Level C protection.
• Don Tyvek and nitrile gloves in addition to the PPE listed above when entering the exclusion zone to complete air monitoring. Inspect that the coveralls are taped at the cuffs and legs with tape if required.</td><td></td></tr>
<tr><td></td><td>MOTION - Laceration from tools used to retrieve sample media</td><td>• Inspect hand tools prior to grabbing them.
• Only place hand in designed location on tools
• Wear cut resistant gloves underneath nitrile to prevent injury from tools.</td><td></td></tr>
<tr><td>5. Post Calibration</td><td>CHEMICAL - Chemical exposure to skin and respiratory system</td><td>• Work upwind of vapors.
• See SDS.
• Don Nitrile Gloves Required when handling chemicals to prevent skin irritation.</td><td></td></tr>
</table>

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Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

JSA Description: Driving Passenger Vehicle	**Date of JSA Development: 01/31/2022**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)

Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
NIck Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	Passenger Vehicle

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- ☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☑ Long pants
- ☑ Long-sleeved shirts
- ☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
- ☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
- ☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
- ☑ Hard hat that complies with ANSI Z89.1

<u>TASK SPECIFIC:</u> Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

- ☐ Impact Goggles
- ☐ Flexible goggles
- ☐ Welding goggles/helmet or face shield. Tinted lenses required
- ☐ Laser safety glasses

Head Protection

- ☐ Type E Hardhat (Electrical)
- ☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

- ☐ Photoionization Detector (PID)
- ☐ Flame Ionization Detector (FID)
- ☐ Dust Monitor
- ☐ LEL / O_2 Meter
- ☐ H_2S Meter

Hearing Protection

- ☐ Ear Plugs (noise 80 db)
- ☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

- ☐ Chemical resistant clothing recommended on SDS
- ☐ Chain saw chaps
- ☐ Snake chaps or boots marketed as "snake proof"[3]
- ☒ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
- ☐ ANSI/ISEA 107-2010 Class 2 or 3 ***<u>BREAKAWAY</u>*** vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☒ Sunscreen lotion >= SPF30
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- ☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

- ☐ Chemical protective goggles that comply with ANSI Z87.1
- ☐ Face Shield over safety glasses

Respiratory Protection

- ☐ Half-face Air Purifying Respirator
- ☐ Full-face Air Purifying respirator
- ☐ SCBA or Supplied Air

Fall Protection

- ☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

- ☐ Chemical resistant gloves per SDS
- ☐ Cut-resistant gloves or liners
- ☐ Leather/Work gloves
- ☐ Welding gloves
- ☐ Leather gloves, insulated
- ☐ Nitrile gloves
- ☐ Impact resistant gloves

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- ☐ Safety shoes or boots with metatarsal guards
- ☐ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
- ☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
- ☐ Rubber-sole boots or grips
- ☐ Chemical resistant boot covers
- ☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

- ☐ Cooling vest
- ☐ Flame resistant clothing (FRC)

***If an item is checked, it is relevant for all job steps. If an item is specific to a particular job step it must be noted in the Critical Action(s) column in the JSA.**

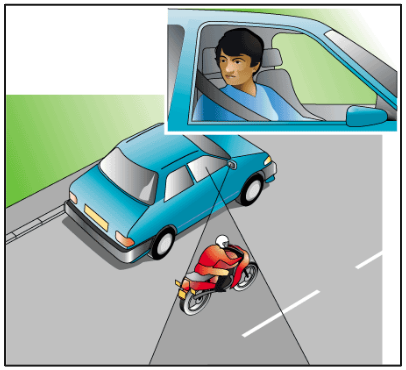
JSA Description: Driving Passenger Vehicle	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
1. Inspect Vehicle	Motion - Being struck by primary or passing vehicle resulting in broken bones, lacerations, abrasions, sprains, or death.	• Set parking brake before inspecting vehicle • Watch for approaching vehicle traffic. If conditions are unsafe, move vehicle to safe location before proceeding with inspection. Use cones or barricades to communicate activity with pedestrians and drivers. • Wear level II traffic vest to make personnel more visible to on and off site traffic.	
	Mechanical - Lacerations or abrasions to hands and arms due to contact with moving engine parts.	• Do not reach in to engine compartment while engine is operating or key is in ignition. • Wear leather/Kevlar level 2 cut resistant gloves with nitrile liners when inspecting hoses and fluid levels to prevent abrasions or fluid contact with skin.	
	Chemical - Dermal exposure to residual oils/lubricants in engine compartment.	• Clean off any residual oils/lubricants in engine compartment.	
	Temperature - Burns to hands from contact with hot engine parts.	• Allow engine to cool a minimum of 30 minutes prior to inspection.	
	Chemical - Dermal abrasions associated with dust, debris, engine fluids contact.	• Inspect the vehicle upwind or behind a wind barricade (ex. building, wall, etc.). • Wear safety glasses to protect eyes from dust, debris and pressurized fluid lines during inspection.	
2. Drive to Destination	Mechanical - Mechanical failure of vehicle leading to collision resulting in broken bones, lacerations, abrasions, sprains, or death.	• Document vehicle inspection. When possible, check previous inspection records. • Fasten seatbelt prior to ignition. ALWAYS wear seatbelt when operating vehicle. • Check up-to-the-minute road conditions and traffic alerts prior to departing at http://www.fhwa.dot.gov/Trafficinfo/ • Familiarize yourself with vehicle controls (windshield wiper, locks, horn, hazard lights, etc.) prior to departing. • Remain at least 4 seconds behind lead vehicles.	

JSA Description: Driving Passenger Vehicle	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)	**Critical Action(s)** (Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)	**Responsible Person(s) – Initials**
		• Allow vehicles a 2 second head start at traffic lights and stop signs. • Stop before pedestrian walkways.	
	Motion - Distractions, blind spots, fatigue or falling asleep while driving associated with vehicle crash resulting in broken bones, lacerations, abrasions, sprains, or death	• Give yourself adequate time to reach destination without the worry of rushing. • Obey all postings and traffic laws. • DO NOT USE CELL PHONE WHILE DRIVING. • Do not drive while tired or not alert. Utilize rest breaks every 2 continous hours of driving to refocus. • Do not drive while under the influence of alcohol or drugs that affects mental alertness. Do not allow illegal drugs or alcohol in company vehicle. • Utilize TRACK before beginning the each task/maneuver. • Be aware of vehicle’s blind spots. Turn head or use blind spot mirror to check before changing lanes, slowing, or turning. 	
	Motion - Slippery / wet / icy roads leading to vehicle collision resulting in broken bones, lacerations, abrasions, sprains, or death	• Inspect current and forecasted weather and road conditions that will be encountered during driving.	

JSA Description: Driving Passenger Vehicle	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)	**Critical Action(s)** (Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)	**Responsible Person(s) – Initials**
		• Use **STOP WORK** if road or weather conditions become dangerous.  The Smith5Keys. Key 1 Aim High In Steering. Key 2 Get The Big Picture. Key 3 Keep Your Eyes Moving. Key 4 Leave Yourself An Out. Key 5 Make Sure They See You. © 2010 Smith System Driver Improvement Institute, Inc. All Rights Reserved SSS-941 REV 05.2011	
3. Park Vehicle at Destination	Motion - Vehicle collision with stationary object, pedestrian or other vehicle resulting in broken bones, lacerations, abrasions, sprains, or death	• Utilize a spotter if available. • Park away from other vehicles when possible. • Utilize pull-through parking when available instead of backing. Slowly pull through and watch for vehicles and pedestrians. • Back in to parking space if adjacent spaces are unoccupied and it is safe to do so. • Maintain a cushion of 3-feet between vehicle and stationary objects. Be aware of vehicle’s blind spots and use a spotter. • Drive at low speed (5 mph) to slowly observe surrounding site objects and pedestrians. • Use headlights to increase visibility of your vehicle and others in parking lots.	

Job Safety Analysis

ARCADIS

JSA Description: Driving Passenger Vehicle	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

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	Mechanical - Vehicle coming out of gear and rolling hitting workers, pedestrians, or other vehicles resulting in broken bones, lacerations, abrasions, sprains, or death	• Set parking brake when parked. • Avoid parking on hills/uneven area whenever possible.	
	Mechanical – Damage to vehicle from other vehicles or individuals.	• Avoid parking in busy locations when feasible. • Park in a safe area where vehicle visibility is not a concern. • Do not leave valuables or equipment visible inside vehicle to mitigate likelihood of break-ins.	

JSA Acknowledgement

"I have read this JSA, and I understand the hazards and safe work practices associated with the task.
If conditions change or an additional hazard is recognized, I will Stop Work and notify the Site H&S Officer immediately:"

This JSA must be acknowledged by affected workers every shift.

Name	Signature	Initials Used on Form	Date	Date	Date	Date	Date	Date

Verification of Critical Actions – Undersigned verifies that critical actions are in place, or have been evaluated based on availability, effectiveness and understood by the crew prior to work starting.

Name of Verifier	Signature	Date	Date	Date

End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

JSA Description: Drum Handling	**Date of JSA Development: 1/24/2022**
Project Name: BNSF – TIme Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)

Minda Moe	
Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	Drum dolly, truck with liftgate, drum labels

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- ☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☑ Long pants
- ☑ Long-sleeved shirts
- ☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
- ☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
- ☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
- ☑ Hard hat that complies with ANSI Z89.1

TASK SPECIFIC: Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

- ☐ Impact Goggles
- ☐ Flexible goggles
- ☐ Welding goggles/helmet or face shield. Tinted lenses required
- ☐ Laser safety glasses

Head Protection

- ☐ Type E Hardhat (Electrical)
- ☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

- ☐ Photoionization Detector (PID)
- ☐ Flame Ionization Detector (FID)
- ☐ Dust Monitor
- ☐ LEL / O_2 Meter
- ☐ H_2S Meter

Hearing Protection

- ☐ Ear Plugs (noise 80 db)
- ☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

- ☐ Chemical resistant clothing recommended on SDS
- ☐ Chain saw chaps
- ☐ Snake chaps or boots marketed as "snake proof"[3]
- ☐ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
- ☐ ANSI/ISEA 107-2010 Class 2 or 3 ***BREAKAWAY*** vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☐ Sunscreen lotion >= SPF30
- ☐ Flying insect control: DEET (primary), permethrin (secondary)
- ☐ Tick control: Permethrin (primary), DEET (secondary)
- ☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

- ☐ Chemical protective goggles that comply with ANSI Z87.1
- ☐ Face Shield over safety glasses

Respiratory Protection

- ☐ Half-face Air Purifying Respirator
- ☐ Full-face Air Purifying respirator
- ☐ SCBA or Supplied Air

Fall Protection

- ☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

- ☐ Chemical resistant gloves per SDS
- ☐ Cut-resistant gloves or liners
- ☒ Leather/Work gloves
- ☐ Welding gloves
- ☐ Leather gloves, insulated
- ☐ Nitrile gloves
- ☐ Impact resistant gloves

Foot Protection

- ☐ Safety shoes or boots with metatarsal guards
- ☐ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
- ☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
- ☐ Rubber-sole boots or grips
- ☐ Chemical resistant boot covers
- ☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

- ☐ Cooling vest
- ☐ Flame resistant clothing (FRC)

***If an item is checked, it is relevant for all job steps. If an item is specific to a particular job step it must be noted in the Critical Action(s) column in the JSA.**

Job Safety Analysis

ARCADIS

JSA Description:	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)	**Critical Action(s)** (Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)	**Responsible Person(s) – Initials**
1. Establish work zone with cones and/or barricades at proposed drum location	MOTION - Injury or death from being struck by motor vehicle	• Utilize buddy system. One person must focus on establishing work zone while the second person must focus on establishing eye contact with approaching motor vehicle drivers and alerting other workers to potential imminent hazards. • Wear DOT Class II or higher hi-visibility traffic vests to make personnel more visible to on and off site traffic.	
	MECHANICAL - Pinch and cuts to hands when carrying A-frame barricades	• Identify pinch points with tape or highly visible marking ink to increase awareness. • Wear minimum class II cut-resistant gloves to reduce potential for soft tissue injuries	
	MOTION - Nails or other sharp objects piercing the bottoms of boot and feet	• Perform a site walk to visually confirm that area is clear of nails and other sharp objects on the ground. Use a broom to push any debris or sharp objects out of the work area. • If puncture hazards are present at the site (debris, rebar, demolition waste) puncture resistant boots or steel sole inserts should be worn to prevent sharp objects from piercing the bottom of boots.	
2. Moving of Drums from work area to staging area and staging area to load out area	GRAVITY - Injury due to slips trips and falls from blocked vision while moving drums	• Plan path of travel and visually inspect ground for trip hazards, choose path to avoid uneven, wet or slippery surfaces • Do not step over objects, maintain a clear pathway before transporting or moving drums	
	MECHANICAL - Personal injury associated with pinch points and potential lacerations or amputations of fingers.	• Do not place hands below the edge of the drum before setting them down. The ring and lid may have sharp edges – do not place your hands here. • Wear leather / cut resistant gloves while opening and closing drum lids and working with drum rings	
	CHEMICAL - Leaks and spills as a result of drums tipping over, incorrectly sealed drum, punctures, pinholes, impacted sides, top or bottom, rust,	• Verify SDS and review SDS for chemicals contained in drums. Review hazards and emergency procedures for all chemicals contained in drums on site prior to handling	

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)	**Critical Action(s)** (Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)	**Responsible Person(s) – Initials**
	weathered conditions, knock drum over resulting in a release or exposure to worker.	• Verify drums and drum lids are completely sealed around all edges by inspecting rim and ring of drum and lid. Do not move drums without closing them first. • All drums must be labeled or otherwise identified with their contents. • Drums containing liquid waste should be staged on secondary containment (drum liners, containment pallet, berm.) The containment structure must be capable of storing 110% of the contents of all containers stored on it. • Inspect all drums before use – do not use drums that show evidence of rusting/perforation and may leak. • Wear nitrile chemical resistant gloves or glove liners while handling drums containing product	
3. Load out of Drums for disposal	MOTION - Back strain from lifting and pushing/pulling drums to staging and load out areas, Contact with chemical resulting in exposure	• Stage drums on hard, level and clean surface. • Only empty drums may be lifted manually, and only if workers are comfortable with the lift. • Bend at knees. Do not over assert back, legs or arms – use team lift if necessary. • Use drum dolly or mechanical means to lift or move drums that contain any materials. Full soil drums can weigh over 800lbs. • 	

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)	**Critical Action(s)** (Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)	**Responsible Person(s) – Initials**
	MECHANICAL - Personal injury, lacerations or amputations associated with Pinch points identified on lift gates, tailgates, between drum rims and stationary objects	• Visually identify all pinch points on equipment and vehicles prior to beginning work • Use TRACK to determine body position in order to be able to move freely around drum and do not place body in-between drum and stationary objects. • Do not place fingers between rim of drum and stationary objects when moving drum • Wear leather and/or cut resistant gloves when handling or moving drums. • Do not attempt to to roll full drums – they can tip and crush extremities.	
	MOTION - Back, arm and shoulder strains from lifting drums for disposal	• Only empty drums should be moved manually – full soil drums can weigh over 800 lbs. • Lift with knees. Do not apply pressure to the arms, legs or back when moving drums to the extent that you feel discomfort or pain in muscles. Have a personal understanding of your own capabilities and limitations. • Use Buddy System to move drums when additional workers are available • Use Drum Dolly or other mechanical means to lift/move drums when available. If not available, do not attempt to move drums full of soil or water. Do not roll drums on their edge. • Use Drum Dolly or mechanical means to place drums directly into Box Truck or onto Lift Gate	
	GRAVITY - Slips, Trips and fall while walking, moving drums, operating a drum dolly or moving drum onto lift gate resulting in personal injury.	• Identify a path clear of obstacles, uneven surface, slippery surfaces and debris prior to moving drum. Remove any obstacles or debris when possible • Visually observe surrounding including vehicle and pedestrian traffic in order to better understand potential traffic and pedestrian hazards in and around work area.	
	MOTION - Struck by vehicle resulting in personal injury or death.	• An exclusion zone must be established where required by the HASP and Traffic Safety plan.	

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		• Stage drum storage area away from traffic and in a protected location. • If heavy equipment is used to move drums, remain outside of the work area/travel path of the equipment. • Equipment spotters must complete the struck by/crushed by checklist and discuss hand signals before beginning. • Keep body out of line of fire when working with swinging lift arms attached to trucks when used to move drums and lift drums into storage area of truck • Do not walk directly behind Skid Steers or loading equipment without making contact with operator prior to moving • Wear DOT Class II or higher hi-visibility traffic vests to make personnel more visible to on and off site traffic.	

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This JSA must be acknowledged by affected workers every shift.

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Name of Verifier	Signature	Date	Date	Date

End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

ARCADIS

JSA Description: Groundwater Monitoring	**Date of JSA Development: 02/01/2022**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)

Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	PID, Pumps, Tubing, Buckets, Water Quality Meter, Sampling Equipment

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- ☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☑ Long pants
- ☑ Long-sleeved shirts
- ☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
- ☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
- ☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
- ☑ Hard hat that complies with ANSI Z89.1

TASK SPECIFIC: Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

- ☐ Impact Goggles
- ☐ Flexible goggles
- ☐ Welding goggles/helmet or face shield. Tinted lenses required
- ☐ Laser safety glasses

Head Protection

- ☐ Type E Hardhat (Electrical)
- ☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

- ☒ Photoionization Detector (PID)
- ☐ Flame Ionization Detector (FID)
- ☐ Dust Monitor
- ☐ LEL / O_2 Meter
- ☐ H_2S Meter

Hearing Protection

- ☐ Ear Plugs (noise 80 db)
- ☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

- ☐ Chemical resistant clothing recommended on SDS
- ☐ Chain saw chaps
- ☐ Snake chaps or boots marketed as "snake proof"[3]
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- ☒ Sunscreen lotion >= SPF30
- ☒ Flying insect control: DEET (primary), permethrin (secondary)
- ☒ Tick control: Permethrin (primary), DEET (secondary)
- ☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

- ☐ Chemical protective goggles that comply with ANSI Z87.1
- ☐ Face Shield over safety glasses

Respiratory Protection

- ☐ Half-face Air Purifying Respirator
- ☐ Full-face Air Purifying respirator
- ☐ SCBA or Supplied Air

Fall Protection

- ☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

- ☐ Chemical resistant gloves per SDS
- ☒ Cut-resistant gloves or liners
- ☐ Leather/Work gloves
- ☐ Welding gloves
- ☐ Leather gloves, insulated
- ☒ Nitrile gloves
- ☐ Impact resistant gloves

Foot Protection

- ☐ Safety shoes or boots with metatarsal guards
- ☒ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
- ☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
- ☐ Rubber-sole boots or grips
- ☐ Chemical resistant boot covers
- ☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

- ☐ Cooling vest
- ☐ Flame resistant clothing (FRC)

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Job Safety Analysis

ARCADIS

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
1. Establish work zone cones and/or barricades at proposed well locations	Motion - Broken bones, sprains, lacerations, or death from being struck by motor vehicle	• Observe vehicle traffic and pedestrian traffic in and/or around potential work zones. When setting up cones and barricades scan work zone and surrounding area for traffic. Make eye contact with drivers and give right-of-way to all motor vehicles present. • Wear DOT Class II or higher hi-visibility traffic vests to make personnel more visible to on and off site traffic.	
	Mechanical - Lacerations, abrasions to hands when carrying A-frame barricades or delineators	• Identify pinch points with tape or highly visible marking ink to increase awareness. • Set up delineators around work area and stage vehicle to provide buffer from traffic if feasible. • Wear Level 2 cut-resistant gloves to prevent soft tissue injuries.	
	Motion - Nails or other sharp objects piercing the bottoms of boot and feet	• Perform a site walk to clear area of nails and other sharp objects on the ground using broom to push the objects out of the work area. • Wear puncture resistant boots or steel sole inserts to prevent sharp objects from piercing the bottom of boots.	
2. Open wells for monitoring	Gravity - Slip/Trips/Falls over sampling equipment resulting in broken bones, sprains, or lacerations	• Visually check and remove trip hazards in the work area prior to starting work at each well. Mark all identified fix hazards with cones or high-visibility tape. • Stage equipment in one central location to minimize trip hazards.	
	Motion - Pinch points from leading edge of well housing and well cap resulting in lacerations, abrasions to hands	• Do not grab well cap around edge to prevent entering line of fire of well cap and well housing and contact with sharp edges. • Use well/vault key to open wells to keep hands from being pinched/crushed by well cap and/or well housing. Do not place hands under lid when removing. • Utilize team lift for opening heavy vault lids. Establish plan prior to opening and maintain good communication while executing.	

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		• Use socket wrench to remove bolts and pry bar to remove lid to prevent having to touch sharp edges. • Keep hands free of lid when removing well cap to keep hands out of line of fire of well lid and well housing. • Wear Level 2 resistant gloves to prevent lacerations to hands from sharp well caps or pinched hands.	
	Biological - Bites/stings from insects or snakes inside or near well housing resulting in allergic reactions or skin irritation	• Visually check for insects and snakes prior to opening the well. If feasible, clear potential biting/stringing insects prior to reaching inside well vault/lid. If unable to perform safely, STOP WORK and contact project team. • Wear gloves, long sleeves and full-length pants to prevent insect bites to skin.	
	Pressure - Lacerations or abrasions by flying well cap due to pressurized well	• Open well cap slowly to depressurize well. • Stay out of the line of fire above well cap. Keep face clear of well head while opening. • Wear hard hat to prevent head injury from a well cap that becomes airborne. Wear safety glasses to prevent debris from inside well contacting eyes.	
	Chemical - Chemical exposure from vapor/gas inhalation resulting in irritation or asphyxiation	• Work upwind of well head. • **STOP WORK** and inform project team of any readings exceeding action level identified in the HASP. • Air monitoring with a calibrated photo-ionization (PID) detector (fitted with a 10.6 eV bulb) must be utilized to determine concentrations of petroleum vapors in breathing zone.	
	Motion - Being struck by motor vehicle resulting in broken bones, lacerations, abrasions, sprains, or death	• Scan work zone and surrounding area for vehicle and pedestrian traffic. If vehicle parks directly beside work zone **STOP WORK** and observe vehicle and driver for movement, make eye contact with driver. • Wear DOT Class II or higher hi-visibility traffic vest to increase visibility to on and off site traffic.	

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
3. Set up of sampling equipment	Motion - Lacerations from sharp edges of well head resulting in hand lacerations or abrasions	• Do not grab edge of well head. Visually identify and verbalize sharp edges and pinch points with site workers. • Wear Level 2 cut resistant gloves while handling equipment/debris to prevent hand lacerations.	
	Gravity - Slip/Trips/Falls over sampling equipment resulting in broken bones, sprains, or lacerations	• Use route planning and visually check for and remove trip hazards prior to setup of sampling equipment. • Stage equipment in one central location to minimize trip hazards.	
	Motion - Struck by vehicle resulting in broken bones, lacerations, abrasions, sprains or death	• Scan work zone and surrounding area for vehicle traffic. If vehicle approaches work zone or parks beside work zone **STOP WORK**, make eye contact with driver and wait for vehicle to stop and driver to exit vehicle leaving work zone prior to resuming activities. • Wear DOT Class II or higher hi-visibility traffic vests to make personnel more visible to on and off site traffic.	
	Motion - Nails or other sharp objects piercing the bottoms of boot and feet	• Perform a site walk to clear area of nails and other sharp objects on the ground using broom to push the objects out of the work area. • Wear puncture resistant boots or steel sole inserts to prevent sharp objects from piercing the bottom of boots.	
	CHEMICAL – Eye or dermal irritation from damaged pump battery	• Inspect the GeoPump Battery for cracks/leaks • Pack baking soda to cleanup/neutralize any spills of battery acid.	
4. Monitor groundwater level with probe	Gravity - Slip/Trip/Falls on measuring tape resulting in broken bones, sprains, or lacerations	• Always deploy and retrieve measuring tape with a spool. • Do not allow tape to drag the ground when walking between well locations to minimize trip hazard.	
		•	

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
	Chemical - Chemical exposure from skin or eye contact with groundwater	• Lower and retract tape slowly to reduce the potential for splashing. • Wear nitrile gloves and safety glasses while using measuring tape over Level 2 cut resistant gloves to prevent chemical exposure to skin and eyes.	
	Motion - Lacerations, back strain, or bruises to knees while gauging well volume	• Inspect ground surface for sharp objects or stones which may cause lacerations of bruising. Removed objects from around well head. • Kneel on soft surfaces or pads instead of bending over at the waist or squatting to prevent knee and back injuries.	
5. Purge groundwater monitoring well	Gravity - Slip, trip and fall hazards over loose bailer twine, twine bucket, bailers, pump cables or associated tubing resulting in broken bones, sprains, or lacerations	• Keep loose twine, tubing, and pump cables off of the ground (utilize vehicle trunk/bed if available). When pulling twine or tubing from bucket or spool determine amount needed to match depth of well to be purged and wind twine into a loop which can be easily carried. Do not place twine buckets, tubing, or pump controllers in walking path in or around work zone. • Keep bailers in bailer box on support truck when not in use.	
	Motion - Cutting twine or pump tubing resulting in hand lacerations	• Use scissors or tubing cutters to cut twine or tubing. • Do not use fixed open blades. . • Wear Level 2 cut-resistant gloves when using scissors or tube cutters to prevent cuts to hands and fingers.	
	Motion - Sprains and strains to arms and back while deploying and retrieving bailer or pump in groundwater monitoring well	• Do not bend over at waist when deploying or retrieving bailers or pumps in wells. Stand upright with back straight. Do not lift arms over head when retrieving bailer or pump from well. Use both hands when dropping or pulling twine attached to bailer or tubing attached to pumps. Deploy and retrieve bailers and pumps slowly. • Use pump to purge wells with high purge volumes to reduce sprains and strains.	

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL | CHEMICAL | ELECTRICAL | GRAVITY | HUMAN PERFORMANCE | MECHANICAL | MOTION | PRESSURE | RADIATION | SOUND | TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
	GRAVITY - Slips and falls due to wet surfaces created by discharging purge water into bucket resulting in broken bones, sprains, or lacerations	• Pour contents of bailer into purge buckets slowly keeping spout of bailer directly over top of bucket. Keep effluent end of tubing inside bucket opening and fixed to the side of the bucket using clips or ties to mitigate splash hazards. • When pouring purge water from bailer into bucket keep effluent end of bailer approximately 1 foot or less from opening of bucket to avoid spilling purge water onto ground creating slippery surface. Pour slowly to mitigate splashing.	
	Temperature - Dermal burns or abrasions to hands while deploying bailer or pump to well	• Do not allow twine, cables or tubing to slide though hands or fingers. Use hand-over-hand technique to deploy and retrieve twine, cables, or tubing. • Wear Level 2 cut-resistant glove with nitrile liners or nitriles over Level 2 cut-resistant gloves when handling twine, bailers, pumps, tubing and cables to prevent abrasions and lacerations to hands from bailer twine.	
	Motion - Abrasions and lacerations to hands by entan gled bailer twine or pump cable	• Do not allow twine or pump cables to entangle hands or fingers creating loops which can potentially cause pinch points, abrasions, and/or lacerations to hands. • Wear Level 2 cut-resistant glove with nitrile liners or nitriles over Level 2 cut-resistant gloves when handling twine, bailers, pumps, tubing and cables to prevent abrasions and lacerations to hands from bailer twine.	
	ELECTRICAL – electric shock, short circuiting or flame from incorrectly connecting pump to power source	• Inspect all cords and connections for frays, cuts or other damage; take out of service and replace if damaged. • Keep all cords and connections away from water and keep battery connections covered with lid until used.	
6. Collection of sample	Motion - Back strain from opening well/bailing water/collecting sample/lifting and carrying 5 gallon bucket of water to remediation system or drum.	• Only fill buckets ½ - ¾ full to prevent awkward loads and splashing. • Kneel instead of bending over at the waist or squatting when working around well. Lift with legs not back or	

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		shoulders. Do not twist at waist to avoid back strains/sprains. • Use knee pads to prevent knee lacerations from kneeling on ground.	
	Chemical - Dermal exposure to groundwater and/or sample preservation fluids while filling VOA/sampling media resulting in allergic reactions, skin irritation, or dermal burns	• Fill sample bottles slowly to avoid splashing/spillage. • Wear nitrile gloves over Level 2 cut-resistant gloves and safety glasses with side shields to prevent chemical exposure to skin. • Pack baking soda to cleanup/neutralize any spills of sample preservation acid.	
	Motion - Lacerations to hands from glass sample bottle breakage	• Never over tighten caps on glass VOA vials to avoid possible breakage. • Place VOA/sampling media in bubble wrap as soon as possible once sample has been taken. • Wear nitrile gloves over level 2 cut-resistant gloves to prevent hand lacerations and dermal exposure due to bottle breakage and preservative contact.	
	Chemical - Chemical exposure from vapor/gas inhalation resulting in irritation or asphyxiation	• Keep face a minimum of 1 ft. away from top of well head and work upwind of well head to prevent chemical exposure. • Conduct air monitoring with a calibrated photo-ionization (PID) detector (fitted with a 10.6 eV bulb) must be utilized to determine concentrations of petroleum vapors in breathing zone. • **STOP WORK** and inform project team of any readings exceeding action level identified in the HASP.	
7. Close Well	Motion - Strain to back and arms when closing well	• Do not bend at waist to replace well cap and lid. Do not over extend arms or back when reaching for cap, lid or tools. Keep cap, lid and tools within arm's reach when closing well.	

JSA Description: Groundwater Monitoring | **Site ID:**

BIOLOGICAL | CHEMICAL | ELECTRICAL | GRAVITY | HUMAN PERFORMANCE | MECHANICAL | MOTION | PRESSURE | RADIATION | SOUND | TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
	Motion - Lacerations or bruises to knees while kneeling	• Avoid placing knee on ground or hard surface when replacing cap and lid. • Use knee pads if necessary to place knee on ground to avoid lacerations, abrasions, and busies	
	Motion - Lacerations or abrasions to fingers or hands when handling and placing well lid	• Keep hands away from leading edges on well lids. Do not place fingers between or under rim of well and edge of well lid. • Use Level 2 cut-resistant gloves when handling well lids to prevent lacerations or abrasions to hands and fingers.	
8. Take down sampling equipment	Motion - Back/muscle strain from loading equipment	• Do not lift awkward loads or weight >50 lbs. • Lift with legs and not the back. Keep all loads close to body. Reposition body using feet, do not twist at waist.	
	Motion - Lacerations to hands from sharp edges of equipment	• Use handles on equipment to avoid grabbing sharp edges. • Avoid grabbing/holding sharp edges/points and wear Level 2 cut-resistant gloves while handling equipment.	
	Gravity - Slip/Trips/Falls on equipment resulting in broken bones, sprains, or lacerations	• Use route planning and visually check for and remove trip hazards in work area. • Stage equipment in one central location to minimize trip hazards.	
9. Transfer purge water into waste drum	MOTION - Back/muscle strain from loading equipment	• Do not lift akward loads or weight >50 lbs without using buddy system. • Lift with legs and not the back and keep all loads close to your body. Reposition body using feet, do not twist at waist.	
	CHEMICAL – Eye or dermal exposure to ground/purge water during transfer process	• Do not fill temporary storage containers over ¾ capacity to avoid spillage and heavy loads. • Cover container with a lid if transporting in a vehicle to transfer location.	

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		• If transferring to a drum, use pump or funnel to minimize potential for spills. • Pour in a slow controlled manner to avoid splashing. 1. Wear nitrile gloves and eye-protection to avoid contact with ground/purge water.	

JSA Acknowledgement

"I have read this JSA, and I understand the hazards and safe work practices associated with the task.
If conditions change or an additional hazard is recognized, I will Stop Work and notify the Site H&S Officer immediately:"

This JSA must be acknowledged by affected workers every shift.

Name	Signature	Initials Used on Form	Date	Date	Date	Date	Date	Date

Verification of Critical Actions – Undersigned verifies that critical actions are in place, or have been evaluated based on availability, effectiveness and understood by the crew prior to work starting.

Name of Verifier	Signature	Date	Date	Date

End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

ARCADIS

JSA Description: Rotosonic Drilling and Soil Sampling	**Date of JSA Development: 02/01/2022**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)	
Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	PID, Drill Rig

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- ☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☑ Long pants
- ☑ Long-sleeved shirts
- ☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
- ☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
- ☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
- ☑ Hard hat that complies with ANSI Z89.1

TASK SPECIFIC: Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

- ☐ Impact Goggles
- ☐ Flexible goggles
- ☐ Welding goggles/helmet or face shield. Tinted lenses required
- ☐ Laser safety glasses

Head Protection

- ☐ Type E Hardhat (Electrical)
- ☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

- ☒ Photoionization Detector (PID)
- ☐ Flame Ionization Detector (FID)
- ☐ Dust Monitor
- ☐ LEL / O_2 Meter
- ☐ H_2S Meter

Hearing Protection

- ☒ Ear Plugs (noise 80 db)
- ☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

- ☐ Chemical resistant clothing recommended on SDS
- ☐ Chain saw chaps
- ☐ Snake chaps or boots marketed as "snake proof"[3]
- ☐ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
- ☐ ANSI/ISEA 107-2010 Class 2 or 3 ***BREAKAWAY*** vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☒ Sunscreen lotion >= SPF30
- ☒ Flying insect control: DEET (primary), permethrin (secondary)
- ☒ Tick control: Permethrin (primary), DEET (secondary)
- ☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

- ☐ Chemical protective goggles that comply with ANSI Z87.1
- ☐ Face Shield over safety glasses

Respiratory Protection

- ☐ Half-face Air Purifying Respirator
- ☐ Full-face Air Purifying respirator
- ☐ SCBA or Supplied Air

Fall Protection

- ☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

- ☐ Chemical resistant gloves per SDS
- ☒ Cut-resistant gloves or liners
- ☐ Leather/Work gloves
- ☐ Welding gloves
- ☐ Leather gloves, insulated
- ☒ Nitrile gloves
- ☐ Impact resistant gloves

Foot Protection

- ☐ Safety shoes or boots with metatarsal guards
- ☐ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
- ☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
- ☐ Rubber-sole boots or grips
- ☐ Chemical resistant boot covers
- ☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

- ☐ Cooling vest
- ☐ Flame resistant clothing (FRC)

***If an item is checked, it is relevant for all job steps. If an item is specific to a particular job step it must be noted in the Critical Action(s) column in the JSA.**

JSA Description: Rotosonic Drilling and Sampling	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
1. Set up necessary traffic and public access controls	MOTION - Struck by vehicle due to improper traffic controls	• Use a buddy system for placing site control cones and/or signage. • Position vehicle so that you are protected from moving traffic. Wear Class II traffic vest	
2. Utiltiy Clearance	ELECTRICAL - Potential to encounter underground or above ground utilities while drilling.	• Complete utility clearance in accordance with the ARCADIS Utility Clearance H&S Standard.	
3. General drill rig operation	NOISE - Excessive noise is generated by rig operation.	• When the engine is used at high RPMs or soil samples are being collected, use hearing protection.	
	TEMPERATURE - Burns due to hot surfaces of drill rig.	• Wear proper work gloves. Due to friction and lack of a drilling fluid, heat will be produced during this method, mainly from augers. • Be careful handling split spoons. • Wear long sleeve shirts and long pants. • Avoid contact with augers as much as possible.	
	CHEMICAL – inhalation of vaporized COCs due to heat from drill rig operation	• When soils and parts become heated, COC could volatilize. Monitor air with a PID during drilling activities. • Stand upwind of soils	
	MOTION – Injury due to pinch points or crushing on rig and auger connections.	• Stay at least 5 feet away from moving parts of the drill rig. • Know where the kill switch is, and have the drillers test it to verify that it is working. • Do not wear loose clothing, and tie long hair back. • Avoid wearing jewelry while drilling. • Cone off the work area to keep general public away from the drilling rig.	
	CHEMICAL – Eye injury due to dust and debris	• Wear safety glasses and stay as far away from actual drilling operation as practicable. • Wear appropriate gloves to protect from COCs.	
	MOTION – slips/trips/falls due to drilling equipment laying on the ground (i.e. augers, split spoons, decon equipment, coolers, etc) and water from decon buckets.	• Keep equipment and trash picked up, and store away from the primary work area.	

JSA Description: Rotosonic Drilling and Sampling	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
	MOTION – property/utility damage due to insufficient overhead clearance while derrick/boom is raised.	• Never move the rig with the derrick up. • Ensure there is proper clearance to raise the derrick, and that you are far enough away from overhead power lines. See the Utility Clearance H&S Standard for guidance.	
4. Rotosonic drilling	PRESSURE - Flying parts/debris and sexcessive slipping hazards from pressurized water use (i.e. fire hydrants).	• Water usage from fire hydrants should be cleared with local muncipalities prior to use. • Only persons that know how to use the hydrant should be performing this task. • Ensure all connections are tight, and hose line is not run over to cut by traffic. • Any leaks from the hydrant should be reported immediately.	
	MOTION - Property damage due to insufficient overhead clearance.	• Ensure sufficient overhead clearance: the drill head can turn 90 degrees to attach to the next drill flight or casing. This usually requires a large support truck to park directly behind the rig. As the drill head raises the new casing flight is angled down at the same time until it can be turned completely vertical.	
	HUMAN PERFORMANCE - Muscle strain due to heavy lifting of cores.	• Always use 2 people to move core containers. • Use caution moving core samples to layout area. • Plan layout area to ensure adequate aisle space between core runs for logging. • Keep back straight and use job rotation.	
	MOTION - Stuck by/caught in moving parts.	• Stay clear of path of drill head. The rotosonic drill head can move very quickly up and down. Moving parts can strike someone or catch body parts. • Communicate with team members (i.e. operator and helpers) • Do not wear loose clothing. Drill utilizes two large hydraulic clamps to continuously hold casings while load/unloading previous casings.	

JSA Description: Rotosonic Drilling and Sampling	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
5. Sample collection and processing	MOTION - Injuries from pinch points on sampling equipment and breakage of sample containers.	• Care should be taken when opening sampling equipment. • Look at empty containers before picking them up, and do not over-tighten container caps. • Use dividers to store containers in the cooler so they do not break.	
	CHEMICAL – Exposure to contaminated soil and sample preservatives	• Wear nitrile gloves when handling sample media and containers.	
	HUMAN PERFORMACE - Lifting heavy coolers can cause back injuries.	• Use two people to move heavy coolers. Use proper lifting techniques.	
6. Soil butting and water management	MOTION - Back injury, or pinching/crushing injury from moving full drums.	• Preferably have the drilling contractor move full drums with their equipment. If this is not practicable, use lift assist devices such as drum dollies, lift gates, etc. • Employ proper lifting techniques, and perfrom TRACK to identify pinch/crush points. • Wear leather work gloves • Clear all walking and work areas of debris prior to moving a drum.	

JSA Acknowledgement

*"I have read this JSA, and I understand the hazards and safe work practices associated with the task.
If conditions change or an additional hazard is recognized, I will Stop Work and notify the Site H&S Officer immediately:"*

This JSA must be acknowledged by affected workers every shift.

Name	Signature	Initials Used on Form	Date	Date	Date	Date	Date	Date

Verification of Critical Actions – Undersigned verifies that critical actions are in place, or have been evaluated based on availability, effectiveness and understood by the crew prior to work starting.

Name of Verifier	Signature	Date	Date	Date

End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

ARCADIS

JSA Description: Monitoring Well Installation	**Date of JSA Development: 1/19/2022**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)	
Minda Moe	
Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	Drill Rig

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- ☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☑ Long pants
- ☑ Long-sleeved shirts
- ☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
- ☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
- ☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
- ☑ Hard hat that complies with ANSI Z89.1

TASK SPECIFIC: Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

- ☐ Impact Goggles
- ☐ Flexible goggles
- ☐ Welding goggles/helmet or face shield. Tinted lenses required
- ☐ Laser safety glasses

Head Protection

- ☐ Type E Hardhat (Electrical)
- ☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

- ☒ Photoionization Detector (PID)
- ☐ Flame Ionization Detector (FID)
- ☐ Dust Monitor
- ☐ LEL / O_2 Meter
- ☐ H_2S Meter

Hearing Protection

- ☒ Ear Plugs (noise 80 db)
- ☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

- ☐ Chemical resistant clothing recommended on SDS
- ☐ Chain saw chaps
- ☐ Snake chaps or boots marketed as "snake proof"[3]
- ☐ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
- ☐ ANSI/ISEA 107-2010 Class 2 or 3 ***BREAKAWAY*** vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☐ Sunscreen lotion >= SPF30
- ☐ Flying insect control: DEET (primary), permethrin (secondary)
- ☐ Tick control: Permethrin (primary), DEET (secondary)
- ☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

- ☐ Chemical protective goggles that comply with ANSI Z87.1
- ☐ Face Shield over safety glasses

Respiratory Protection

- ☐ Half-face Air Purifying Respirator
- ☐ Full-face Air Purifying respirator
- ☐ SCBA or Supplied Air

Fall Protection

- ☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

- ☐ Chemical resistant gloves per SDS
- ☐ Cut-resistant gloves or liners
- ☒ Leather/Work gloves
- ☐ Welding gloves
- ☐ Leather gloves, insulated
- ☒ Nitrile gloves
- ☐ Impact resistant gloves

Foot Protection

- ☐ Safety shoes or boots with metatarsal guards
- ☐ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
- ☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
- ☐ Rubber-sole boots or grips
- ☐ Chemical resistant boot covers
- ☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

- ☐ Cooling vest
- ☐ Flame resistant clothing (FRC)

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Job Safety Analysis

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
1. Set up work zone	MOTION – Broken bones, sprains, lacerations, or death resulting from being struck by vehicle	• Observe proposed area of work for potential hzards including moving vehicles and pedestrian traffic. • Use Traffic Control Plan to position work vehicles and cones or barricades. • Wear hi-visibility vest or long sleeve shirt to increase visibility to vehicular traffic.	
	MOTION – Nails or other sharp objects piercing the bottoms of boots and feet	• Perform a site walk to visually confirm that the area is clear of nails and other sharp objects on the ground. Use a broom to push any debris or sharp objects out of the work area. • Wear puncture resistant boots or steel sole inserts to prevent sharp objects from piercing the bottoms of your boots.	
	GRAVITY – Slip, trips, and fall hazards resulting in broken bones, sprains, abrasions, or lacerations	• Utilize TRACK and route planning prior to setting up work zone. • Inspect work zone for potential slip, trip, and fall hazards including uneven surfaces, potholes, or wet or slick surfaces. Move work zone or remediate hazards before beginning work, if possible.	
	MECHANICAL – Lacerations or abrasions associated with handling A-frame barricades	• Do not place fingers in the line of fire when handling barricades or assembling cones. • Wear Level II cut-resistant gloves to prevent hands from lacerations or abrasions.	
2. Soft dig to clear for utilities	MOTION – Muscle strain due to twisting motion and pulling auger from borehole	• Stretch prior to beginning hand auger activities. • Take breaks every 30 minutes and switch personnel at 2 foot intervals. Do not twist hand auger above shoulder level or below waist level. Keep back straight while advancing hand auger. • Lift auger with the knees and arms and not back. If auger is stuck, get assistance from other personnel to free.	

Job Safety Analysis

ARCADIS

JSA Description:	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
	MOTION – Lacerations to hands while utilizing hand auger	• Inspect hand auger handle, rods, and bucket for sharp edges or burs. Do not handle hand auger by sharp or leading edges. • Wear class II cut-resistant gloves to prevent lacerations, abrasions and blisters.	
	ELECTRICAL – electrocution or explosion from contact with underground utilities	• Confirm that utility location mark outs are current and visible, and that USA/811/DigAlert ticket is active. • Verify Utility and Structures Checklist has been completed and reviewed by PM or designee. • Underground utilities must be physically identified and cleared prior to excavating. • Do not begin excavation until the area has been cleared by the Site Supervisor. ELECTRIC GAS-OIL COMMUNICATION WATER SEWER TEMPORARY SURVEY MAKER RECLAIMED WATER-IRRIGATION PROPOSED EXCAVATION ○	
	GRAVITY – Cuttings falling onto workers and resulting in chemical exposure and dermal irritations	• Remove cuttings at chest level by tapping with a rubber mallet. • When removing hand auger bucket, keep bucket a minimum of 2 feet from face to reduce risk of dermal contact with soil.	

JSA Description:	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		• Wear hard hat, nitrile gloves, long sleeves and safety glasses reduce risk of dermal contact.	
3. Inspection of Heavy Equipment	CHEMICAL - Potential release of fluids to the ground surface (i.e. hydraulic, fuel, etc.).	• Inspect hoses and fittings for signs of damage (bulging lines, pieces of hose missing, leaks, etc) before equipment start up, prior to resuming operation after mid-day safety meeting, and again at the end of the day. • If damage or leaks are identified, stop work, notify project superintendent, and remove excavator from service. • Wear safety glasses with side shields (Spoggles must be worn when winds exceed 25mph) to reduce the potential of eye injury resulting from leaking or spraying hydraulic oils in the event of a leak.	
4. Position drill rig at proposed well location	MOTION – Broken bones, lacerations, abrasions, sprains or death due to drill rig striking workers or pedestrians during vehicle movement to proposed boring location	• Establish a pedestrian-free zone between parked drill rig and proposed boring location. • Spotter must escort drill rig while maintaining a 45-degree position to movement of the drill rig. • Spotter must maintain a buffer of 10 feet from drill rig. Do not allow workers to walk within 20 feet of front of or 20 feet behind drill rig while it is moving. • Maintain communication with driver of drill rig. Drill rig operator must wait for spotter to confirm it is safe to back vehicle. • All personnel must remain at least 20 feet from drill rig while it is moving. Spotter must remain outside of the line of fire (direct path) of the drill rig. Any time the driver and spotter cannot see each other, the driver must stop the drill rig immediately. • Ground workers must wear DOT Class II or higher hi-visibility traffic vests to increase visibility of workers to operator.	
	MECHANICAL – Broken bones, lacerations, abrasions, sprains, or death due to drill rig striking workers by slipping out of gear	• When drill rig, trailers, and support vehicles are in final position, place wheel chocks on both sides of rear tire.	

Job Safety Analysis

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

<table>
<tr><th>Job Steps
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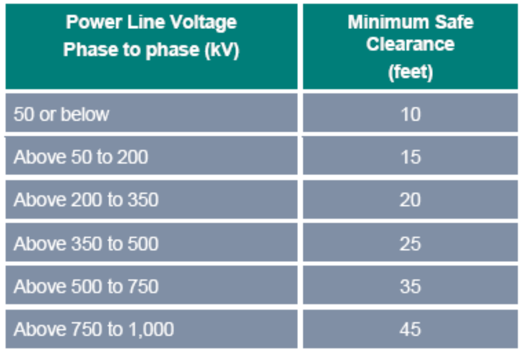
(Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)</th><th>Critical Action(s)
(Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)</th><th>Responsible Person(s) – Initials</th></tr>
<tr><td></td><td>ELECTRICAL – electrocution or explosion from contact with overhead or underground utilities</td><td>

Confirm that utility markouts are current and visible and USA/811/DigAlert Ticket is active
Look up to check for any overhead power lines
Do not operate any equipment within 10 feet of an overhead power line (see below chart for safe distances to overhead power lines).


<table>
<tr><th>Power Line Voltage Phase to phase (kV)</th><th>Minimum Safe Clearance (feet)</th></tr>
<tr><td>50 or below</td><td>10</td></tr>
<tr><td>Above 50 to 200</td><td>15</td></tr>
<tr><td>Above 200 to 350</td><td>20</td></tr>
<tr><td>Above 350 to 500</td><td>25</td></tr>
<tr><td>Above 500 to 750</td><td>35</td></tr>
<tr><td>Above 750 to 1,000</td><td>45</td></tr>
</table>
ANSI standard B30.5-1994, 5-3.4.5
</td><td></td></tr>
<tr><td>5. Drill to desired TD</td><td>MECHANICAL – Broken bones, lacerations, abrasions, sprains or death due to worker being pulled into machinery</td><td>

All non-essential workers/personnel must remain out of active work zone.
Loose clothing and jewelry must be removed prior to drilling. Long hair must be tied up and tucked under clothing or hard hat.
Only one operator may stand at controls, and must take hands off of controls when permitting helpers into working area to add casing or augers.

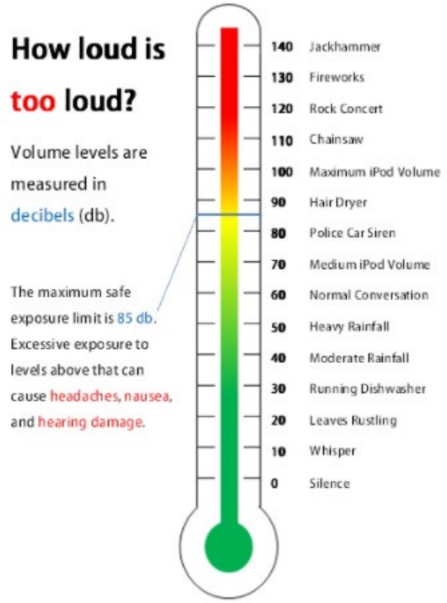
</td><td></td></tr>
<tr><td></td><td>MECHANICAL – Crush point and pinch point incidents resulting in hand or foot injury from auger flights</td><td>

Use buddy lift for attachingauger flights greater than 50 lbs or if unable to safely lift with one person.

</td><td></td></tr>
</table>

JSA Description:	Site ID:

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)	**Critical Action(s)** (Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)	**Responsible Person(s) – Initials**
	SOUND - Hearing loss due to exposure to excessive/ prolonged noise from drill rig	• Keep non-essential personnel away from active work zone. • Wear task required hearing protection (ear plugs) to mitigate noise exposure greater than 85 dba.  How loud is too loud? Volume levels are measured in decibels (db). The maximum safe exposure limit is 85 db. Excessive exposure to levels above that can cause headaches, nausea, and hearing damage. •	
	CHEMICAL – Inhalation, eye, or dermal exposure to petroleium impacted soil resulting in irritation	• Air monitoring with a calibrated photo-ionization (PID) detector (fitted with a 10.6 eV bulb) must be utilized to determine concentrations of petroleum vapors in breathing zone. Consult HASP monitoring section for action levels. • Workers must wear safety glasses to prevent soil to eye contact. • Work upwind when feasible.	
6. Prepare borehole	MECHANICAL – Broken bones, lacerations, abrasions, sprains or death due to worker being pulled into machinery	• Ensure all machinery is stopped before approaching to remove augers or casing.	

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		• When removing augers or casing, limit number hoisted out of hole – loose screws or slipped threads may result in overhead hazards	
	CHEMICAL – Inhalation, eye, or dermal exposure to petroleium impacted soil or water resulting in irritation	• Depending on drilling method, flushing of the borehole to remove native soil inside augers or metal casing may be advised. • Stand clear of borehole during flushing in case materials are ejected. • Work upwind when feasible.	
7. Install well casing	MOTION – muscle strain due to lifting heavy PVC well casing	• Utilize buddy system or machinery to place well casing in borehole to reduce muscle strain. Lift with knees, not back. Assemble well casing in phases to reduce weight and muscle strain.	
	MOTION – being struck by PVC casing resulting in lacerations, abrasions, or bruises	• Utilize buddy system and maintain control of casing ends. Non-essential workers should remain outside of exclusion zone during assembly of monitoring well casing • Ensure that all lines and lifters holding casing are secure before releasing hold on casing. Improperly secured lifters can damage threads.	
	MOTION – Lacerations or abrasions from rough edge of PVC or cutting tools	• If cutting PVC, keep hands one foot away from cutting surface and do not cut towards yourself. • Wear Class II cut-resistant gloves to prevent soft tissue injuries.	
8. Placing annular materials such as sand packs, seals, and grout	MOTION – Lacerations to hands when opening bags	• Utilize scissors or retracting utility knife when opening bags. Do NOT use fixed blade knives. • Wear Level II cut-resistant gloves when using scissors or spring loaded utility knife.	
	MOTION – Sprains/strains to back or arms when pouring bags of sand, bentonite, or grout mix	• Do not pour materials from elevated position in well casing or drums. Place opened back on ground or rim of drum.	

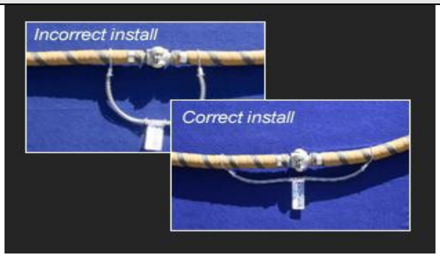
JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		• Place annular materials next to well location in order to avoid excessive lifting or carrying of supplies. • Do not solo lift awkward loads or loads over 50 lbs. Bend at knees, not with back, to lift bags. • 	
	CHEMICAL – Bentonite/concrete/silica dust inhalation resulting in lung irritation or damage	• Place body upwind from location while pouring materials. Pour materials slowly from upwind position. • Wear dust mask if unable to mitigate dust inhalation hazard with body positioning.	
	CHEMICAL – Splashing of grout mix and water during mixing or pouring resulting in eye or dermal irritation	• Keep face a minimum of 1 foot away from bucket or drum during mixing or pouring of grout. Do not place face over top of container during mixing. Add water and materials slowly to reduce splashing potential. • Immediately stop work and wipe off grout which has splashed onto bare skin, as chemical burns may result from prolonged exposure.	
	PRESSURE – Lacerations or abrasions if excessive pressure damages hoses or fittings	• Check that whip-checks are in place on hoses. Do not allow slack in whip check when installing.	

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		 Incorrect install Correct install - Wear face shield if required to be close to pressurized lines.	
9. Install well box and concrete pad	MOTION – Lacerations or abrasions from metal to skin contact	- Carry well box or manhole assembly in box to the well location. Remove lid from assembly by touching the lid, not the thin skirt to lower chances of laceration. - Wear Class II cut-resistant gloves to prevent soft tissue injury.	
	MOTION – Muscle strain due to lifting bags of concrete and mixing components	- Scoot bags to edge of trailer or truck bed before attempting lift to prevent worker from lifting in awkward position. Lift with arms and legs to prevent muscle strain. Carry bags close to body, keeping back straight. - Read labels which identify weight of bag before lifting bags, do not carry over 50 pounds at one time.	
	CHEMICAL – Inhalation of concrete dust during concrete mixing phase	- Remain upwind of dry concrete when mixing to avoid inhalation of silica-containing concrete dust . - Wear dust mask if body positioning does not mitigate breathing zone hazard.	
	MOTION – Cuts and abrasion to knees when finishing well pad	- Inspect ground surface for puncture hazards and abrasive material. - Wear knee pads to prevent soft tissue abrasions and bruises.	

JSA Acknowledgement

*"I have read this JSA, and I understand the hazards and safe work practices associated with the task.
If conditions change or an additional hazard is recognized, I will Stop Work and notify the Site H&S Officer immediately:"*

This JSA must be acknowledged by affected workers every shift.

Name	Signature	Initials Used on Form	Date	Date	Date	Date	Date	Date

Verification of Critical Actions – Undersigned verifies that critical actions are in place, or have been evaluated based on availability, effectiveness and understood by the crew prior to work starting.

Name of Verifier	Signature	Date	Date	Date

End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

ARCADIS

JSA Description: Sample Packing and Cooler Handling	**Date of JSA Development: 2/2/2022**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)	
Minda Moe	
Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	Coolers, sample bottles

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
☑ Long pants
☑ Long-sleeved shirts
☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
☑ Hard hat that complies with ANSI Z89.1

TASK SPECIFIC: Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

☐ Impact Goggles
☐ Flexible goggles
☐ Welding goggles/helmet or face shield. Tinted lenses required
☐ Laser safety glasses

Head Protection

☐ Type E Hardhat (Electrical)
☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

☐ Photoionization Detector (PID)
☐ Flame Ionization Detector (FID)
☐ Dust Monitor
☐ LEL / O_2 Meter
☐ H_2S Meter

Hearing Protection

☐ Ear Plugs (noise 80 db)
☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

☐ Chemical resistant clothing recommended on SDS
☐ Chain saw chaps
☐ Snake chaps or boots marketed as "snake proof"[3]
☐ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
☐ ANSI/ISEA 107-2010 Class 2 or 3 ***BREAKAWAY*** vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
☒ Sunscreen lotion >= SPF30
☐ Flying insect control: DEET (primary), permethrin (secondary)
☐ Tick control: Permethrin (primary), DEET (secondary)
☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

☐ Chemical protective goggles that comply with ANSI Z87.1
☐ Face Shield over safety glasses

Respiratory Protection

☐ Half-face Air Purifying Respirator
☐ Full-face Air Purifying respirator
☐ SCBA or Supplied Air

Fall Protection

☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

☐ Chemical resistant gloves per SDS
☐ Cut-resistant gloves or liners
☒ Leather/Work gloves
☐ Welding gloves
☐ Leather gloves, insulated
☒ Nitrile gloves
☐ Impact resistant gloves

Foot Protection

☐ Safety shoes or boots with metatarsal guards
☐ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
☐ Rubber-sole boots or grips
☐ Chemical resistant boot covers
☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

☐ Cooling vest
☐ Flame resistant clothing (FRC)

***If an item is checked, it is relevant for all job steps. If an item is specific to a particular job step it must be noted in the Critical Action(s) column in the JSA.**

JSA Description:	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
1. Set up sample processing area and unpack equipment.	MOTION – Struck by vehicles due to lack of traffic controls or poor visibility	• Locate non-traffic or low traffic areas to setup work station. • Park support vehicle away from active traffic or between work area and active traffic to protect workers from traffic. • Scan area for moving vehicles and hazards before opening door. • Place cones around vehicle to alert drivers of upcoming work and to demarcate work area. • Wear reflective vest to increase visibility to drivers and reduce struck by hazard.	
	GRAVITY – Personal injury from tripping over debris or equipment on the ground	• Visually check area to identify and remove trip hazards (equipment, debris). If hazards cannot be removed (uneven ground, roots, rocks) mark with cones, high visibility tape, or flagging and notify others working in area. • Designate equipment storage area within work area to prevent clutter and reduce trip hazards. • Do not place any equipment in walking path.	
	MOTION – Back strain from lifting coolers using improper lifting techniques	• Do not lift loads heavier than 50 pounds without assistance from another person. • Get a firm grip, lift using legs, and keep back straight. Do not bend or twist at waist. • If possible, use portable field table, or secure work surface at table height to prepare packages. • Stage field vehicle as close as possible to cooler packing/staging area to minimize distance that coolers must be carried during loading.	
	GRAVITY – Dropping equipment on self or others causing injury	• Lift coolers using designated handles and confirm they are securely attached prior to lifting. • Plan route and verify clear before starting lift.	

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

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	MECHANICAL – Lacerations/injuries from pinch points on equipment while setting up work area	• Identify pinch points on equipment and cases such as hinges, and keep hands 6 inches from identified pinch areas. • Use only closed-blade or self-retracting cutting tools to cut tape when opening taped coolers and wear cut resistant gloves. • Maintain a 4-foot radius from others when using cutting tools and always cut away from body.	
	CHEMICAL – Chemical burns from broken/leaking sample bottles containing preservatives	• Use wet paper towel to carefully remove leaking preservative from the outside of other sample containers and the cooler. • Do not touch broken sample bottles; discard bottles in accordance with Site waste disposal practices. • Do not touch glass or preservatives with bare hands, wear at least nitrile gloves and add work gloves if handling broken glass. • If chemicals contact clothes, removed soiled clothing and wash contacted area on body. • Wear safety glasses at all times to protect eyes from contact with chemicals.	
2. Packing samples	CHEMICAL – Contact with contaminated soils on outside of sample bottles	• Visually inspect bottles and wipe off any soil observed on outside of container before placing into bubble wrap and cooler. • Wear nitrile gloves when handling sample containers to avoid contact with soils or groundwater.	
	MOTION – Lacerations from broken sample containers or when taping coolers for shipment	• Place glass containers in bubble wrap before placing in cooler. • Handle full bottles with 2 hands and dry outside with paper towels to avoid dropping.	

JSA Description:	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

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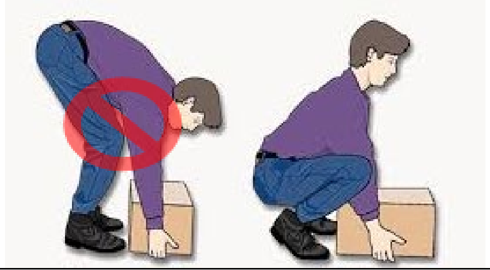
		• Use minimal hand pressure necessary to remove or tighten bottle lids/caps. • Once lids/caps on VOA vials are placed on containers and tightened to where there is no leakage, do not over-tighten to prevent breakage of glass and potential lacerations to hands. • Pack sample bottles tightly in cooler and use bubble wrap to reduce excess space/potential for breakage. • Use only closed-blade cutting tools to cut tape when preparing coolers for shipment to prevent potential lacerations to hands.	
	GRAVITY – Exertion or muscle strain from lifting heavy coolers to place in vehicle	• Bend at knees and keep back straight, do not twist or bend at waist. • Limit weight of each cooler when packing and use two-man lift if carrying loads heavier than 50 pounds. • Use countdown of 3 and keep continuous conversation if using 2 people to lift and carry coolers. • Use cooler handles when lifting coolers, verify that handles are not broken prior to lifting. • Plan route and have clear path of travel, secure equipment in vehicle once loaded. 	

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End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

ARCADIS

JSA Description: Utility Locating and Land Surveying	**Date of JSA Development: 02/01/2022**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)	
Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	GPR and Utility Location Equipment

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- ☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☑ Long pants
- ☑ Long-sleeved shirts
- ☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
- ☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
- ☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
- ☑ Hard hat that complies with ANSI Z89.1

TASK SPECIFIC: Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

- ☐ Impact Goggles
- ☐ Flexible goggles
- ☐ Welding goggles/helmet or face shield. Tinted lenses required
- ☐ Laser safety glasses

Head Protection

- ☐ Type E Hardhat (Electrical)
- ☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

- ☐ Photoionization Detector (PID)
- ☐ Flame Ionization Detector (FID)
- ☐ Dust Monitor
- ☐ LEL / O_2 Meter
- ☐ H_2S Meter

Hearing Protection

- ☐ Ear Plugs (noise 80 db)
- ☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

- ☐ Chemical resistant clothing recommended on SDS
- ☐ Chain saw chaps
- ☐ Snake chaps or boots marketed as “snake proof”[3]
- ☐ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
- ☒ ANSI/ISEA 107-2010 Class 2 or 3 *BREAKAWAY* vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☒ Sunscreen lotion >= SPF30
- ☒ Flying insect control: DEET (primary), permethrin (secondary)
- ☒ Tick control: Permethrin (primary), DEET (secondary)
- ☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

- ☐ Chemical protective goggles that comply with ANSI Z87.1
- ☐ Face Shield over safety glasses

Respiratory Protection

- ☐ Half-face Air Purifying Respirator
- ☐ Full-face Air Purifying respirator
- ☐ SCBA or Supplied Air

Fall Protection

- ☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

- ☐ Chemical resistant gloves per SDS
- ☒ Cut-resistant gloves or liners
- ☒ Leather/Work gloves
- ☐ Welding gloves
- ☐ Leather gloves, insulated
- ☐ Nitrile gloves
- ☐ Impact resistant gloves

Foot Protection

- ☐ Safety shoes or boots with metatarsal guards
- ☐ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
- ☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
- ☐ Rubber-sole boots or grips
- ☐ Chemical resistant boot covers
- ☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

- ☐ Cooling vest
- ☐ Flame resistant clothing (FRC)

***If an item is checked, it is relevant for all job steps. If an item is specific to a particular job step it must be noted in the Critical Action(s) column in the JSA.**

Job Safety Analysis

JSA Description: Utility Locating	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)	**Critical Action(s)** (Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)	**Responsible Person(s) – Initials**
1. Set up survey grid with white paint and control point	Gravity - Broken bones, lacerations or sprains from slips, trips, and falls from uneven ground or over vegetation	• Make multiple trips with loads to eliminate obstructed view of ground. • Plan route of travel prior to performing survey of area marking grid to identify all tripping hazards.	
	Motion - Hand stress/strain from inserting pins and stakes	• Use ergonomically designed hammer to prevent stress to hands when putting stakes or pins in ground to mark grid. • Take breaks and hydrate to avoid employee fatigue from hammering. • Wear level 2 cut resistant gloves when handling and inserting pins and stakes.	
	Motion - Injury or death from being struck by vehicles in survey area	• Stage support vehicle as a barrier when feasible. • Delinate workzone with cones, flags, and caution tape where applicable. • Use buddy system when marking survey grid. • One person apply paint while the other watches for motor vehicles. • Wear clean Class II hi-visibility traffic vest to increase visibility.	
	Mechanical - Pinch and cuts to hands when carrying A-frame barricades	• Identify pinch points with tape or other material to increase awareness. • Wear minimum class II cut-resistant gloves to reduce potential for soft tissue injuries.	
	Motion - Back and leg stress/strain from repetitive bending or squatting during marking survey grid with white paint	• Utilize a marking pistol wand to minimize bending action and keep paint can as far from breathing zone as possible.	
	Motion - Nails or other sharp objects piercing the bottoms of boot and feet	• Perform a site walk to visually confirm that area is clear of nails and other sharp objects on the ground. Use a broom to push any debris or sharp objects out of the work area. • Wear puncture resistant boots or steel sole inserts to prevent sharp objects from piercing the bottom of boots	

JSA Description: Utility Locating	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
	Chemical - Chemical exposure to marking paint	• Stand up wind of paint spraying activities and utilize marking pistol wand when available to prevent chemical exposure.	
2. Locate underground utilities while performing site survey with Ground Penetrating Radar (GPR) and/or other utility locating equipment	Gravity - Injury from slips, trips, and falls on wet, uneven, or steep sloped surfaces	• Make multiple trips with loads to eliminate obstructed view of ground. • Plan route prior to performing survey of area marking grid to identify all tripping hazards. • Park as close as safely possible to minimize trip distance.	
	Biological - Scrapes or cuts to hands, arms, or legs from vegetation in survey grid area	• Use TRACK and route planning to access survey grid location from safest approach. STOP WORK and contact project team if vegetation is too dense and requires clearance.	
	Biological - Bites/stings from insects inside or near tall vegetation	• Remove utility vault lid with tools and inspect interior of manhole for biting/stinging insects. • Wear insect repellant to protect against bites/stings from insects. • Perform tick check as needed throughout work day and at the end of shift. Refer to HASP biological tab as needed. • Wear level 2 cut resistant gloves and long sleeve shirts to prevent skin and hand exposure to vegetation and insects	
	Electrical - Electrical shock from connecting to electrical conduits during utility location	• Inspect electrical conduits to confirm that the outer casing is not damaged and the inner wires are not exposed. • Use a volt meter to determine if an electrical hazard exists before connecting the locate equipment to the electrical conduit. • Stop work if the volt meter indicates that the conduit is energized. • Wear leather gloves to avoid direct contact with potential frayed wiring.	

JSA Description: Utility Locating	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
	Motion - Back and leg stress/strain from prolonged use or over-extending survey tools	• Use job rotation and/or take frequest breaks to hydrate and reduce prolonged exposure to back and leg stress from operating GPR survey tools.	
3. Site Clean Up	Mechanical - Pinch hazards to fingers from closing equipment cases	• Visually identify pinching hazards from equipment cases around edges and locking mechanisms. • Wear leather work gloves where feasible to mitigate pinch/crushing hazards.	
	Gravity - Slip, trips, and falls from carrying equipment that obstructs view or on wet/ uneven surfaces	• Pack equipment so no wires or cables protrude from casing to eliminate tripping hazards while transporting equipment. • Utilize TRACK and route planning prior to loading equipment to identify all slip/trip/fall hazards.	
	Motion - Back and leg stress/strain from lifting and loading equipment into truck	• Utilize buddy system to lift awkward loads or loads with weight >50 lbs, lift knees not the legs and keep all loads close to your body. 	

JSA Acknowledgement

"I have read this JSA, and I understand the hazards and safe work practices associated with the task.
If conditions change or an additional hazard is recognized, I will Stop Work and notify the Site H&S Officer immediately:"

This JSA must be acknowledged by affected workers every shift.

Name	Signature	Initials Used on Form	Date	Date	Date	Date	Date	Date

Verification of Critical Actions – Undersigned verifies that critical actions are in place, or have been evaluated based on availability, effectiveness and understood by the crew prior to work starting.

Name of Verifier	Signature	Date	Date	Date

End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

JSA Description: Vegetation Management	**Date of JSA Development: 01/31/2023**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)	
Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	Hand Saw, String Trimmer, Riding Lawn Mower, Push Lawn Mower, Chain Saw

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- ☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☑ Long pants
- ☑ Long-sleeved shirts
- ☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
- ☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
- ☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
- ☑ Hard hat that complies with ANSI Z89.1

TASK SPECIFIC: Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

- ☐ Impact Goggles
- ☐ Flexible goggles
- ☐ Welding goggles/helmet or face shield. Tinted lenses required
- ☐ Laser safety glasses

Head Protection

- ☐ Type E Hardhat (Electrical)
- ☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

- ☐ Photoionization Detector (PID)
- ☐ Flame Ionization Detector (FID)
- ☐ Dust Monitor
- ☐ LEL / O_2 Meter
- ☐ H_2S Meter

Hearing Protection

- ☒ Ear Plugs (noise 80 db)
- ☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

- ☒ Chemical resistant clothing recommended on SDS
- ☒ Chain saw chaps
- ☐ Snake chaps or boots marketed as “snake proof”[3]
- ☐ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
- ☐ ANSI/ISEA 107-2010 Class 2 or 3 ***<u>BREAKAWAY</u>*** vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☒ Sunscreen lotion >= SPF30
- ☒ Flying insect control: DEET (primary), permethrin (secondary)
- ☒ Tick control: Permethrin (primary), DEET (secondary)
- ☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

- ☒ Chemical protective goggles that comply with ANSI Z87.1
- ☒ Face Shield over safety glasses

Respiratory Protection

- ☐ Half-face Air Purifying Respirator
- ☐ Full-face Air Purifying respirator
- ☐ SCBA or Supplied Air

Fall Protection

- ☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

- ☐ Chemical resistant gloves per SDS
- ☒ Cut-resistant gloves or liners
- ☒ Leather/Work gloves
- ☐ Welding gloves
- ☐ Leather gloves, insulated
- ☐ Nitrile gloves
- ☐ Impact resistant gloves

Foot Protection

- ☐ Safety shoes or boots with metatarsal guards
- ☒ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
- ☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
- ☐ Rubber-sole boots or grips
- ☐ Chemical resistant boot covers
- ☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

- ☐ Cooling vest
- ☐ Flame resistant clothing (FRC)

***If an item is checked, it is relevant for all job steps. If an item is specific to a particular job step it must be noted in the Critical Action(s) column in the JSA.**

Job Safety Analysis

ARCADIS

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL | CHEMICAL | ELECTRICAL | GRAVITY | HUMAN PERFORMANCE | MECHANICAL | MOTION | PRESSURE | RADIATION | SOUND | TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
1. Prepping equipment for clearing activities	MOTION - Improperly maintained tools and equipment increase risk for injury to workers using tools/equipment	• Maintain tools and equipment according to manufacturer recommendations, including proper oiling and inspection of tools/equipment. • Ensure all components and lines are secure and cutting blades are sharp.	
	MOTION - Cuts to hands, fingers, forearms from sharpening tool/equipment blades	• Wear protective gloves suitable for the tool/device being sharpened. • Use proper sharpening techniques and do not hurry through the sharpening process.	
	CHEMICAL - Exposure to fuel during refueling activities	• Wear protective gloves during refueling activities. • Avoid breathing fuel vapors by standing up wind when practical. • Promptly wash exposed skin or clothing.	
2. Clearing small brush/tall grass with weed trimmer and mowers	MOTION - Struck by flying debris from weed trimming and/or mowing activity	• Continuously monitor surroundings for individuals entering work area when using weed trimmer. • Keep unnecessary workers 100 ft from mowing activities. • If individuals enter work area while actively using weed trimmer, suspend weed trimming activities until the work zone clear.	
	MOTION - Foot hazards from slipping into cutting blades or trimming string/blades using walk behind mowers and weed trimmers	• Do not remove and promptly repair guards that reduce potential for foot entry into blade housing of mowers and weed trimmers. • Plan mowing/trimming to reduce situations that increase risk of foot slippage towards blade/string housing. • Wear steel toe boots with good tread.	

Do not remove and promptly repair guar

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL · CHEMICAL · ELECTRICAL · GRAVITY · HUMAN PERFORMANCE · MECHANICAL · MOTION · PRESSURE · RADIATION · SOUND · TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**

ds that reduce potential for foot entry into blade housing of mowers and weed trimmers. Plan mo

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**	
				wing/trimming to reduce situations that increase risk of foot slippage towards blade/string housing, wea

Job Safety Analysis

ARCADIS

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**	
				r steel toe boots with good tread.
	SOUND - Noise from mowing activities	• Wear hearing protection.		
	BIOLOGICAL - Contact with poison ivy, poison oak or sumac may result in severe skin irritation.	• Learn to identify how urushiol-containing plants appear during all seasons. Avoid contact with skin or clothing. • Give plants a wide berth as younger plants in the area may be more difficult to recognize and the vines extending from recognized areas also contain urushiol. • Consider applying a barrier cream to exposed skin. • In areas where the plants are prevalent or in cases where individuals have known allergic responses to urushiol (ie. poison ivy), wear chemically protective disposable coveralls. • Wear long pants and long sleeve shirt, in heavy briar infested areas requiring walking, wear briar chaps.		
	BIOLOGICAL - Contact with poisonous or biting insects	• Watch for and avoid hazardous insects. • Monitor clothing for ticks and other insects. • Use insect repellent when needed.		
	BIOLOGICAL - Exposure to ticks	• Assess locations for possible tick habitat. When possible, walk over thin, low grasses, dirt or rock paths.		

JSA Description: **Groundwater Monitoring**

Site ID:

BIOLOGICAL | CHEMICAL | ELECTRICAL | GRAVITY | HUMAN PERFORMANCE | MECHANICAL | MOTION | PRESSURE | RADIATION | SOUND | TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		• Avoid tall grasses, weeds and beds of fallen leaves (likely nest areas). • Wear permethrin spray, heavily applied, on clothing (where permitted) and DEET (30% or higher) on exposed skin. • Wear light colored clothing to make ticks more visible. Check for ticks on clothing and skin frequently. • Tape pant legs to boots if working in potential tick habitat for extended periods. • In areas with very high potential for exposure or known infestations, wear disposable coveralls.	
3. Clearing large brush/trees with hand tools/chainsaws	MOTION - Cuts to arms, legs, hands from cutting tools or chainsaw	• Wear protective gloves. • When using chainsaw, use chainsaw chaps and helmet equipped with face shield. • When using manual tools, cut away from body, maintain large distance between workers using hand tools or chainsaw. • When using chainsaws, don't reach over running saw, don't saw over head height, don't use saw in low visibility situations, and don't use chainsaws on ladders or use one handed.	
	HUMAN PERFORMANCE - Physical stresses from repetitive motion or excessive push/pulling during clearing	• Use job or task rotation or frequent rest breaks. • Don't use excessive force pulling or pushing on vegetation.	
	MOTION - Scrapes, cuts to skin from vegetation	• Wear protective gloves, long pants and long sleeve shirt. • Wear briar chaps in thorny vegetation.	
	NOISE - Noise form chainsaws	• Wear hearing protection, keep unnecessary workers away form sawing activity	
	BIOLOGICAL - Exposure to ticks.	• Assess locations for possible tick habitat. When possible, walk over thin, low grasses, dirt or rock paths. • Avoid tall grasses, weeds and beds of fallen leaves (likely nest areas).	

JSA Description: Groundwater Monitoring	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		• Wear permethrin spray, heavily applied, on clothing (where permitted) and DEET (30% or higher) on exposed skin. Wear light colored clothing to make ticks more visible. • Check for ticks on clothing and skin frequently. • Tape pant legs to boots if working in potential tick habitat for extended periods. • In areas with very high potential for exposure or known infestations, wear disposable coveralls.	
	BIOLOGICAL - Contact with poison ivy, poison oak or sumac may result in severe skin irritation.	• Learn to identify how urushiol-containing plants appear during all seasons. Avoid contact with skin or clothing. • Give plants a wide berth as younger plants in the area may be more difficult to recognize and the vines extending from recognized areas also contain urushiol. • Consider applying a barrier cream to exposed skin. • In areas where the plants are prevalent or in cases where individuals have known allergic responses to urushiol (ie. poison ivy), wear chemically protective disposable coveralls.	
4. Using herbicides	CHEMICAL - Worker exposure to herbicide during mixing or application.	• Follow manufacturer mixing and application instructions. • Review product MSDS for additional hazards or PPE requirements. • Wear impermeable gloves and clothing during mixing and application. • Promptly wash any skin exposed to herbicide. • Wear safety goggles and face shield during mixing and application.	
	HUMAN PERFORMANCE - Fatigue and physical stresses form carrying hand applicator for prolonged period of time.	• Use job or task rotation to reduce fatigue. • For applicators carried by hand, switch hands periodically. • Opt for backpack versions of applicators when possible.	

JSA Acknowledgement

"I have read this JSA, and I understand the hazards and safe work practices associated with the task.
If conditions change or an additional hazard is recognized, I will Stop Work and notify the Site H&S Officer immediately:"

This JSA must be acknowledged by affected workers every shift.

Name	Signature	Initials Used on Form	Date	Date	Date	Date	Date	Date

Verification of Critical Actions – Undersigned verifies that critical actions are in place, or have been evaluated based on availability, effectiveness and understood by the crew prior to work starting.

Name of Verifier	Signature	Date	Date	Date

End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date
Did anything come up during this task worthy of further updates, revisions, or conducting a Learning Team?		

Job Safety Analysis

JSA Description: Waste Sampling	**Date of JSA Development: 2/2/2022**
Project Name: BNSF – Time Oil	**Field Lead: Emily Zikmund**
Site Address: 2737 West Commodore Way, Seattle, Washington	**Project No: 30102090**

Development Team (Include employer & email if not employed by Arcadis.)	
Minda Moe	
Dawn Monico	

Reviewed By (Include employer & email if not employed by Arcadis.)	**Position/Title:**	**Review Date** (MM/DD/YYYY)
Nick Monico	HASP Reviewer	1/31/2023

Permits/Plans Required (general, Specialized, etc.):	
Specialized tools/equipment:	Sampling equipment

MINIMUM REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- ☑ ANSI/ISEA 107-2010 Class 2 or 3 vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☑ Long pants
- ☑ Long-sleeved shirts
- ☑ Safety glasses, wraparound or with side shields labeled with ANSI Z87.1 rating, or a certification card for lenses and frames
- ☑ Safety footwear meeting ASTM F2413-05 standard with chemical or oil resistant soles
- ☑ High visibility work gloves (when high visibility glove options exist for a particular glove type)
- ☑ Hard hat that complies with ANSI Z89.1

TASK SPECIFIC: Personal Protective Equipment (PPE) Determination*

Eye Protection

Must comply with ANSI Z87.1

- ☐ Impact Goggles
- ☐ Flexible goggles
- ☐ Welding goggles/helmet or face shield. Tinted lenses required
- ☐ Laser safety glasses

Head Protection

- ☐ Type E Hardhat (Electrical)
- ☐ Hardhat with chin strap, miner's helmet with chin strap or mountaineering helmet with chin strap

Hazardous Atmosphere

- ☒ Photoionization Detector (PID)
- ☐ Flame Ionization Detector (FID)
- ☐ Dust Monitor
- ☐ LEL / O_2 Meter
- ☐ H_2S Meter

Hearing Protection

- ☐ Ear Plugs (noise 80 db)
- ☐ Ear Muffs with Ear Plugs (noise 105 db)

Body Protection

- ☐ Chemical resistant clothing recommended on SDS
- ☐ Chain saw chaps
- ☐ Snake chaps or boots marketed as "snake proof"[3]
- ☐ ANSI/ISEA 107-2010 Class 3 vest or ANSI/ISEA 107-2015 Type R, Class 2 vest if low light conditions or traffic flow at 50 mph or more
- ☐ ANSI/ISEA 107-2010 Class 2 or 3 ***BREAKAWAY*** vest or ANSI/ISEA 107-2015 Type R, Class 1 or 2 vest
- ☐ Sunscreen lotion >= SPF30
- ☐ Flying insect control: DEET (primary), permethrin (secondary)
- ☐ Tick control: Permethrin (primary), DEET (secondary)
- ☐ US Coast Guard approved personal flotation device (PFD) – Type I, II or III

Face Protection

- ☐ Chemical protective goggles that comply with ANSI Z87.1
- ☐ Face Shield over safety glasses

Respiratory Protection

- ☐ Half-face Air Purifying Respirator
- ☐ Full-face Air Purifying respirator
- ☐ SCBA or Supplied Air

Fall Protection

- ☐ Personal fall arrest system designed or approved by a qualified person OR other means of fall protection determined by qualified person

Hand Protection

- ☐ Chemical resistant gloves per SDS
- ☐ Cut-resistant gloves or liners
- ☐ Leather/Work gloves
- ☐ Welding gloves
- ☐ Leather gloves, insulated
- ☒ Nitrile gloves
- ☐ Impact resistant gloves

Foot Protection

- ☐ Safety shoes or boots with metatarsal guards
- ☐ Safety boots with puncture-resistant midsoles or that have built-in puncture resistance (PR rated)
- ☐ Safety boots with electric hazard (EH) protection (standard in most footwear)
- ☐ Rubber-sole boots or grips
- ☐ Chemical resistant boot covers
- ☐ Lace-up safety boots conforming to ASTM F2413-05 or equivalent in non-US jurisdictions

Heat, Flame, Flash Fire or Arc Hazard

- ☐ Cooling vest
- ☐ Flame resistant clothing (FRC)

***If an item is checked, it is relevant for all job steps. If an item is specific to a particular job step it must be noted in the Critical Action(s) column in the JSA.**

Job Safety Analysis

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. “slip, trip, fall” or “fire”. Example of better wording: “tripping on silt fence” or “fire due to static discharge in hose”.)	**Critical Action(s)** (Avoid using generic words (i.e. use “proper” PPE or “proper” lifting techniques). Consider “wear Level A2 cut resistant gloves under nitrile gloves” or “lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads”.)	**Responsible Person(s) – Initials**
1. Set up sampling equipment	MOTION - Lacerations from sharp edges of sampling point, resulting in hand lacerations or abrasions	• Do not grab edge of sampling port or drum. Visually identify and verbalize sharp edges and pinch points with site workers. • Wear Level 2 cut resistant gloves while handling equipment/debris to prevent hand lacerations.	
	GRAVITY - Slip/Trips/Falls over sampling equipment resulting in broken bones, sprains, or lacerations	• Visually check for and remove trip hazards prior to setup of sampling equipment. • Stage equipment in one central location to minimize trip hazards.	
	MOTION - Struck by vehicle resulting in broken bones, lacerations, abrasions, sprains or death	• Scan work zone and surrounding area for traffic. If vehicle approaches work zone or parks beside work zone STOP WORK, make eye contact with driver and wait for vehicle to stop and driver to exit vehicle leaving work zone prior to resuming activities. • Wear level II traffic vest to increase visibility of personnel to on and off site traffic.	
	MOTION - Nails or other sharp objects piercing the bottoms of boot and feet	• Perform a site walks to clear area of nails and other sharp objects on the ground using telescope magnets to pick up and dispose of the sharp object or brooms to push the objects out of the work area. • Wearing puncture resistant boots or steel sole inserts to prevent sharp objects from piercing the bottom of boots.	
2. Collection of sample	MOTION - Back strain from bailing water/collecting sample/lifting and carrying 5 gallon bucket to drum	• Only fill buckets ½ - ¾ full to help avoid carrying over 50 lbs.	

JSA Description:	**Site ID:**

BIOLOGICAL	CHEMICAL	ELECTRICAL	GRAVITY	HUMAN PERFORMANCE	MECHANICAL	MOTION	PRESSURE	RADIATION	SOUND	TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		 • Kneel instead of bending over at the waist or squatting when working at low levels. Lift at knees/with legs not back or shoulders. Do not twist at waist to avoid back strains/sprains. • Use knee pads to prevent knee scrapes and abrasions from kneeling on ground.	
	CHEMICAL - Chemical exposure to waste or soil and/or sample preservation fluids while filling VOA/sampling media resulting in personal injury	• Fill sample bottles slowly to avoid splashing/spillage. • Wear nitrile gloves over Level 2 cut-resistant gloves to prevent chemical exposure to skin.	
	MOTION - Lacerations from glass sample bottle breakage resulting in hand injury	• Never overtighten caps on glass VOA vials to avoid possible breakage. • Place VOA/sampling media in bubble wrap as soon as possible once sample has been taken. • Wear Level 2 cut-resistant gloves to prevent hand lacerations due to bottle breakage.	
	CHEMICAL - Chemical exposure from vapor/gas inhalation resulting in personal injury or asphyxiation	• Keep face away from sampling port or drum • Work upwind of sampling point • STOP WORK and report any noticeable vapors to supervisor. • Conduct air monitoring per HASP. • If a full-face respirator must be worn worn during sampling operations to prevent inhalation and splash hazards to the face and eyes, conduct pressure testing prior to beginning operations.	

JSA Description:	**Site ID:**

BIOLOGICAL CHEMICAL ELECTRICAL GRAVITY HUMAN PERFORMANCE MECHANICAL MOTION PRESSURE RADIATION SOUND TEMPERATURE

Job Steps (Avoid listing too many job steps for a task. Consider multiple JSAs instead.)	**Potential Hazard(s)** (Avoid being too general- i.e. "slip, trip, fall" or "fire". Example of better wording: "tripping on silt fence" or "fire due to static discharge in hose".)	**Critical Action(s)** (Avoid using generic words (i.e. use "proper" PPE or "proper" lifting techniques). Consider "wear Level A2 cut resistant gloves under nitrile gloves" or "lift with the legs and not the back, get assistance when carrying over 50 pounds or bulky loads".)	**Responsible Person(s) – Initials**
		 Positive Pressure Check Negative Pressure Check	
3. Load equipment into work truck	MOTION - Back/muscle strain from loading equipment	• Do not lift weight >50 lbs on your own, lift with legs and not the back and keep all loads close to your body. Reposition body using feet, do not twist at waist.	
	MOTION - Lacerations to hands from sharp edges	• Use equipment handles to move equipment. • Wear Level 2 cut-resistant gloves while handling equipment and avoid grabbing/holding sharp edges/points.	
	GRAVITY - Slip/Trips/Falls on equipment resulting in broken bones, sprains, or lacerations	• Visually check for and remove trip hazards in work area. • Stage equipment in one central location to minimize trip hazards.	

JSA Acknowledgement

"I have read this JSA, and I understand the hazards and safe work practices associated with the task.
If conditions change or an additional hazard is recognized, I will Stop Work and notify the Site H&S Officer immediately:"

This JSA must be acknowledged by affected workers every shift.

Name	Signature	Initials Used on Form	Date	Date	Date	Date	Date	Date

Verification of Critical Actions – Undersigned verifies that critical actions are in place, or have been evaluated based on availability, effectiveness and understood by the crew prior to work starting.

Name of Verifier	Signature	Date	Date	Date

End of Day Lookback – Use this section to log changes made to the JSA throughout the day and note any recommendations for Task JSA.

Brief description Lookback	Lookback Leader Name	Date

Job Safety Analysis

General

JSA ID	HASP 1	**Status**	Complete
Job Name	General Industry-Driving - passenger vehicles	**Created Date**	1/27/2023
Task Description	Driving a car, van, or truck on public roadways.	**Completed Date**	01/27/2023

Client / Project

Client	BNSF
Project Number	30102090
Project Name	BNSF - Time Oil
Project Manager	Kyle Haslam

User Roles

Role	**Employee**	**Due Date**	**Completed Date**
Developer	Dawn Moncio	1/27/2023	1/27/2023
HASP Reviewer	Monico, Nicholas - Wexford PA	1/27/2023	1/27/2023
Quality Reviewer			

Job Steps

Job Step No.	**Job Step Description**		**Potential Hazard**	**Critical Action**	**H&S Reference**
1	Pre-Trip Inspection	1	Failing to perform pre-trip inspections may cause mechanical failure, accident or injury.	Perform walk around of vehicle with particular attention to tire inflation and condition. Check lights, wipers, seatbelts for proper operating condition. Properly adjust seat and mirrors prior to vehicle operation. Use or review vehicle inspection checklist as required under the MVSP.	ARC HSGE024 Motor Vehicle Safety Standard (MVSP)
		2	Scrapes, cuts, burns to hand if inspecting engine fluids and/or tires. Eye splash hazard if inspecting engine fluids. Pinch or crush hazards when opening or closing hood, trunk, or tailgate.	Wear protective gloves and safety glasses as described below when checking under hood or tires. Use TRACK and keep hands clear when opening/closing hood, trunk, or tailgate to avoid crush or pinch hazard.	
		3	Struck by other vehicles while walking around vehicle performing inspections.	Wear high visibility vest, shirt, or coat while performing inspections in parking lots or other areas with a traffic hazard. Remain vigilant of moving vehicles or equipment in area, face oncoming vehicles to extent practical.	
		4	Improperly secured cargo may dislodge creating injury, property damage, or road hazard.	Ensure all cargo is properly secured to prevent movement while the vehicle is in operation. This includes cargo in the cab of the vehicle.	
2	Driving a motor vehicle on public streets	1	Failing to observe traffic flow ahead increases risk of hard braking resulting in potential impact of vehicle ahead, being struck by another vehicle from behind, and decreases decision making time.	Use Smith System Key #1, "Aim High in Steering". **Look ahead (15 seconds if possible) to observe traffic flow and traffic signals.** Adjust speed accordingly to keep vehicle moving and avoid frequent braking. Select lane of least traffic and adjust speed based on observed signal timing when possible. Avoid following directly behind large vehicles that obscure view ahead.	Smith System "5-Keys" is a registered trademark of Smith System Driver Improvement Institute, Inc.

		2	Failing to observe vehicles, pedestrians, bicyclists, and other relevant objects in vicinity of your vehicle increases risk of side swipes, rear ending, and third party injury.	Use Smith System Key #2, "Get the Big Picture". **Maintain 360 degrees of awareness around vehicle.** Check a mirror every 6-8 seconds, maintain space around the vehicle, choose a lane that avoids being boxed in. Look for pedestrian activity ahead in crosswalks or sidewalks. Watch for construction zone approach signs and act early by executing lane changes and reducing speed.	
		3	Failing to keep your eyes moving increases risk of not seeing relevant vehicles, pedestrians, and objects in your vicinity that may impair your ability to make timely and appropriate driving decisions and also increases risk of accident.	Use Smith System Key #3, "Keep Your Eyes Moving". **Move your eyes every 2 seconds and avoid staring while evaluating relevant objects.** Scan major and minor intersections prior to entering them. Check mirrors.	
		4	Failing to maintain space around and in front of your vehicle increases risk of striking another vehicle or being struck by another vehicle. Insufficient space shortens time for effective driving decision making resulting in increased accident risk.	Use Smith System #4, "Leave Yourself an Out". **Use 4 second rule when following a vehicle.** Avoid driving in vehicle clusters by adjusting speed and using lanes that permit maximum space and visibility. When stopped, keep one car length space in front of vehicle ahead or white line.	
		5	Failing to communicate with other drivers and pedestrians increases risk of striking vehicles, pedestrians, or being struck by other vehicles, especially from the rear.	Use Smith System Key #5, "Make Sure They See You". **Brake early and gradually when stopping to reduce potential of being rear ended.** Keep foot on brake while stopped. Use turn signals and horn effectively. Establish eye contact with other drivers and pedestrians to extent practical. Use vehicle positioning that promotes being seen.	
		6	Distractions within the vehicle takes focus off driving, increases risk of accident decreases time for making effective driving decisions.	**Cell phone use (any type or configuration) is prohibited while the vehicle is in motion.** Familiarize yourself with vehicle layout and controls (radio, temperature controls, etc.) prior to operating unfamiliar vehicles. Set controls prior to operating vehicle. Use GPS in unfamiliar areas to avoid use of paper maps/directions while driving. Set GPS prior to vehicle operation. Pull over and stop to modify GPS functions. Avoid consuming food or drink while driving.	
3	Parking	1	Parking vehicle in areas of clustered parked vehicles or near facility entrance may impair visibility to oncoming traffic in lot and increase exposure to pedestrian traffic.	**Use pull through parking or back into parking space when permitted or practical.** When practical and safe to do so, park away from other vehicles and avoid parking near the facility entrance or loading docks. If available, use a spotter to aid in backing activity. Back no further than necessary and back slowly. Get out and look (GOAL) if uncertain of immediate surroundings. Tap horn prior to backing.	

PPE Personal Protective Equipment

Type	Personal Protective Equipment	Description	Required
Eye Protection	safety glasses	While checking engine or tires	Required
Hand Protection	work gloves (specify type)	Leather or equivalent checking engine or	Required

Supplies

Type	Supply	Description	Required
Communication Devices	mobile phone		Required
	other	Vehicle kit (applies to company trucks)	Required
Miscellaneous	fire extinguisher	Applies to company trucks	Required
	first aid kit	Applies to company trucks	Required

Attachment E

Arcadis H&S Standards

Table of Contents

QUICK SHEET

Applicability

Heat related illnesses (also referred to as “Heat Stress”) are caused by working in hot environments. The hazards associated with working in hot environments can be controlled and minimized by using safe work practices such as applying administrative controls, engineering controls, and providing the appropriate personal protective equipment (PPE).

Need To Know

Project personnel are responsible for understanding the conditions, signs, and symptoms that can lead to heat illness and adhering to the prescribed control and mitigation and methods.

Personal risk factors for heat illness include poor health, age, excessive weight, and pre-existing medical conditions; inadequate acclimation to working in the heat; and a previous episode of heat illness. Environmental risk factors include workload severity and duration, high temperature and humidity, direct sun exposure, and insufficient air movement. If left unchecked, heat illness will progress to the heat stroke stage, which is a life-threatening condition, and emergency personnel should be contacted immediately.

Preventive safe work practices involve avoidance of working in the heat when possible; taking regularly scheduled shade breaks; acclimatization; rotating personnel; avoiding beverages containing caffeine or sugar; staying appropriately nourished; maintaining hydration; and providing readily available fresh, pure, and suitably cool potable water access at all times.

Engineering controls that should be implemented include monitoring and measuring temperature and heat index factors, designing appropriate work/rest cycles, and choosing clothing that allows for wicking of perspiration.

Personnel will report any signs and symptoms of heat illness exhibited by themselves or by other personnel.

Training

Training for heat illness prevention will be provided to all supervisory employees before project assignment. Topics will include the importance of acclimatizing, risk factors, signs and symptoms of various heat illnesses, and procedures to follow in the event of an emergency. Staff working in California, Washington, or other states with specific heat illness standards must receive documented training before assignment. Other affected employees not working in these states must be familiar with this HSS and the information detailed in the Field Health & Safety Handbook. Corporate H&S recommends that all staff that might reasonably be anticipated to be exposed to the risk of heat illness complete the online heat illness training course.

Equipment

Equipment required for work in hot environments may include but is not limited to cooling devices, shade structures and weather monitoring devices. Refer to the Heat Plan H&S Plan Supplement for project or task specific equipment required.

Permits or Forms Required

The Heat Plan H&S Plan Supplement will be prepared during project planning to document and communicate the site-specific heat illness prevention provisions for projects in California and Washington State (best management practice [BMP] for other states).

1. POLICY

It is Arcadis policy that the project team and field staff will work together to protect on-site personnel from the hazards of heat illness when employees are required to work in hot, outdoor places of employment or in other areas where the environmental risk factors for heat illness are present.

Heat-related illnesses may be prevented by using safe work practices including administrative controls, engineering controls, and/or appropriate personal protective equipment (PPE).

2. PURPOSE AND SCOPE

2.1 Purpose

The purpose of this Health & Safety Standard (HSS) is to promote employee awareness regarding heat illness symptoms, direction on the controls and prevention of heat-related illnesses, and guidance on appropriate response actions if symptoms do occur.

2.2 Scope

This HSS applies to Arcadis projects that include, but are not limited to: indoor operations in hot environments or outdoor operations conducted in hot weather such as construction, refining, oil and gas extraction, asbestos removal, and hazardous waste site activities, especially those that require employees to wear semipermeable or impermeable chemical protective clothing (CPC) that are likely to cause heat illness among the exposed. California and Washington State enforce specific occupational heat illness prevention requirements, which are addressed in this HSS. Project teams are advised that, for all other states and U.S. territories, the information provided in this HSS will be used as best management practices (BMPs) for addressing heat-related illness prevention.

Project sites located in California and Washington State must comply with the requirements set forth in this HSS, which has been developed to comply with the California Occupational Safety and Health Administration (Cal/OSHA) Title 8 California Code of Regulations (CCR) 3395 Heat Illness Prevention Standard and the Washington State Outdoor Heat Exposure Regulations 296-62-09510 thru 09560. Project sites in California and Washington State must complete the HASP Supplement and include this HSS as an attachment to the field copy of the HASP, along with the completed HASP Supplement.

3. DEFINITIONS

There are a number of definitions associated with this standard. These definitions are presented in Exhibit 1 of this document. A list of acronyms and abbreviations used in this HSS is provided in Exhibit 2.

4. RESPONSIBILITIES

4.1 Project Managers, Associate Project Managers, and Task Managers

Project Managers (PMs), Associate Project Managers (APMs) and Task Managers (TMs) are responsible for ensuring that heat illness is considered and addressed in project task hazard analysis, risk assessment, and project planning.

Ensure that the project Health & Safety Plan (HASP) addresses the need for adequate water, provisions for shade are available at a job site, and that time is available for staff to eat when the environmental risk factors for heat illness are present.

Ensure that the HASP addresses the need for affected employees to receive applicable training on heat illness prevention and that staff are provided time to complete the training before starting work.

4.2 Supervisory Personnel

Supervisory personnel (e.g., Site Safety Officers [SSOs], PMs, APMs, and/or TMs who are supervising employees working on site and in the heat) must review this HSS and complete training in the prevention of heat related illnesses before supervising employees that work in the heat (risk of heat illness). Supervisory personnel will be trained in heat illness prevention methods and provided procedures in this HSS to follow when an employee exhibits symptoms consistent with possible heat illness including emergency response procedures. Supervisory personnel must ensure that personal risk factors that contribute to heat-related illness are considered before assigning a task where there is the possibility of a heat-related illness occurring (See Section 5.2 for risk factors) and plan for and implement preventive measures and controls when heat advisories are issued for those areas in which staff will be working.

Ensure that effective communication by voice, observation, or electronic means is maintained so that site employees can contact a supervisor, WorkCare, or emergency medical services when necessary. Devices, such as radios or mobile phones or satellite phones, may be used for this purpose only if reception in the area is reliable. If an electronic device does not provide reliable communication in the work area, the project team must ensure that a suitable means of summoning emergency medical services is available.

Ensure that affected employees working on site have received proper training on heat illness prevention.

Ensure that the requirements in this HSS are documented and followed.

Ensure that staff working in the heat have constant access to suitably cool, fresh, pure potable water; are provided routine breaks; and have access to shade.

4.3 Affected Employees

Employees are responsible for understanding the conditions, signs, and symptoms that can lead to heat illness and for using and adhering to the prescribed control and mitigation and methods. Personnel will report to the SSO and/or PM any signs and symptoms of heat illness exhibited by themselves or by other personnel on the project site.

If site personnel have not received heat illness training before conducting work, then site personnel will be educated on heat illness prevention by reviewing this HSS, reading the site HASP (including the site-specific Heat Illness Prevention Plan [HIPP] HASP Supplement as required for California and Washington States), and by attending the daily tailgate meeting.

Employees must review and comply with the provisions of this HSS.

Employees must ensure that they have suitably cool, fresh, pure (potable) water available at all times and that they eat before starting work and during the day when the environmental risk factors for heat illness are present.

Employees will ensure that they have constant access to a shaded area to prevent or recover from heat-related symptoms.

4.4 Corporate Health & Safety

Corporate H&S is responsible for keeping this HSS up to date with regulatory requirements and best work practices.

As requested, provide training to potentially impacted employees and their supervisors on the risks and prevention of heat illness, including how to recognize symptoms and how to respond when they appear.

5. PROCEDURE

5.1 Safe Work Practices

Arcadis staff will follow these general safe work practices when working in hot environments:

- Where determined by regulation, the project site will implement heat illness prevention measures when temperatures in the work area exceed an equivalent heat index temperature of 80 degrees (°) Fahrenheit (F) or 26.6° Celsius (C), accounting for ambient air temperature, humidity, use of semi-permeable and impermeable PPE, and the degree of exertion by the workers.
- Staff will avoid working during periods of high heat (≥ 95°F / 35°C) when possible. This can be accomplished by avoiding scheduling work during the hottest parts of the day, working in cooled enclosures, or providing cooling units in the work area. Severe heat conditions can be cause for stopping or not starting work.
- Allow personnel to acclimatize and adapt to the heat; specifically, those employees new to the project, wearing semi-permeable/impermeable PPE, conducting strenuous tasks, or working in high heat areas.
- The SSO will be particularly watchful of the condition of new employees and stay alert to the onset of heat-related symptoms. New employees will be assigned a “buddy” or experienced co-worker for monitoring each other closely for symptoms of heat illness.
- Whenever possible, rotate personnel in/out of working conditions where heat is a hazard.
- Personnel will have constant access to suitably cool, fresh, pure (“fresh and pure” is defined as being free of odors) water. Where the supply of water is not plumbed or otherwise continuously supplied, water will be provided at no cost to the employee(s) (or employee will be reimbursed) in sufficient quantity at the beginning of the work shift and for the shift duration.

Note: *Thirst cannot be relied on as a guide for hydration. Employees need to drink cool, fresh water throughout the day (four 8 oz cups per hour) during hot weather. Electrolyte replacement drinks or "Sports Drinks" can be used to replace essential minerals lost during sweating. Generally, such drinks should supplement water intake such as one "sports drink" to every three bottles of water. One teaspoon of salt added to every gallon of water could also be used.*

Electrolyte replacement and "Sport Drinks" should not be used as the primary source of hydration or as a substitute for food or water.

- Employees will be notified of the location(s) of the closest drinking water supplies.
- Employees should be advised to choose non-carbonated water over sodas and other beverages containing caffeine or sugar.
- Employees should eat before work and then during the work rotation.
- Employees and the SSO must understand the individual, pre-disposing susceptibilities to heat illness (e.g., previous exposure to heat illness or when taking certain medications).
- Employees must understand the signs and symptoms of heat illness including discomfort, excessive sweating, headache, poor concentration, muscle pain, cramping, dizziness, fatigue, irritability, loss of coordination, vomiting, blurry vision, confusion, lack of sweating, fainting, and seizures.
- Employees must understand first aid and emergency response procedures associated with heat illness.
- If an emergency arises, it is critical that employees understand the process and contact information for requesting emergency medical support. The reception coverage for the site must be evaluated to ensure that adequate communication is in place across the project site and for contacting emergency responders.
- See Exhibit 3 for more safe work practices information.
- See Exhibit 4 for a link to the HASP Supplement, contained in the Standard Excel® HASP template.

5.2 Risk Factors for Heat-Related Illnesses

The personal and environmental risk factors for heat-related illnesses must be evaluated as part of the TRACK process before performing a task.

5.2.1 Personal Risk Factors

Risk factors applicable to the individual employee must be considered when evaluating a working environment for potential exposure to heat illness. The following risk factors should be considered for each individual employee, as these may vary among individuals.

- No recent exposure to high heat work areas is a risk factor because the individual's body is not acclimatized to working in the heat.
- Individual susceptibilities, such as age, weight, degree of physical fitness, use of medications, and certain medical conditions (such as hypertension and diabetes), all affect the potential to experience a heat-related illness.
- A person is at greater risk for heat illness when they are in poor health, are dehydrated, have not eaten, have not been acclimated to working in the heat, or have experienced previous heat illness.

- Working in a hot environment tends to lower the mental alertness and physical performance of an individual. Increased body temperature and physical discomfort promote irritability, anger, and other emotional states that have the potential to cause personnel to overlook safety procedures or to divert attention from hazardous tasks.
- Wearing PPE that increases the potential for the onset of heat illness symptoms is also considered a risk factor for the onset of heat illness.

5.2.2 Environmental Risk Factors

Some risk factors are considered environmental, and therefore apply to all individuals working in a specific area. These are additional to any personal risk factors identified for individual employees. The following risk factors should also be considered when determining the potential for the occurrence of heat illness.

- High temperature and humidity
- Working in direct sun
- No breeze or wind
- Radiant heat or heated air movement
- Conducting strenuous tasks and long duration work.

Working in the heat tends to increase the likelihood of accidents due to the slipperiness of sweaty palms, dizziness, or the fogging of safety glasses. The frequency of accidents, in general, appears to be higher in hot work environments (> 80°F/26.6°C) than in environments involving moderate temperatures.

5.3 Administrative and Engineering Controls

When feasible, Arcadis staff will implement the following administrative and engineering controls:

- Avoid scheduling work during the hottest parts of the day when possible. Alternatively, schedule more strenuous tasks or tasks that require use of semi-permeable or impermeable (e.g. non-breathable, non-venting) PPE early in the morning when conditions are typically cooler than midday or afternoon conditions.
- Monitor the temperature and humidity at the site. These comprise the heat index factors, which convey the magnitude of the heat hazard. Discussion during the daily safety briefings is critical to ensure that this hazard is understood by on-site personnel. Monitoring can be accomplished with on-site instrumentation, especially when working indoors or in enclosed spaces, or by monitoring outdoor weather conditions through the internet, radio, or local weather bureaus. See Section 5.3.4.
- Encourage personnel to wear appropriate clothing that allows for the wicking away of perspiration as a form of evaporative cooling to help cool the wearer.
- Develop and implement appropriate work/rest cycles to allow for adequate cool-down periods.
- Employees suffering from heat illness related symptoms must be allowed, and will be encouraged, to take a preventive cool-down rest in an area with shade that is either open to the air or provided with ventilation or cooling (e.g., cooling stations, misters, air-conditioned spaces). While taking a preventive rest, the employee will be monitored for heat illness symptoms by the SSO and encouraged to remain in the shade and not allowed to return to work until the symptoms are gone. Access to shade will always be permitted.

5.3.1 Procedure for Acclimatization

Supervisors, SSOs, and employees will be trained on the importance of acclimatization, how it is developed, and how to implement an acclimatization process consistent with applicable regulations and the guidelines set forth in this HSS. An employee is at risk of heat illness during a sudden increase in the ambient temperatures of the work environment if not given time to adjust to the changing conditions. Acclimatization (the physiological process of becoming accustomed to changing conditions) is necessary especially in conditions of high heat and for tasks requiring strenuous physical exertion. In addition to acclimatization, other factors can affect employees working at sites where high temperatures are anticipated, such as: poor general health, age, weight, pre-existing medical conditions, and having previously experienced heat illness. Employees are not required to share personal health information such as pre-existing medical conditions. However, including a discussion of how these factors can contribute to the onset of heat illness in the Tailgate Safety Meeting discussion raises individual awareness of the risks involved with heat illness.

A gradual acclimatization period will be implemented for new employees that have not been exposed to a work environment where high temperatures are present (e.g., employees not accustomed to the conditions of the work site will be given slower paced, less physically strenuous tasks during the hot parts of the day and given the more physically strenuous tasks during cooler parts of the day). New employees will be closely monitored during their acclimatization period, which can last up to 2 weeks. The steps taken to reduce the workload intensity for employees not yet acclimated to working in high heat conditions will be documented in the field copy of the HASP Supplement.

The SSO or designee is responsible for implementing the following procedures for acclimatization. These procedures include, but are not limited to, the following:

- Observing employees closely for signs of heat illness. Specific site conditions warranting close observation include, but are not limited to, any day when the temperature is 80°F/26.6°C or greater and is at least 10°F (6°C) higher than the average daily temperature for the preceding 5 days.
- Providing effective acclimatization procedures for employees during exposure to a sudden increase in temperature. The SSO will be aware of those employees who are not yet acclimatized to sudden changes in temperature and will attend to those employees to prevent heat illness.
- Monitoring weather daily. The SSO will be on the lookout for sudden heat wave(s) or increases in temperatures that employees haven't been exposed to for several weeks or longer per Section 5.3.4 Weather Monitoring Procedures, detailed in this HSS.
- Implementing specific Work/Rest Cycles based on monitoring vital signs of on-site personnel, see Section 5.4.3.

5.3.2 Provisions for Water at the Site

At the start of work, the importance of drinking water, the signs and symptoms of heat illness, the location(s) of the water/water coolers, and the schedule of water/rest breaks will be communicated to all staff during each Tailgate Safety Meeting. The SSO or the designated alternate will provide for distribution of suitably cool, fresh, clean potable (drinking) water at the project site. An adequate supply of suitably cool, fresh, clean potable water will always be maintained on site to allow each employee to consume 1 quart (1 liter [1 L]) of water per hour (i.e., 2 gallons [8 L] per employee for an 8-hour shift).

Where unlimited drinking water is not immediately available from a plumbed system or otherwise continuously supplied, water will be provided to staff via coolers containing bottled water or insulated drinking water dispensers (verify that coolers/dispensers are of a sufficient capacity to support the amount of field staff present) accompanied with disposable cups to maintain sanitary conditions for potable water consumption. When conditions are anticipated to exceed 80°F/26.6°C, SSOs and/or supervisors will encourage employees to drink water before they "feel" thirsty. Ideally, drinking 8 ounces of water every 15 minutes will allow the body to remain properly hydrated while working in high temperature conditions.

If the decision is made not to provide all site employees the full-shift quantity of drinking water at the start of a work shift (i.e., 2 gallons [8 L] per employee for an 8-hour shift), then effective procedure(s) must be documented and implemented to ensure drinking water replenishment to allow each employee to drink 1 quart (1 L) per hour. This means that a sufficient quantity of water must always be present and readily accessible to allow every employee to consume at least 1 quart of water per hour until the water supply has been replenished.

- Coolers containing bottled water or drinking water coolers should be maintained to provide for a minimum of 3 hours of water per employee (at least 1 quart [1 L] of water will be made available per employee per hour) to account for a sufficient quantity of water to always be present.
- Water supplies will be positioned as close as reasonably possible to site workers. Ideally, water supplies will be positioned within 50 feet of employee activity or in vehicles used by employees to gain access to individual work areas; however, coolers will be stationary when employees are essentially stationary. Placing water only in shaded areas or by toilet facilities is not sufficient, particularly at large work sites or at multi-story construction sites. Drinking water sources need to be close enough to workers to allow for routine consumption.
- Coolers will be inspected and replenished with water and ice for cooling periodically (e.g., every 30 minutes, or based on site temperature and number of employees present) by the SSO or designee.
- Ice will be added to the coolers, as necessary, during the required inspections.

  ***Note**: When the temperature exceeds 90°F (32°C), inspections will be increased in frequency and ice will be added as needed to keep water cool*.

- Ice will be distributed from a separate cooler or service and added to coolers to ensure that the drinking water remains potable and appropriately cool for employee consumption. Ice used to chill the water will be stored separately to remain sanitary. Sanitary ice storage can include storage of ice in bags when bottled water is used or use of separate storage coolers when using drinking water dispensers.
- Coolers will be inspected and cleaned after each work shift or before starting work each shift. The SSO will oversee cooler maintenance and provide appropriate cleaning supplies.
- The SSO or designee will document the weekly review of the HASP Supplement and make the necessary adjustments each week for weather changes or when new employees are introduced to the project. The reminder may include water ordering information if purchased in bulk from an appropriate supplier.

5.3.3 Access to Shade

The project team is responsible for making sure that the necessary equipment to provide shade is available at the project site. The temperature threshold for shade to be in place is when site temperatures exceed 80°F/26.6°C. The SSO or designee is responsible for directing how shade will be coordinated and placed. The term “shade,” for the purposes of complying with applicable regulations, will be defined as “The blockage of sunlight to the extent that no shadow is cast while sitting in the designated area.” Flecks of sunlight are acceptable as long as, overall, the shade provides substantially complete blockage of sunlight. Where trees or other vegetation are used to provide shade, the thickness and shape of the canopy must cast sufficient shadow, given the changing angles of the sun, to protect employees from the sun during the entire shift.

At the start of each shift, the importance of taking shade breaks, recognizing the signs and symptoms of heat illness, the duration of shade breaks (> 5 minutes per break), and the shade location will be addressed during each Tailgate Safety Meeting. Access to shade must be allowed at all times.

***Note**: Where required by regulation, shade breaks will be taken at a minimum rate of 15 minutes of shade for every 2-hour work period. As temperature increases shade breaks will increase in frequency. See the Heat Index table in Section 5.4 for Heat Index specific Action Levels defining shade break frequency and duration.*

Establishing adequate shaded areas for employees involves:

- If the temperature at the site exceeds 80°F, shade structures will be opened and made available to employees.
- Shaded areas must be able to accommodate all employees taking a recovery or rest break including those employees who are on meal breaks. This does not mean that the shaded area(s) must provide shade to accommodate all employees on a site or working a shift *at the same time.* An example includes rotating routine breaks among employees. Also, additional portable shade structures can be erected as needed.
- Employees must have enough shaded space to sit comfortably while fully shaded and to allow for sitting without being in physical contact with each other.

  ***Note**: When establishing shade, it is important to ensure that employees who desire access to shade will not be deprived of it due to lack of space. One such procedure to address this point would be to rotate employees in and out of shaded areas to ensure that all have sufficient access for the 15-minute interval required. Another option would be to have additional shade structures on hand to deploy as needed.*

- Shade structures will be relocated to follow the crew for moving tasks.
- Shade structures will be placed within 50 feet of the work area if practical. A key consideration when placing a shade structure is that it is a short walk away (e.g., 2 to 3 minutes) from the work area. This consideration becomes critical as the temperature rises above 80°F/26.6°C.
- Where it is not safe or feasible to provide shade, notes will be made to the HASP Supplement of the unsafe or unfeasible conditions. The SSO will also document the steps taken to provide alternative cooling measures equivalent to providing shade, such as vehicles equipped with air conditioning or air-conditioned office trailers.
- An employee who takes a preventive cool-down rest:

  - Will be monitored by the SSO and asked if they are experiencing symptoms of heat illness.
  - Will be encouraged to remain in the shade.
  - Will not be ordered back to work until any signs or symptoms of heat illness have abated.
  - If an employee exhibits signs or symptoms of heat illness while taking a preventive cool-down rest, the SSO will provide appropriate first aid or emergency response.

5.3.4 Monitoring of Weather and Procedures for Heat Waves

The SSO or designee will be trained in consulting weather forecasting resources and is responsible for checking the extended weather forecast before work. Work schedules will be adjusted in advance, considering whether high temperatures or a heat wave is expected. The SSO will be responsible for obtaining thermometers before the start of the project and ensuring that they are readily accessible or posted on site for ease of monitoring throughout the workday. The following web pages are considered accurate and reliable sources for checking weather forecasts:

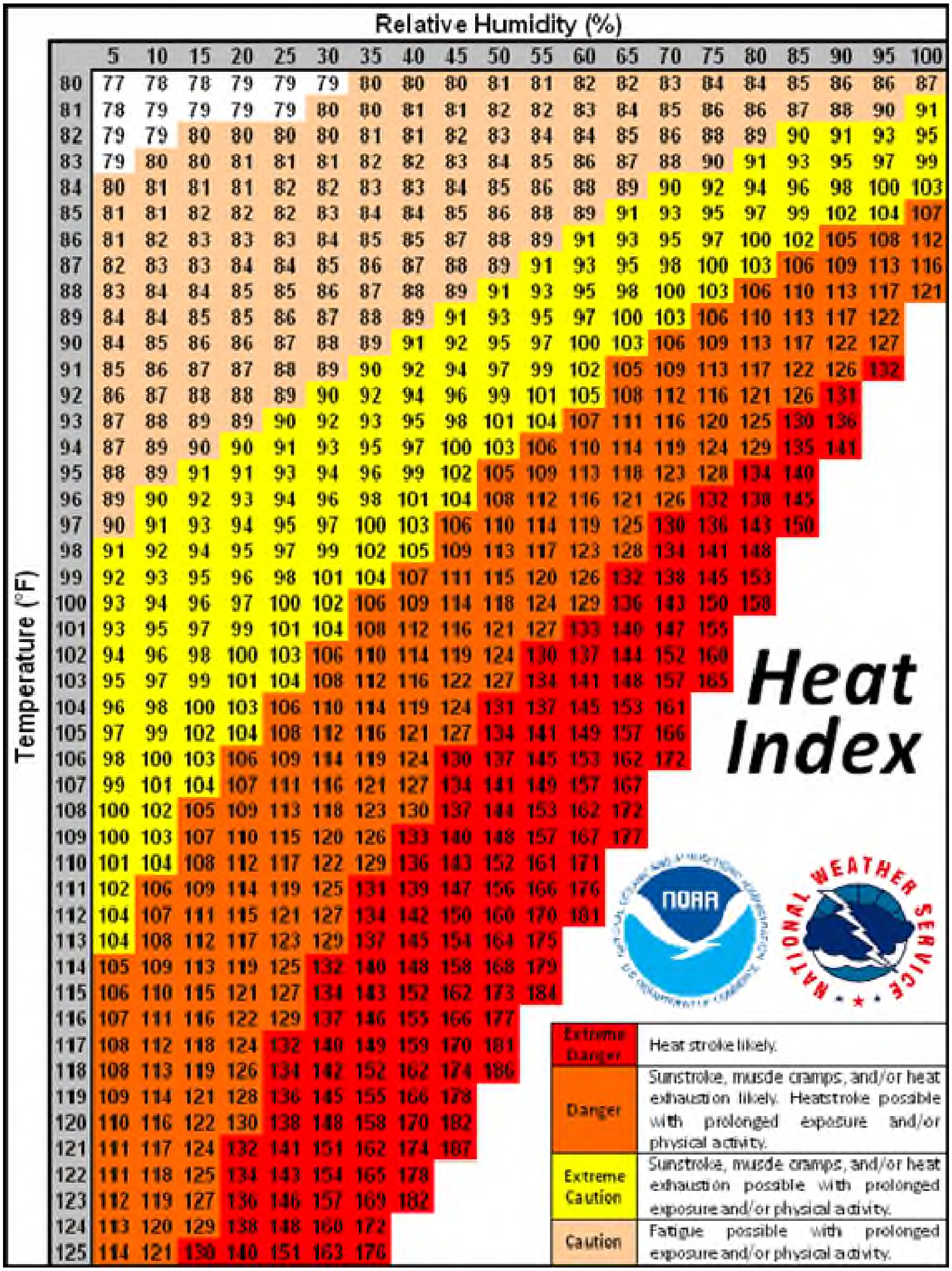
- http://www.noaa.gov/
- https://www.weather.gov/

Before starting each shift, the SSO or designee will review the forecasted temperature and humidity for the work site and compare conditions against the National Weather Service Heat Index (See Table 1) to evaluate the risk level for heat illness. A “heat wave,” as defined by the National Oceanic and Atmospheric Administration (NOAA), is a period of abnormally and uncomfortably hot and unusually humid weather.” Typically, a heat wave lasts 2 or more days.

5.4 Heat Index Table, Heat Index Action Levels, and Recommended Hazard Controls

The following action levels and controls information are intended to be used as recommended guidance by project teams for work conducted in all states except where heat-related illness hazard controls are required by regulation.

Table 1 – Heat Index Table



Relative Humidity (%)

Temperature (°F)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
80	77	78	78	79	79	79	80	80	80	81	81	82	82	83	84	84	85	86	86	87
81	78	79	79	79	79	80	80	81	81	82	82	83	84	85	86	86	87	88	90	91
82	79	79	80	80	80	80	81	81	82	83	84	84	85	86	88	89	90	91	93	95
83	79	80	80	81	81	81	82	82	83	84	85	86	87	88	90	91	93	95	97	99
84	80	81	81	81	82	82	83	83	84	85	86	88	89	90	92	94	96	98	100	103
85	81	81	82	82	82	83	84	84	85	86	88	89	91	93	95	97	99	102	104	107
86	81	82	83	83	83	84	85	85	87	88	89	91	93	95	97	100	102	105	108	112
87	82	83	83	84	84	85	86	87	88	89	91	93	95	98	100	103	106	109	113	116
88	83	84	84	85	85	86	87	88	89	91	93	95	98	100	103	106	110	113	117	121
89	84	84	85	85	86	87	88	89	91	93	95	97	100	103	106	110	113	117	122	
90	84	85	86	86	87	88	89	91	92	95	97	100	103	106	109	113	117	122	127	
91	85	86	87	87	88	89	90	92	94	97	99	102	105	109	113	117	122	126	132	
92	86	87	88	88	89	90	92	94	96	99	101	105	108	112	116	121	126	131		
93	87	88	89	89	90	92	93	95	98	101	104	107	111	116	120	125	130	136		
94	87	89	90	90	91	93	95	97	100	103	106	110	114	119	124	129	135	141		
95	88	89	91	91	93	94	96	99	102	105	109	113	118	123	128	134	140			
96	89	90	92	93	94	96	98	101	104	108	112	116	121	126	132	138	145			
97	90	91	93	94	95	97	100	103	106	110	114	119	125	130	136	143	150			
98	91	92	94	95	97	99	102	105	109	113	117	123	128	134	141	148				
99	92	93	95	96	98	101	104	107	111	115	120	126	132	138	145	153				
100	93	94	96	97	100	102	106	109	114	118	124	129	136	143	150	158				
101	93	95	97	99	101	104	108	112	116	121	127	133	140	147	155					
102	94	96	98	100	103	106	110	114	119	124	130	137	144	152	160					
103	95	97	99	101	104	108	112	116	122	127	134	141	148	157	165					
104	96	98	100	103	106	110	114	119	124	131	137	145	153	161						
105	97	99	102	104	108	112	116	121	127	134	141	149	157	166						
106	98	100	103	106	109	114	119	124	130	137	145	153	162	172						
107	99	101	104	107	111	116	121	127	134	141	149	157	167							
108	100	102	105	109	113	118	123	130	137	144	153	162	172							
109	100	103	107	110	115	120	126	133	140	148	157	167	177							
110	101	104	108	112	117	122	129	136	143	152	161	171								
111	102	106	109	114	119	125	131	139	147	156	166	176								
112	104	107	111	115	121	127	134	142	150	160	170	181								
113	104	108	112	117	123	129	137	145	154	164	175									
114	105	109	113	119	125	132	140	148	158	168	179									
115	106	110	115	121	127	134	143	152	162	173	184									
116	107	111	116	122	129	137	146	155	166	177										
117	108	112	118	124	132	140	149	159	170	181										
118	108	113	119	126	134	142	152	162	174	186										
119	109	114	121	128	136	145	155	166	178											
120	110	116	122	130	138	148	158	170	182											
121	111	117	124	132	141	151	162	174	187											
122	111	118	125	134	143	154	165	178												
123	112	119	127	136	146	157	169	182												
124	113	120	129	138	148	160	172													
125	114	121	130	140	151	163	176													

Heat Index

Extreme Danger	Heat stroke likely.
Danger	Sunstroke, muscle cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	Fatigue possible with prolonged exposure and/or physical activity.

During the planning stages for future field work, develop a communications plan where field staff will contact the project team when conditions are expected that will trigger Heat Index Action Levels.

Use the information in Table 1 to determine if employees will be exposed to a combination of temperature and humidity that pose a risk for heat illness. If the site conditions are characterized as falling inside the ranges for “Extreme Caution,” "Danger," or “Extreme Danger” for heat illness, additional steps must be taken. It is important to note that the NOAA Heat Index was developed with an understanding that partial shade and light wind conditions are present. Work conducted in direct/full sunlight without light wind conditions (e.g., no partial shade or no breeze) adds up to 15°F (8°C) to the Heat Index value.

Each Heat Index level detailed below is additive.

- If the Heat Index indicates "CAUTION" 80° to 90°F (26° to 32°C), implement one or more of the following:
    - Provide and direct hydration, schedule rest breaks, ensure lightweight clothing is worn, provide break areas with shade / ventilation / air conditioning.
- If the Heat Index indicates "EXTREME CAUTION" 90° to 105°F (32° to 40.5°C), implement all the above and add one or more of the following:
    - Provide light-duty PPE, cooled break areas, and shaded work areas.

      ***Note:** “Light-duty PPE” includes items such as hard hat sunshades, sun hats, dry or wet evaporative cooling vests, microfiber cooling towels, scarves, headbands, hard hat neck shades, hard hat suspension inserts, and sweatbands.*

- If the Heat Index indicates "DANGER" 105° to 130°F (40.5° to 54.4°C.), implement all the above and add one or more of the following:
    - Provide cooled work areas, modify work schedule, provide heavy-duty PPE,and personnel physiological monitoring.

      ***Note:** “Heavy-duty PPE” includes phase-change cooling vests, and gel pack and ice pack equipped cooling vests. Ice pack vests generally offer the coldest option and should not be worn directly against the skin. Consider engineering controls such as forced ventilation.*

- If the Heat Index indicates "EXTREME DANGER" +130°F (+54.4°C) or greater, Stop Work until conditions change or hazards are effectively controlled using items listed above. At this range of temperatures it is critical to implement personnel vital sign monitoring for determining the appropriate frequency and duration of Work / Rest cycles.

5.4.1 Procedures for High Heat

High heat procedures will be implemented when the temperature rises above 95°/35°C. High heat procedures include:

- Hold a Tailgate Safety Meeting to review the high heat procedures, encourage employees to drink plenty of water, and remind employees of the importance of taking a preventive or recovery cool-down rest when necessary.
- Arcadis will ensure that effective employee observation and monitoring procedures are put in place including:

  - SSO or designee will supervise 20 or fewer employees.
  - The "Buddy System" is mandatory.
  - Regular communication with SSO or designee will be implemented via mobile phone or radio.
  - One or more employees will be designated as authorized to contact emergency medical services and communicating that, if no designate is identified and the SSO is unavailable, any employee can call for emergency medical assistance.
- Employees will be reminded throughout the shift to drink plenty of water.
- The "Buddy System" must be implemented for worker monitoring. Particular attention will be paid to new employees or employees who have yet to acclimate to high heat conditions. Additionally, frequent communication will be maintained with employees working by themselves (via cell phone or two-way radio), to be on the lookout for possible symptoms of heat illness.
- During high heat conditions, employees will be provided with a minimum 10-minute cool-down period every 2 hours.
- Employees will be regularly observed for alertness and signs and symptoms of heat illness to be documented in the field book or field log.
- When the SSO is not available, an alternate responsible person must be assigned to look for signs and symptoms of heat illness. Such a designated observer will be trained to know what steps to take if heat illness occurs.

5.4.2 Procedures for Heat Waves

A "heat wave," as defined by NOAA, is a period of abnormally and uncomfortably hot and unusually humid weather. Typically, a heat wave lasts 2 or more days. A "heat wave," as defined for the purposes of this HSS, is when temperatures are sustained above 80°F (26°C), or if site conditions indicate the potential for "Extreme Caution," "Danger," or "Extreme Danger" per Table 1, the following steps will be taken:

- The SSO or designee, in coordination with the project team, will use their Stop Work Authority; evaluate the following actions; and document the action in the daily field log:
  - Modify the work shift or cut the work day short (e.g., 12:00 pm).
  - Reschedule the work (e.g., conduct the remaining work during cooler times of the day) or suspend strenuous tasks.
  - Use Stop Work Authority to cease work for the day.
- If schedule modifications are not possible, the Heat Illness HASP Supplement will be reviewed before work resumes. At a minimum, procedures for heat illness prevention, the provisions for high heat procedures, the weather forecast, and emergency response protocols will be reviewed.
- Employees will be provided with additional water and rest breaks and will be observed more frequently. They will also be reminded throughout the shift to drink plenty of water.
- During work activities and rest breaks, employees will be observed for signs and symptoms of heat illness.
- All employees will maintain frequent communication with the SSO or designee, who will be monitoring employees for possible symptoms of heat illness.

> ***Note**: At large project sites where the SSO is unable to be near the employees (to directly observe or communicate with them), communication via a cell phone or radio may be used for this purpose if reception in the area is reliable.*

5.4.3 Work/Rest Cycle Duration and Frequency Procedures

The occurrence of heat illness depends on a variety of factors. All workers, regardless if they are wearing permeable or semi-permeable clothing, should be monitored when conditions warrant monitoring (e.g., when temperatures exceed 80°F/26.6°C). If semi-permeable clothing is worn (e.g., not standard cotton or synthetic work clothing), it is recommended to begin monitoring those workers when temperatures exceed 70°F in the work area and prioritize workers completing strenuous tasks. Personnel monitoring becomes particularly important when work is conducted indoors, includes strenuous tasks, and additional PPE is worn (such as Level C respiratory protection or CPC). If semi-permeable clothing, Level C PPE, or CPC is not worn, follow the Heat Index table instructions and prepare to implement monitoring as part of the high heat measures discussed in Section 5.4.1. Table 2 below details procedures to be followed to determine an appropriate work/rest cycle with the default rest cycle duration beginning with a 15-minute period every hour when working in temperatures exceeding 90°F.

***Note:** Warning signs include: When a person's sustained (e.g., several minutes) heart rate exceeds 180 beats per minute (bpm) minus their age (e.g., 180 - age = X) for individuals with normal cardiac performance per their physician; or a body core temperature exceeds 101.3°F/38.5°C for acclimatized workers or 100°F/38°C for unacclimated workers; a recovery heart rate at 1 minute after a peak work effort is greater than 120 bpm; or there are symptoms of sudden and severe fatigue, nausea, dizziness, or lightheadedness.*

Table 2 - Suggested Frequency and Duration of Work/Rest Cycles Applying Physiological Monitoring of Acclimatized Personnel

Adjusted Air Temp. [1]	Wearing Permeable PPE [2]	Wearing Impermeable PPE [3]
> 90°F/32°C	After ea. 45 mins. of work	After ea. 15 mins. working
87.5 to 90°F/30.8 to 32.2°C	After ea. 60 mins. of work	After ea. 30 mins. working
82.5 to 87.5°F/28.1 to 30.8°C	After ea. 90 mins. of work	After ea. 60 mins. working
77.5 to 82.5°F/25.3 to 28.1°C	After ea.120 mins. of work	After ea. 90 mins. working
72.5 to 77.5°F/22.5 to 25.3°C	After ea.150 mins. of work	After ea. 120 mins. working

Notes:

[1] - Adjusted air temp (ta adj) calculation: ta adj F = ta F + (13 x % sunshine). Measure the air temperature (ta) with a thermometer (shielded from radiant heat). Estimate the percent sunshine by judging what percent time the sun is not covered by clouds that are thick enough to produce a shadow. (100 percent sunshine = no cloud cover and a sharp, distinct shadow; 0 percent sunshine = no shadows.)

[2] - Permeable PPE consists of cotton clothing with long sleeves and pants or breathable coveralls.

[3] - Add 1.8 °F for Tyvek coveralls; add 5.4 °F for heavy clothing; add 19.8 °F for impermeable/semi-impermeable PPE - Level A/B suits)

5.4.4 Monitoring Personnel Vital Signs for Determining Work/Rest Cycles

To conduct heart rate monitoring, first collect and record a resting heart rate to establish the baseline value for each individual to be monitored. Count the heartbeats at the radial pulse (located on the inside of the wrist below the base of the thumb) during a 30-second interval. During rest cycles, count and record the heart rate as early as possible at the beginning of the rest cycle and again 3-5 minutes later. The pulse rate should fall rapidly and soon approach the individuals baseline heart rate level. The heart rate will remain elevated for a worker experiencing onset of heat illness.

- If the heart rate exceeds 110 beats per minute at the beginning of the rest period, shorten the next work cycle by one third and keep the rest period the same.
- If the heart rate still exceeds 110 beats per minute at the next rest period, shorten the following work cycle by one third.

Body temperature monitoring is used in conjunction with heart rate monitoring to evaluate an individual’s condition and ability to sufficiently cool down during breaks when working in hot environments. Monitor and record body temperature orally using a clinical thermometer (3 minutes under the tongue and before drinking liquids) or using an infrared forehead swipe thermometer per manufacturer’s directions. Take temperatures at the end of the work period before the rest cycle.

- If oral temperature exceeds 99.6°F (37.6°C), shorten the next work cycle by one third without changing the rest period.
- If oral temperature still exceeds 99.6°F (37.6°C) at the beginning of the next rest period, shorten the following work cycle by one third.
- Do not permit a worker to wear a semi-permeable or impermeable garment when the oral temperature exceeds 100.6°F (38.1°C).

5.5 Heat Exhaustion and Heat Stroke Symptoms, First Aid and Emergency Procedures

Emergency procedures include recognizing the more serious symptoms associated with the third and fourth stages of heat-related illness: heat exhaustion and heat stroke. A critical step to having effective emergency procedures involves ensuring that effective communication has been established and maintained to contact emergency responders.

5.5.1 Heat Exhaustion and Heat Stroke Symptoms

Signs of heat exhaustion include:

- Cool, moist, pale, or flushed skin
- Heavy sweating
- Headache
- Nausea, dizziness, and exhaustion
- Normal or below normal body temperature.

Signs of heat stroke include:

- Hot, red skin, which can be dry or moist from exercise
- Changes in consciousness
- Rapid, weak pulse

- Rapid, shallow breathing, vomiting
- A person experiencing heat stroke can have a very high body temperature—sometimes as high as 106°F (41°C).

5.5.2 First Aid Procedures for Heat Exhaustion

If an employee is determined to be suffering from heat exhaustion, perform the following steps:

1. Move the person to a cooler place.
2. Remove or loosen tight clothing and apply cool, wet cloths, such as towels or sheets soaked in water.
3. If the person is conscious, give him or her cool water to drink. Make sure the person drinks slowly. Give a half glass of cool water every 15 minutes.
4. Contact the employees' supervisor, the project manager, and Work Care 1-888-449-7787 (US & Canada).
5. Let the person rest in a comfortable position.
6. Watch carefully for changes in his or her condition.

Do not give liquids that contain alcohol or caffeine because they can cause further dehydration, making conditions worse.

5.5.3 First Aid and Emergency Procedures for Heat Stroke

Heat stroke is a life-threatening situation. If you suspect that someone is suffering from heat stroke, call 9-1-1 or the local emergency number immediately.

1. Move the person to a cool place.
2. Loosen tight clothing.
3. Remove perspiration-soaked clothing.
4. Apply cool, wet cloths to the skin.
5. Fan the person.
6. If conscious, give small amounts of cool water to drink.
7. Place the person on his or her side.
8. Contact the employees' supervisor, the project manager, and Work Care 1-888-449-7787 (US & Canada).
9. Continue to cool the person using ice or cold packs on the wrists, ankles, groin, and neck and in the armpits.
10. Continue to check breathing and circulation.

Do not give liquids that contain alcohol or caffeine because they can cause further dehydration, making conditions worse. Ensure that 911 or the local emergency number is called if the person refuses water, vomits, or starts to lose consciousness.

Emergency contact telephone numbers and hospital directions/map must be included in each site-specific HASP for employee reference.

6. TRAINING

The Arcadis Heat Illness Prevention online training offered through the Arcadis Learning Center is required to be completed before Supervisory Personnel and Affected Employees working in California or Washington States will be permitted to begin work. Project teams conducting work in locations other than California or Washington States are expected to complete the training before conducting work as defined in the H&S training matrices specific to each Business Line. Completion of the training once is generally considered sufficient to satisfy the training requirement; however, the training may be required to be completed again as determined by Arcadis policy or management, or by client or specific state requirements. Refresher training is encouraged for all staff that infrequently conducts or supervises work where heat illness is a hazard.

6.1 Supervisory Personnel

Personnel supervising staff on a California or Washington State site who might reasonably be anticipated to be exposed to the risk of heat illness will be provided training in the following topics before assignment:

- The environmental and personal risk factors for heat illness
- The importance of frequent consumption of small quantities of water; consuming 8 fl. oz. every 15 minutes or 32 fl. oz. per hour, when the work environment temperature exceeds 80°F/26.6°C because employees are more likely to be sweating more than usual in the performance of their duties.
- The importance of staying appropriately nourished and hydrated
- The importance of acclimatizing before work
- The different types of heat illness and the common signs and symptoms
- The importance for employees to immediately report to the employer, directly or through the employee’s supervisor, symptoms or signs of heat illness in themselves or in co-workers
- The procedures to follow for responding to symptoms of possible heat illness, including how emergency medical services will be provided should they become necessary
- The procedures for contacting emergency medical services, and if necessary, for transporting employees to a point where they can be reached by an emergency medical service provider
- The procedures for ensuring that, in the event of emergency, clear and precise directions to the work site can and will be provided as needed to emergency responders.

In addition, these supervisory personnel must review and understand:

- This Heat Illness Prevention HSS and the associated HASP Supplement
- How to implement the emergency response procedures detailed in the site-specific HASP when an employee exhibits symptoms consistent with possible heat illness
- Weather monitoring reports as detailed in the field Health & Safety Handbook
- How to monitor weather reports and how to plan for and respond to hot weather advisories.

This training will be documented within the Learning Center database along with details on the subject matter covered and date of training recorded.

6.2 Affected Employees

For those employees who work in California or Washington State, or when using this HSS as a BMP in any other state and might reasonably be anticipated to be exposed to the risk of heat illness, training in the following topics is required before assignment:

- The environmental and personal risk factors for heat illness
- The importance of frequent consumption of small quantities of water; 8 fl. oz. every 15 minutes or 32 fl. oz. per hour when the work environment temperature exceeds 80°F/26.6°C and employees are more likely to be sweating more than usual in the performance of their duties
- The importance of acclimatizing
- The different types of heat illness and the common signs and symptoms
- The importance for employees to immediately report to the employer, directly or through the employee's supervisor, symptoms or signs of heat illness in themselves or in co-workers
- The procedures for responding to symptoms of possible heat illness, including how emergency medical services will be provided should they become necessary
- The procedures for contacting emergency medical services, and if necessary, for transporting employees to a point where they can be reached by an emergency medical service provider
- The procedures for ensuring that, in the event of emergency, clear and precise directions to the work site can and will be provided as needed to emergency responders.

This training will be documented within the Learning Center database along with details on the subject matter covered and date of training recorded.

Note: *For those staff who are not working in California, Washington State, or other states that have specified heat illness training requirements, staff that might reasonably be anticipated to be exposed to the risk of heat illness will (at a minimum) review the information detailed in the Field Health & Safety Handbook and this HSS. Corporate H&S recommends that all staff that might be reasonably be anticipated to be exposed to the risk of heat illness complete the online heat illness training course through the Learning Center.*

7. REFERENCES

- Occupational Safety and Health Administration (OSHA) Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities Section 8 "Heat Stress and Other Physiological Factors" OSHA, National Institute for Occupational Safety and Health (NIOSH), United States Environmental Protection Agency (USEPA), U.S. Coast Guard (USCG). Chapter 8. 1985.
- OSHA Technical Manual – Section III Chapter 4
- National Institute of Occupational Safety and Health (NIOSH) Publication Number 86-112
- American Conference of Governmental Industrial Hygienists (ACGIH) "Guidelines for Limiting Heat Strain" 2018
- American Red Cross 2007
- Cal/OSHA Title 8 CCR 3395 Heat Illness Prevention Standard and Title 8 CCR 3202 Injury and Illness Prevention Program
- Washington State Outdoor Heat Exposure Regulations 296-62-09510 thru 09560
- See Exhibit 3 for links to additional regulatory resources.

8. RECORDS

Heat illness training records will be maintained by the Arcadis Training Team.

Heat Plan H&S Plan Supplement will be maintained with project files.

9. APPROVALS AND HISTORY OF CHANGE

Approved by: Julie Santaniello, CSP – Corporate H&S Manager of Technical Programs

Julie

History of Change

Revision Date	Revision Number	Standard Developed/Reviewed By or Revised By	Reason for change
31 August 2011	01	Tony Tremblay & Mija Coppola	Original document
13 March 2012	02	Tony Tremblay	Detailed Supervisory Personnel requirement to plan/detail preventive measures/controls when heat advisories are issued; clarified training requirements for staff and supervisory personnel; inserted heat advisory and excessive heat warning definitions
19 June 2012	03	Pat Vollertsen	Information added about nourishment
16 June 2014	04	Pat Vollertsen & Alec MacAdam/Tony Tremblay	Revised standard format and History of Change Section. Updated to include specific prescriptive language to address Cal OSHA and Washington State requirements. Inclusion of HASP supplement and preparation guidance. Clarification of the use of sports/electrolyte drinks
7 August 2014	05	Alec MacAdam	Update guidance for use of “Sports Drinks”

Revision Date	Revision Number	Standard Developed/Reviewed By or Revised By	Reason for change
6 April 2015	06	Alec MacAdam	Revise temperature threshold from 85° to 80°F, provisions for shade, guidance for preventative rest breaks, revised high heat procedures and clarification of acclimatization procedures
15 March 2017	07	Alec MacAdam & Denis Balcer/ Tony Tremblay & Julie Santaniello	Updated brand. Updated links to Exhibits 2 & 3, Revised Admin. Controls in Section 5.3, Additional regulatory detail in Sections 5.3.2 and 5.3.3. Added Section 5.4 Heat Index Action Levels and Recommended Hazard Controls. Revised the HIPP HASP Supplement to reflect changes in the HSS.
2 January 2020	08	Alec MacAdam	Updated format. Clarifications in Roles & Responsibilities § 4; Updated Safe Work Practices in § 5.1; Updated Administrative and Engineering Controls in § 5.3; Updated Heat Index Table 1 § 5.4; Added Work/Rest Cycle Guidance § 5.4.3; and Personnel Vital Signs Monitoring § 5.4.4; Revised Heat Exhaustion and Heat Stroke Emergency Procedures; Updated References; Updated HASP Supplement with above noted revisions on 6 May 2019.
17 February 2020	09	Julie Santaniello	Updated Heat Index ranges in Section 5.4 so text matches Table 1.

EXHIBIT 1 - DEFINITIONS

Acclimation – A process by which the body adjusts to increased heat exposure. The body needs time to adapt when working in hotter environments. Employees working in a hot environment are more likely to develop heat illness if not allowed or encouraged to allow their body to acclimate when a heat wave strikes or when starting a job that newly exposes them to heat. Acclimatization is fully achieved in most people within 4 to 14 days of regular work involving at least 2 hours per day in the heat.

Excessive Heat Warning - Extreme Heat Index making it feel very hot, typically above 110°F (43°C) for 3 hours or more during the day for two consecutive days or above 110°F (43°C) at any time. Specific criteria vary over different county warning areas.

Heat Advisory - Issued when the Heat Index is expected to exceed 105°F (40°C) during the day and 80°F (27°C) during the night for at least two consecutive days.

Heat Cramps – Normally caused by performing hard physical labor in a hot environment. These cramps have been attributed to an electrolyte imbalance caused by sweating. Salt tablets should not be taken.

Heat Collapse – Commonly known as “Heat Stress,” technically referred to as heat syncope. Heat collapse or syncope (fainting) is the condition where the brain does not receive enough oxygen because blood pools in the extremities. To prevent heat collapse, the employee should gradually acclimatize to the hot environment.

Heat Exhaustion – Less severe than heat stroke, but the victim must be treated as soon as possible. Symptoms include clammy and moist skin; pale or flushed complexion; sweating along with extreme weakness or fatigue, giddiness, nausea, or headache; and (in more serious cases) vomiting or loss of consciousness.

Heat Fatigue – The signs and symptoms of heat fatigue include impaired performance of skilled sensorimotor, mental, or vigilance jobs. There is no treatment for heat fatigue except to remove the person from the heat before a more serious heat-related condition develops.

Heat Index – an “apparent temperature” that is a measure of how hot it feels when relative humidity is added to the actual air temperature.

Heat Rashes – Also referred to as prickly heat, is the most common problem in hot work environments. Prickly heat is manifested as red papules and usually appears in areas where the clothing is restrictive.

Heat Stress – A physiological condition induced when high temperatures and humidity compromise the body’s ability to cool itself, resulting in heat-related illness.

Heat Stroke – The body's system of temperature regulation fails, and body temperature rises to critical levels. This condition is caused by a combination of highly variable factors, and its occurrence is difficult to predict. **Heat stroke is a medical emergency.** The primary signs and symptoms of heat stroke include confusion; irrational behavior; loss of consciousness; convulsions; a lack of sweating (usually); hot, dry skin; and an abnormally high body temperature.

Heat Wave - A “heat wave,” as defined by NOAA, is a period of abnormally and uncomfortably hot and unusually humid weather. Typically, a heat wave lasts 2 or more days. A "heat wave," as defined for the purposes of this HSS, is when temperatures are sustained above 80°F.

Provision of Water - Employees will have access to potable drinking water meeting the requirements of Section 5.3.2 of this HSS including but not limited to the requirements that it be fresh, pure (water must be potable and free of odors), suitably cool (the water must be cooler than the ambient temperature but not so cool as to cause discomfort), and provided to employees free of charge. The water will be located as close as practicable to the areas where employees are working. Where drinking water is not plumbed or otherwise continuously supplied, it will be provided in sufficient quantity at the beginning of the work shift to provide 1 quart per employee per hour for drinking for the entire shift. Employers may begin the shift with smaller quantities of water if they have effective procedures for replenishment during the shift as needed to allow employees to drink 1 quart or more per hour. The frequent drinking of water will be encouraged. The purpose of requiring that water is “fresh, pure, suitably cool, and provided to employees free of charge” and “located as close as practicable to the areas where employees are working” is to encourage workers to drink water often and avoid making the workers interrupt their work in order to do so. To ensure that water is fresh, pure, and suitably cool, Cal/OSHA advises that employers or supervisors visually examine the water and pour some on their skin.

Shade - The blockage of direct sunlight. Canopies, umbrellas, and other temporary structures or devices may be used to provide shade. One indicator that blockage is sufficient is when objects do not cast a shadow in the area of blocked sunlight. Shade is not adequate when heat in the area of shade defeats the purpose of shade, which is to allow the body to cool. For example, a car sitting in direct sunlight does not provide acceptable shade to a person inside it unless the car engine is operating with air conditioning on. Shade may be provided by any natural or artificial means that does not expose employees to unsafe or unhealthy conditions and that does not deter or discourage access or use.

Transient Heat Fatigue – The temporary state of discomfort and mental or psychological strain arising from prolonged heat exposure. Employees unaccustomed to the heat are particularly susceptible and can suffer, to varying degrees, a decline in task performance, coordination, alertness, and vigilance.

EXHIBIT 2 - ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
ANA	Arcadis North America
APM	Assistant Project Manager
Arcadis	Arcadis U.S. Inc.
BMP	Best Management Practice
BPM	Beats Per Minute
°C	Degrees Celsius
Cal/OSHA	California Occupational Safety and Health Administration
CCR	California Code of Regulations
CPC	Chemical Protective Clothing
°F	Degrees Fahrenheit
HASP	Health & Safety Plan
HIPP	Heat Illness Prevention Plan
HS	Health and Safety
H&S	Health and Safety
HSS	Health and Safety Standard
L	Liter
NIOSH	National Institute of Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
OSHA	Occupational Safety and Health Administration
Oz	Ounce
PM	Project Manager
PPE	Personal Protective Equipment
SSO	Site Safety Officer
TM	Task Manager

EXHIBIT 3 – Heat Illness Links

CDC / NIOSH Occupational Exposure to Heat and Hot Environments - 2016

Heat Illness Symptoms

Heat Illness Thermometer and PPE

OSHA Working Outdoors Fact Sheet

OSHA Worker Protection from Heat Stress

California Heat Illness Prevention Enforcement Q&A

Washington State Outdoor Heat Exposure Enforcement Procedures

EXHIBIT 4 – Heat Illness Prevention Plan HASP Supplement Template

The Heat Plan HASP Supplement is contained in the Standard Excel® HASP template. The most current version of the HASP template is located on the ANA H&S Intranet site on the “Forms and Templates” page.

Link to the H&S “Forms and Templates” page:
https://arcadiso365.sharepoint.com/sites/naintranet/en-us/HealthandSafety/FormsTemplates

The Heat Plan supplement can be accessed by right clicking on the lower toolbar of the excel HASP template and selecting “Unhide” and selecting the “Heat Illness Prevention Plan.”

Implementation Date	ARCADIS HS Standard Name	
13 December 2006	Utility Location and Clearance	
Revision Date	ARCADIS HS Standard No.	Revision Number
13 May 2020	ARC HSFS019	17

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QUICK SHEET

Applicability

This HSS assigns responsibilities and expectations for proper utility location and clearance by both Arcadis employees and Arcadis subcontractors at project sites

Need to Know

PMs are responsible for ensuring the requirements of this HSS are followed. Project personnel are responsible for understanding the HSS and Supplemental document, having the minimum 1 year of required training in order to clear sites, understand and apply the requirement for a minimum three reliable lines of evidence for each point of work, know and understand the Arcadis 30-in tolerance Zone requirements.

If and when any line of evidence reveals planned subsurface work will occur within the Arcadis 30-inch Tolerance Zone of known/marked/located/observed utilities or structures, the project team must Stop Work and contact Corporate H&S for a review of steps the team has taken to prevent injury or incident involving the conflict.

Additional details addressing hazards, risk factors, and safe work practices are discussed in the HSS Supplemental document Sections:

1. Best Practices for Project Managers (or Their Delegates) Concerning Utility Clearance.
2. Best Practices for Field Personnel Concerning Utility Clearance.
3. Use and Limitations of Common Underground Locating Technologies and Clearance Methods.
4. Best Practices for State One Call Notification Process and Mark Outs.
5. Emergency Action Plan Guidelines for Utility Strikes.
6. Utility Location Procedures for Aquatic Work Activities.

Arcadis field personnel involved with any strike incidents including contact with a structural feature, subsurface, submerged, and/or aboveground utilities must immediately STOP WORK and contact the Project Manager to discuss the incident. If there are life threatening injuries, or the incident presents a risk to public safety (e.g. natural gas leak, downed live electrical line, flooding, or an unstable building) first call 911 or the available emergency services number for the client site or area and then call the Project Manager. The incident must be reported to Corporate Health and Safety immediately and no later than 24 hours after gaining knowledge of the incident. Compliant notification within 24 hrs. requires an acknowledgement of the notification by Corporate H&S.

The Arcadis standard client and subcontractor contracts contain required terms and conditions defining responsibility for utility clearance and the allocation of risk associated with an impacted utility.

Training

Field staff must complete a minimum of one year of utility clearance-related experience before accepting responsibility for any utility clearance tasks. This experience requires mentorship by a currently trained and experienced Arcadis employee for the processes of; completing DigSafe 811 notifications, developing a working understanding of the types of utilities present at project sites, developing a working understanding of the various reliable lines of evidence, and participating in on-site training led by another Arcadis employee with detailed knowledge and experience in identifying utilities and structures.

Permits or Forms Required

The Utility Location HSS and associated supplements will be reviewed, and the Utility and Structures Checklist will be prepared during project planning to document and record the location and clearance process for the Site.

1. POLICY

It is the practice of Arcadis and its affiliated companies to implement appropriate, reasonable, and practical standards within acceptable and customary industry practices to promote the health and safety of its employees and avoid and mitigate exposure of risk in the performance of their work. In furtherance of this policy, Arcadis promotes and encourages compliance by all employees with this policy and standards relating to work in the vicinity of subsurface, submerged, or aboveground utilities.

2. PURPOSE AND SCOPE

2.1 Purpose

Arcadis is committed to providing a healthy and safe work environment for our employees, subcontractors, clients, and visitors. To this end, this health and safety standard (HSS) establishes general safety standards and best practices associated with the identification, management and avoidance of subsurface, submerged, and aboveground structures and utilities on project sites.

2.2 Scope

This HSS assigns responsibilities and expectations for proper utility location and clearance by both Arcadis employees and Arcadis subcontractors at project sites.

3. DEFINITIONS

Definitions related to Utility Location and Clearance can be found in Exhibit 1. Acronyms and Abbreviations are found in Exhibit 2.

4. RESPONSIBILITIES

Project staff involved in subsurface and aboveground work activities are expected to read, understanding and comply with this HSS and the ARC HSFS-019 Supplements, specifically ARC HSFS-019 Supplement Sections 2 and 3, make the required DigSafe notification(s), and complete the appropriate checklists during the on-site utility and structures locate and clearance process.

4.1 Project Managers

For every project site having the potential to come into contact with utilities, Project Managers (PMs) are responsible for the requirements of this HSS in that:

- The requirements of this HSS are followed.
- Local regulations governing utility clearance are followed. This includes ensuring local and/or state laws defining activities or depth of intrusive work/excavation requiring utility clearance are reviewed as they vary by location. For further information, refer to the

Common Ground Alliance One Call State Law Directory (https://commongroundalliance.com/map).

- Efforts are made to work with the client, project site representatives, public utility companies, and subcontractors to identify the nature of any utilities and to determine control processes that need to be implemented by Arcadis and the subcontractors to prevent damage to these utilities and to properly manage the effects in the event there is utility damage.

- In jurisdictions where the actual contractor performing the subsurface intrusive work is required to perform utility clearance notifications (811, State One Call, etc.) ***and*** Arcadis is also self-performing the work, Arcadis will complete the clearance notifications and include the ticket number on the Utility Clearance Checklist. Refer to ARC HSFS-019 Supplement Section 4 for Best Practices for State One Call procedures.

- Utility clearance activities are only delegated to a Task Manager or other individual meeting the requirements of Section 4.2 below, as appropriate. However, even if the Project Manager delegates certain responsibilities, the Project Manager maintains primary responsibility for the completion of utility clearance. For additional information on Project Manager responsibilities and best practices, refer to ARC HSFS-019 Supplement 1.

- Prior to beginning subsurface work, Project Managers or designee must review the Utility and Structures Checklist with staff and Arcadis subcontractors (including subs of subs). The Project Manager or designee review must be documented on the Utility and Structures Checklist prior to starting subsurface intrusive work

4.2 Field Personnel Responsibilities

Arcadis field personnel conducting work on a project site having the potential to come into contact with utilities have the responsibility to:

- Read, understand, and follow this HSS and ARC HSFS-019 Supplement document.

- Complete a minimum of one year of utility clearance-related experience before accepting responsibility for any utility clearance tasks. This experience requires mentorship for notifying DigSafe 811, developing a working understanding of the types of utilities present at project sites, developing a working understanding of the various reliable lines of evidence, and participating in on-site training led by another Arcadis employee with detailed knowledge and experience in identifying utilities and structures.

- Request and review the 811 DigSafe notification(s) in place for the appropriate work area(s).

- Prior to beginning any subsurface intrusive work (i.e., any work or activity that breaks the plane of the ground surface), excavation work involving heavy and mechanized equipment, or operating high clearance equipment at the Site, the Utility and Structures Checklist must be completed and signed by the staff member completing or overseeing the clearance. Confirm that the Utility and Structures Checklist was reviewed by the Project Manager or designee as discussed in Section 4.1 above. Review the Utility and Structures Checklist daily prior to starting subsurface intrusive activities to ensure all utilities are identified and markings are present. A copy of the completed Utility and Structures Checklist will remain on-site during all subsurface intrusive work.

- Use their STOP WORK Authority to eliminate any reasonable concern if utilities cannot be reasonably located and contact the Project Manager to review the STOP WORK situation and confirm the direction of action before proceeding with the work.
- Check that Arcadis subcontractors conduct their own reasonable independent utility clearance efforts as required by state and local laws and the Arcadis subcontractor agreement.
- Be on-site and provide oversight during utility location and clearance activities and any active subsurface intrusive work or activities involving subcontractor under contract to Arcadis.
- If a utility is damaged and repaired during the course of the field event, Arcadis field staff must provide oversight and document that the repair was tested to ensure the repaired utility is competent and complete to prevent further damage to the site when the damaged utility is re-activated.

4.3 Corporate Health & Safety

Corporate H&S is responsible for keeping this HSS up to date with regulatory requirements and best work practices.

Corporate H&S will, as requested, provide guidance to employees and their supervisors engaged in work involving utility location and clearance on the risks and measures prevention utility strikes, including how to recognize the presence of utilities whether overhead, underground, or submerged and how to mark and protect them from damage.

4.4 Arcadis Subcontractor Responsibilities

According to the Arcadis standard subcontract terms and conditions, subcontractors agree to take responsibility for any damages resulting from a utility impact caused by their work. Therefore, Arcadis subcontractors are expected to take reasonable time and diligence to conduct their own independent utility clearance using reasonable standards and processes. Subcontractors have the responsibility to stop their work if utility concerns are identified and will report those concerns to the Arcadis employee overseeing their work activities. Arcadis staff should reinforce these responsibilities with subcontractors during job safety briefings.

In jurisdictions where the actual contractor performing the subsurface intrusive work is required to perform utility clearance notifications (811, State One Call, etc.), the contractor will perform the clearance notification and will provide evidence of the notification to Arcadis (ticket or ticket number, etc.). Refer to ARC HSFS-019 Supplement Section 4 for Best Practices for State One Call procedures.

- If overhead utilities are present in areas where heavy equipment will be operated, ensure adequate clearance is provided. For heavy equipment with extendable or telescoping (e.g., excavators, dump trucks, extendable lift trucks) equipment, evaluate whether the use of a spotter is necessary prior to operating heavy equipment when in proximity to the overhead utility.

- Consider signage and/or other forms of identification to ensure aboveground and overhead utilities that need to be protected during Arcadis work are effectively addressed.

- If a utility is struck and requires repair, the repair must be tested prior to restoring the utility to full service.

5. PROCEDURE

5.1 General Safe Work Practices

Arcadis staff will follow these general safe work practices when working around utilities. Procedures to be followed during utility and structures location and clearance activities are outlined in the following sections of the Utility Location and Clearance Supplemental document:

7. Best Practices for Project Managers (or Their Delegates) Concerning Utility Clearance.
8. Best Practices for Field Personnel Concerning Utility Clearance.
9. Use and Limitations of Common Underground Locating Technologies and Clearance Methods.
10. Best Practices for State One Call Notification Process and Mark Outs.
11. Emergency Action Plan Guidelines for Utility Strikes.
12. Utility Location Procedures for Aquatic Work Activities.

5.2 Lines of Evidence

When locating utilities and structures three (3) reliable “lines of evidence” must be established to help determine where a subsurface utility may be located. A line of evidence may be a scaled site drawing showing where a utility is located, it could be information obtained verbally from owners or employees who meet the definition of a “knowledgeable person” regarding utility and structural features, it could be established using any number of non-intrusive geophysical methods including but not limited to; ground penetrating radar (GPR), electromagnetic survey (EM), radio-frequency methods (RF), or it could involve probing for or exposing the utility by soft dig technologies (AKA “daylighting” or “potholing”) using air knife, Hydroknife and/or soil vacuum. Some lines of evidence will identify utility locations with a high degree of certainty (e.g., direct connect radio-frequency technique, daylighting, or potholing, sonde tracing, etc.). Other lines of evidence will identify utilities will less certainty (e.g., GPR, historical reports, old design drawings, etc.).

Effective utility locate practices must use multiple lines of evidence until there is a high degree of certainty that the various underground utility services have been adequately located. A minimum of three (3) reliable lines of evidence are required for an appropriate utility clearance as defined in this HSS. All reliable lines of evidence used during the utility clearance procedure will be recorded on the Utility and Structures Checklist or equivalent client-provided checklist or ground disturbance permit. If three (3) reliable lines of evidence have not established certainty regarding the location of a utility, STOP WORK and do not proceed until the certainty has improved, the work has been modified to resolve the lack of certainty. Additional reliable lines of evidence must be utilized until the presence or absence of the underground utility can be established. During work activities, if a line of evidence is lost or not apparent (e.g., paint markings have faded), STOP WORK, and re-establish the line of evidence prior to resuming subsurface intrusive work.

Generally, the following example reliable lines of evidence may be used to meet the minimum three lines utility clearance requirement:

1. Contacting the State One Call or equivalent service (Nationwide "811") in advance of intrusive work is **REQUIRED BY LAW**.. Contacting the State One Call or equivalent service (Nationwide "811") is an acceptable reliable line of evidence when working within or adjacent to the public right of way or easement. Note that the State One Call can provide valuable information regarding locations and types of utilities entering a privately owned property.

   Note: When conducting work on private property or in areas not served by State One Call or equivalent service, teams are to evaluate using a reputable private utility locating company to locate and mark the utilities. **Use of a reputable private utility locator is encouraged for all projects with subsurface or submerged utilities.** When working with a private utility location subcontractor, it is best practice to pre-plan clearance areas, review the necessary clearance equipment needed based on the types of utilities anticipated to be present, and the re-clearing/confirmation of any public utility location markings (State One Call or equivalent service Nationwide "811").

2. Use detailed, scaled site utility plans, preferably in the form of an "as-built" or "record" drawing, to identify and/or confirm utility locations. Document request and/or receipt of utility drawings from the property owner/client on the Utilities and Structures Checklist.

3. Interview(s) with knowledgeable site or client personnel. The following questions should be asked during the interview and answers documented on the Utility and Structures Checklist:

   - Employees(s) Name and Affiliation(s) with the site.
   - Types of utilities, including utility composition and location of utilities on-site.
   - Depths of known utilities; and
   - Any other pertinent information regarding utilities on the site.

4. Conduct a detailed visual site inspection of areas around all planned subsurface intrusive work points or areas to identify and/or confirm utility locations. The area needed to conduct a thorough site inspection can vary significantly depending on the number and type of utilities present, notably gravity-fed utilities such as sewers. Sewer network manhole spacing can often include 100-foot distances or greater between manholes. For underground utilities, conduct an inspection for structures that tend to indicate the presence and general location of such utilities, including, but not limited to manholes, vaults, valve covers, valve markers, telephone pedestals, transformer housings, fire hydrants, fire suppression post indicator valves (PIVs), spigots, sprinkler heads, air relief valves, backflow preventers, meters, vent lines, downspouts going into the subsurface, power poles with wiring going into the subsurface and line markers, stakes, and monuments. Saw cut lines and concrete/asphalt repairs often yield valuable information regarding utility locations.

Always discuss the presence of utilities with the site owner, operator, facility representative and/or occupant to identify any potential utilities that might not be readily identified by non-intrusive geophysical clearing methods. Situations where non-intrusive clearance methods may not be effective include:

- Depths > 5 ft. below ground surface (BGS).
- Small diameter or certain utility construction materials (e.g. plastics).
- Multiple layers of surface cover e.g. reinforced concrete, multiple layers of historical roadbed.
- Soil conditions such as dense soils or shallow groundwater table.

A discussion of use and limitations associated with common utility location and clearance geophysical methods is provided in ARC HSFS-019 Supplement Section 3.

Standard operating procedures for utility location in submerged settings are presented in ARC HSFS-019 Supplement Section 6.

The lines of evidence will be recorded on the Utility and Structures Checklist or equivalent client-provided checklist or permit.

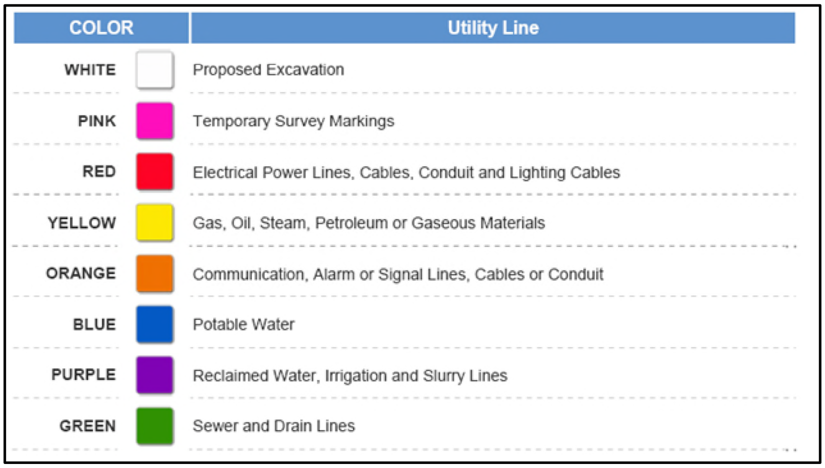
Note: If a line of evidence is lost, not apparent, no longer applicable or utility location markings are removed/worn/unclear, or area of previous clearance is not confirmed, STOP WORK and re-establish the line(s) of evidence prior to resuming subsurface intrusive work. **Each location of subsurface intrusive work must have a minimum of 3 reliable lines of evidence.** All lines of evidence used during the utility clearance procedure will be recorded on the Utility and Structures Checklist or equivalent client-provided checklist or permit. The Utility Structures and Checklist is valid for 15 business days from the date of completion. Prior to the end of the 15 day period the checklist detailing the utilities which have been located and marked must be reviewed to verify no new utilities have been identified but are unmarked and, utilities which have been located and marked continue to be clearly marked. Update the checklist with the date of the review and reviewer name to “re-set” the 15-day period. A copy of the completed Utility and Structures Checklist will remain onsite while work involving or in the vicinity of utilities is conducted.

Caution: If and when any line of evidence reveals planned subsurface work will occur within the Arcadis 30-inch Tolerance Zone of known/marked/located/observed utilities, the project team must Stop Work and contact Corporate H&S for a review of the steps the team has taken to prevent injury or incident involving the utility conflict.

5.3 Color Codes Used for Utility Markings

The following colors are used for marking utilities. Some government agencies or large industrial facilities may use additional colors not provided below. Arcadis policy is to assume any paint marking or pin flag color not provided below is a subsurface utility marking until proven otherwise.

If utilities or subsurface anomalies are identified but the utility type or anomalies are not classified, it is recommended the color pink (Temporary Survey Marking) be used to mark the location pending confirmation. Once the type of utility is established, the pink marks will be repainted/remarked to represent the correct type of utility.



COLOR	Utility Line
WHITE	Proposed Excavation
PINK	Temporary Survey Markings
RED	Electrical 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	Sewer and Drain Lines

APWA and ANSI standard Z-53.1

5.4 Locating Technologies

There are several types of locating technologies that can be used to identify and locate utilities in the subsurface. Project teams need to work closely with private utility locators (PUL) in order to best match locating technology with site conditions. To provide the best results, all possible locating technologies should be available for use and implementation at the project location. Any potential interferences should also be discussed up front and then at the project site during utility location activities. Potential interferences could be soil moisture, soil type, standing water on concrete/asphalt, rebar, fencing, and metal structures that are in the subsurface. Employees overseeing locating technology activities should have an understanding of device operation and limitations. For further information, refer to ARC HSFS-019 Supplement Section 3, Use and Limitations of Common Utility Location Technologies and Clearance Methods.

5.5 Clearance Methods

In some cases, proposed subsurface intrusive locations may be pre-cleared using other intrusive methods. Determine the clearance or soft dig method based on-site conditions and utilize the least invasive method possible. The number of subsurface intrusive locations and soil type should be taken into consideration. The following clearance methods are listed from least invasive to most invasive:

1. Vacuum Extraction/Potholing (air or water-based)
2. Air knifing
3. Hydro knifing
4. Probing
5. Hand augering
6. Hand digging
7. Posthole digging

“Single-Point” clearance involves clearing the intrusive location to 110% of the proposed subsurface intrusive area or the diameter plus 2 inches of the largest piece of tooling used in the subsurface (e.g. clear the borehole to 10-in. when setting wells using 8-in. hollow stem auger tooling), or whichever is greater.

“Three-Point” clearance involves clearing the utility using a triangular pattern placed around the proposed borehole location and in a configuration such as to not allow utilities to pass undetected between the clearance boreholes. In some cases, it is more practical to advance three individual slot trenches which connect at each end making a “clearance triangle” instead of advancing multiple boreholes side-by-side. Using the Three-Point clearance triangle trenching method allows for teams to inspect larger areas for potential utilities. The teams can advance trenches along each side of the proposed work area extending down to a target depth based on suspected depth of utilities at the Site. Each method of clearance will be documented on the Utility and Structures Checklist.

Manual clearing methods, such as shoveling, using pickaxes, digging bars (AKA “Spud bars” and other hand tools, should be avoided completely or only used when absolutely necessary and used with caution. Excessive downward force, prying or use in poor/obstructed visibility conditions is prohibited as these tools are known to be capable of damaging utilities.

Surface cover (e.g., asphalt) removal methods that pose excessive downward force, such as jackhammering, must be used with extreme caution. Methods that only cut the surface cover (coring or saw cutting) present less risk due to the absence of the blunt downward force, which could cause collateral damage to shallow subsurface utilities by unintentionally pushing buried debris into the utility. Note that certain utilities are often present at the concrete or pavement/soil interface or encased within the concrete or pavement and are easily damaged during concrete coring or pavement removal. Always work slowly, methodically, and frequently STOP WORK to evaluate conditions during these work activities.

For borings and excavations, if the utility is known to be at depths where hand clearing is not feasible or creates additional safety concerns, no work will be performed within the Arcadis 30-inch Tolerance Zone vertically or horizontally of the utility unless manual clearing of the utility is performed under the oversight of an Excavation Competent Person as defined in ARC HSCS005 HSS Arcadis Excavation and Trenching.

5.5.1 Temporary Backfilling of Pre-Cleared Boreholes

In some cases, it may be necessary to temporarily backfill a pre-cleared / daylighted location until the remaining subsurface activities are performed. At these locations where subsurface intrusive work does not immediately follow pre-clearance, it is important to properly backfill and mark the pre-cleared location in order to protect the utility integrity and maintain the location. In general, wooden stakes, survey flags, whisker markers, paint marking, or other surface markings alone are inadequate because these markings can be easily removed, damaged, or otherwise lost creating uncertainty for the pre-cleared location. Although the specific steps for backfilling a pre-cleared location will depend on site-specific conditions, use the following steps to prevent loss of the pre-cleared location:

- Backfill a pre-cleared location with clean sand or other granular material that is recognizably different from the surrounding subsurface native material. Native soil should not be used to backfill a pre-cleared location that may require further subsurface work.

- Backfill the top 2 feet of a pre-cleared location with dyed sand or gravel to facilitate re-location.

- Place wooden stakes or delineators to mark locations as an additional measure, if practical.

- In the event that the pre-cleared borehole is located on asphalt or concrete and an asphalt cold patch is required, use white paint to mark the intrusive location over the asphalt cold patch.

- In some instances, such as projects potentially affected by unexploded ordinance (UXO), the pre-cleared borehole may require that a PVC pipe of matching diameter be inserted into the pre-cleared borehole, filled with clean sand and affixed with a matching cap. Project teams are to discuss client specific utility location and marking requirements with the project manager prior to conducting work.

- Always use a physical subsurface marker such as described above to identify the pre-cleared borehole location. Don’t rely solely on field measurements or GPS coordinates as the only means for locating pre-cleared locations.

- If a utility or anomaly/obstruction is encountered during the pre-clearing process, backfill the hole with the native soil and mark the location with a pink-painted X and/or NO.

In the event that a previously pre-cleared location cannot be located, the location must be re-cleared prior to performing subsurface intrusive work

5.6 Clearance for Working in Vicinity of Subsurface Utilities – The Arcadis Utility Tolerance Zone

Prior to the start of subsurface intrusive activities (i.e., excavating / test pitting, drilling, installing grounding rods, manual soil sampling etc.), all utilities must be located, and steps taken to avoid unintentionally contacting or damaging subsurface utilities. See exemptions for subsurface intrusive work in Exhibit 1 (Definitions). Field Teams are not to procced with subsurface work involving utilities located within 30 inches of a line marking as measured radially (e.g. 360 degrees) from the outermost point of the marked utility. If only the centerline of the utility or utility bank is marked, but the utility width or diameter is known or suspected, the diameter of the utility or utility bank (Exhibit 1) must be incorporated into the Arcadis 30-inch Tolerance Zone, see Figure 1 located in Exhibit 2 for further instructions and an illustration of the Arcadis 30-in. Tolerance Zone.

If and when any line of evidence reveals planned subsurface work will occur within the Arcadis 30-inch Tolerance Zone of known/marked/located/observed utilities or structures, the project team must Stop Work and contact Corporate H&S for a review of steps the team has taken to prevent injury or incident involving the conflict.

If subsurface work using heavy or mechanized equipment must take place within the Arcadis 30-inch Tolerance Zone of the marked utility, the utility must be exposed (daylighted) using soft dig clearance methods prior to starting subsurface intrusive activities as described in Section 5.5 of this HSS.

Note: No heavy or mechanized equipment is permitted to be used within the Arcadis 30-inch Tolerance Zone for the purpose of daylighting the utility.

Once the utility in conflict has been daylighted, and heavy or mechanized equipment use is planned within the Arcadis 30-inch Tolerance Zone of the utility, such work must receive pre-approval by Corporate H&S to review steps the team has taken to assess and mitigate the risk associated with the planned work. Additional excavation safety procedures may have to be developed as part of the Corporate H&S approval to proceed. It should be noted that any disturbance within 30 inches of the marked utility, or disruption of the surrounding bedding materials could affect the integrity of the utility.

For horizontal borings, to avoid striking a utility, damage from vibration, damage by pressure of the advancing boring, do not drill within 30 inches in all directions (3-Dimensional cylinder) of a line marking. Make sure to factor the diameter of the line or utility bank when calculating the extent of the 30-inch Tolerance Zone. When crossing a utility during horizontal drilling, it is recommended that the utility be exposed 30 inches in a 360°-direction. When exposing utilities for horizontal borings, the utility must be exposed (potholed) by soft dig/clearance methods. This recommendation applies even if the operating contractor has technology that places the location to within a few inches. Make sure to factor the diameter of the utility when determining the 30-inch Tolerance Zone. If subsurface work must take place within the 30-inch Tolerance Zone of the line marking, the utility must be exposed (potholed) by soft dig/clearance methods prior to starting subsurface intrusive work (see Section 5.5 for options); no mechanized equipment is permitted for the exposing of the utility. Once the utility has been exposed, if mechanized equipment is planned for use within the 30-inch Tolerance Zone of the utility, such activity must receive pre-approval by Corporate H&S, as necessary, to mitigate or accept the risk associated with the planned work. Additional excavation safety procedures may have to be developed as part of the approval to proceed. It should be noted that any disturbance within the 30 inches or disruption of the bedding materials could affect the integrity of the utility.

Additional cautions for horizontal borings include gravity-fed utilities, such as sewers and storm drains. The depth of these utilities will change (sometimes significantly) as they run across the project site. Project teams need to obtain sewer utility depths in the work area(s) and determine the depth of the sewer at the location where the boring will actually intersect with the sewer line by collecting sewer pipe invert elevations from identified manholes and interpolating those depths to the area of the subsurface intrusive work.

During well installations and well abandonment via mechanical equipment, the Arcadis 30-inch Tolerance Zone rule applies in an outward direction extending from the outermost edge of the largest diameter auger or greatest width tool used for installation and abandonment (e.g. “over drilling”). In cases where wells have been previously installed and the 30-inch rule has not been followed, work proposed using heavy or mechanized equipment falling within the Arcadis 30-inch Tolerance Zone requires approval from Corporate H&S. For more information, see Figure 1 in Exhibit 2 for further instructions.

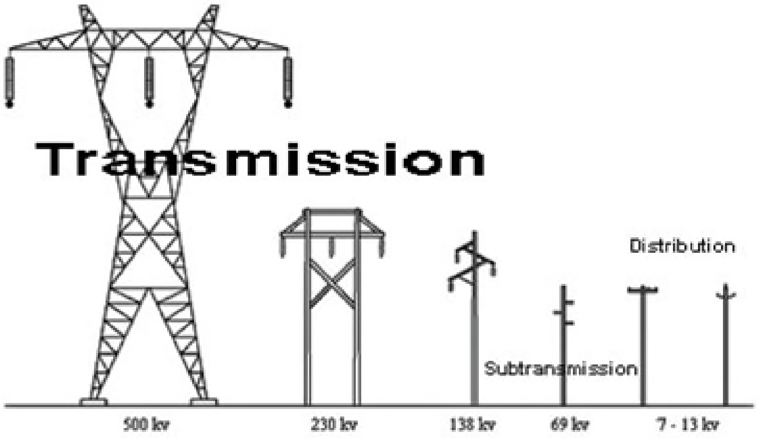
5.6.1 Aboveground Activities causing Subsurface Disturbance in the Vicinity of Underground Utilities

Aboveground work-related activities can cause damage to shallow underground utilities or structures. Asses the intended travel paths, mobilization, staging, and operation of heavy equipment and take steps to ensure shallow utilities are not damaged. If heavy equipment must cross over shallow utilities, the team is responsible for confirming the utilities will be protected.

Other subsurface disturbances may lead to damage such as removing trees/tree stumps, shrubs, or dense vegetation as roots may be entangled with underground piping or structures. For more information, see ARC HSFS-019 Supplement Section 2 Best Practices for Field Personnel Concerning Utility Clearance.

5.7 Acceptable Clearance for Working in Vicinity of Overhead Power Lines and Other Overhead Lines and Structures

No work will be performed by Arcadis or our subcontractor near overhead power lines where any Unqualified Person or equipment is within the limits specified below, unless the power line has been properly covered or de-energized by the owner or operator of the power line, or a qualified electrical subcontractor. Qualified Person approach distances are defined in Exhibit 5A and 5B of **ARC HSFS0006 Electrical Safety Standard**. Illustrations of general types of overhead utility conveyances are provided in **Exhibit 3** - Overhead Power Utility Illustrations



OSHA Electric Power etool illustration

Power Line Voltage Phase to phase (kV)	Minimum Safe Clearance (feet)
50 or below	10
Above 50 to 200	15
Above 200 to 350	20
Above 350 to 500	25
Above 500 to 750	35
Above 750 to 1,000	45

ANSI standard B30.5-1994, 5-3.4.5

5.7.1 Reducing Vehicle and Mechanical Equipment Clearance Requirements

Any vehicle or mechanical equipment capable of having parts of its structure elevated near energized overhead lines shall be operated so that a minimum clearance of 10 feet (305 centimeters [cm]) is maintained. If the voltage is greater than 50 kilovolts (kV), the clearance shall be increased 4 inches (10 cm) for every 10 kV over that voltage. However, under any of the following conditions, the clearance may be reduced:

- If the vehicle is in transit with its structure lowered, the clearance may be reduced to 4 feet (122 cm).
- If insulating barriers or "power line shields" rated for the voltage of the line being guarded are installed to prevent contact with the lines, and the barriers are not a part of, or an attachment to, the vehicle or its raised structure, the clearance may be reduced to a distance within the designed working dimensions of the insulating barrier.
- If the equipment is an aerial lift that is insulated for the voltage involved and if the work is performed by a qualified person, the clearance (between the uninsulated portion of the aerial lift and the power line) may be reduced to the distance given in OSHA 1910.333(c)(3)(ii)(C) Table S-5. Reference information from OSHA 1910.333 Table S-5 and NFPA 70E Table 130.4(C)(a) for alternating-current systems and 130.4(C)(b) for the distances associated with direct-current voltage systems is included as Exhibit 5 of ARC HSFS0006 Electrical Safety Standard.

Employees standing on the ground may not contact the vehicle or mechanical equipment or any of its attachments unless:

- The employee is using protective equipment rated for the voltage; or
- The equipment is located so that no uninsulated part of its structure (that portion of the structure that provides a conductive path to employees on the ground) can come closer to the line than permitted in this section of this HSS.

If any vehicle or mechanical equipment capable of having parts of its structure elevated near energized overhead lines is intentionally grounded, employees working on the ground near the point of grounding may not stand at the grounding location whenever there is a possibility of overhead line contact. Additional precautions, such as the use of barricades or insulation, shall be taken to protect employees from hazardous ground potentials, depending on earth resistivity and fault currents, which can develop within the first few feet or more outward from the grounding point.

When a machine is in contact with an overhead power line, do not allow anyone to come near or touch the machine. Stay away from the machine and summon outside assistance.

5.7.2 Acceptable Clearance for Working in Vicinity of Non-Electrical Overhead Utilities and Structures

Arcadis field personnel will identify non-electrical overhead utilities and structures and where possible, work is not be conducted within the 30-inch Tolerance Zone of these overhead utilities and structures. It is recommended that if work will be completed in the vicinity of non-electric overhead utilities, the overhead utilities should be labeled with warning signs, protective barricades, and/or flags. Non-electrical overhead utilities and structures may include, but is not limited to, pipe chases, water lines, ceilings in buildings, etc. Arcadis field personnel will notify its site workers (employees, subcontractors, vendors, etc.) of known overhead utilities and structures during the tailgate safety meeting. See Exhibit 2 for additional details.

5.8 Reporting Utility Incidents

Arcadis field personnel involved with any strike incidents including contact with a structural feature, subsurface, submerged, and/or aboveground utilities must immediately STOP WORK and contact the Project Manager to discuss the incident. If there are life threatening injuries, or the incident presents a risk to public safety (e.g. natural gas leak, downed live electrical line, flooding, or an unstable building) first call 911 or the available emergency services number for the client site or area and then call the Project Manager. The incident must be reported to Corporate Health and Safety immediately and no later than 24 hours after gaining knowledge of the incident. Compliant notification within 24 hrs. requires an acknowledgement of the notification by Corporate H&S. Team must provide critical details of the incident when notifying Corporate H&S such as; 3rd party involvement, any injuries, known extent of damage and estimate of potential repair cost, service interruption, and client reporting requirements. The project team and field staff will use the Arcadis Utility Line Strike Investigation Form to record initial details of the incident as part of the notification process.

Selected utility strike incidents may also utilize a conference call with operations management to review findings and lessons learned. The Business Line H&S Director will make the determination concerning the need to have the incident investigation review call and will arrange the call, if deemed necessary.

5.9 Relationship of this HSS to the Project Specific HASP

With the exception of the Utility and Structures Checklist, this HSS and the supplement documents, are not required to be printed and attached to project HASPs. Project teams have discretion to include such supplements as a BMP or reference guide when developing a project HASP. During project health and safety planning, this HSS will be reviewed and applicable clearance technologies and methods will be documented on the Utility and Structures Checklist.

Additionally, emergency response procedures specific to utility strikes should be addressed. See ARC HSFS-019 Supplement Section 5 which provides general guidelines for emergency response to utility strikes. Applicable information may be attached to the HASP or the Utility and Structures Checklist to facilitate communication of response expectations.

5.10 Required Contract Terms and Conditions

The Arcadis standard client and subcontractor contracts contain required terms and conditions defining responsibility for utility clearance and the allocation of risk associated with an impacted utility. These terms and conditions have prescribed language concerning subsurface work that is presented in Arcadis client contracts and the Arcadis subcontractor contracts, which can be found on the ANA Intranet Legal webpage. If such provisions cannot be agreed upon, the reasons are documented and other risk-management actions should be identified, such as limits of liability, add additional physical investigations, additional lines of evidence or utility location, assignment of risk to subcontractors, etc. In addition, any changes to these terms and conditions require approval by Legal Services.

6. TRAINING

Employees responsible for coordinating or conducting utility clearance activities will be familiar with the requirements of this HSS and the supplemental documents. Arcadis in-house 8-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) refresher may provide awareness-level training regarding this utility location and clearance HSS.

Field staff must complete a minimum of one year of utility clearance-related experience before accepting responsibility for any utility clearance tasks. This experience requires mentorship by a currently trained and experienced Arcadis employee for the processes of; completing DigSafe 811 notifications, developing a working understanding of the types of utilities present at project sites, developing a working understanding of the various reliable lines of evidence, and participating in on-site training led by another Arcadis employee with detailed knowledge and experience in identifying utilities and structures.

7. REFERENCES

- Occupational Safety and Health Administration (OSHA) 29 CFR Subpart P, Excavations, 1926.651, Specific Excavation Requirements.
  - Common Ground Alliance State Law Directory - https://commongroundalliance.com/map
  - Arcadis Utilities and Structures Checklist:
    - Excel Version - Utility and Structures Checklist
    - PDF Version - Utility and Structures Checklist
  - Arcadis Utility Line Strike Investigation Form
  - The Arcadis ARC HSFS-019 Supplement Documents include the following Sections:
    - Section 1 - Best Practices for Project Managers (or Their Delegates) Concerning Utility Clearance
    - Section 2 - Best Practices for Field Personnel Concerning Utility Clearance
    - Section 3 - Use and Limitations Associated with Location Technologies and Common Utility Clearance Methods
    - Section 4 - Best Practices for State One Call Procedures and Notifications
    - Section 5 - Emergency Action Plan guidelines for Utility Strikes
    - Section 6 - Utility Location SOP for Aquatic Work Activities
  - Figure 1 – 30-Inch Tolerance Zone
  - Arcadis H&S Standard ARC HSCS005 Excavation and Trenching

- Arcadis H&S Standard ARC HSFS0006 Electrical Safety Standard

8. RECORDS

8.1 Utility Clearance Records

All records (maps, checklists, and documentation of communications) used to determine the location of utilities should be retained and kept in the project file.

9. APPROVALS AND HISTORY OF CHANGE

Approved by Julie Santaniello, CSP – Corporate H&S Manager of Technical Programs

Julie

History of Change

Revision Date	Revision Number	Standard Developed/Reviewed by or Revised By	Reason for change
13 December 2006	01	Mike Thomas/Pat Vollertsen	Original document
26 March 2007	02	Mike Thomas/Pat Vollertsen	Put in new company format
15 May 2007	03	Mike Thomas/Pat Vollertsen	Added nation-wide 811 number
6 September 2007	04	Mike Thomas/Pat Vollertsen	Changing over to new template format
22 February 2008	05	Mija Coppola	Changing over to new template format
13 January 2009	06	Mija Coppola	Define lines of evidence
4 October 2010	07	Sam Moyers/Mija Coppola	Reformatting and addition of utility clearance information
13 February 2012	08	Sam Moyers/Mija Coppola	Modified link information for utility strike reporting, clarified local/state requirements in section 4.1 and 4.3

Revision Date	Revision Number	Standard Developed/Reviewed by or Revised By	Reason for change
28 January 2013	09	Tony Tremblay	Utility and Structures Checklist revised; hyperlink updated
12 February 2013	10	Amanda Tine/Tony Tremblay	Clarified clearance boundaries for Unqualified staff in Section 5.7 and added information about vehicles and equipment being used near power lines in Section 5.7.1
15 March 2013	11	Kurt Merkle, Rebecca Lindeman / Tony Tremblay	Added additional text to HSS for recent lessons learned, added section 5.4 (Locating Technologies) and 5.5 (Clearance Methodologies), added additional details to section 5.6 when working in close proximity to subsurface utilities, and added Supplement 6 - Utility Location SOP for Aquatic Work Activities.
07 July 2013	12	Andrew McDonald/ Tony Tremblay	Removed HSFS-019 Supplement 1, Utility Definitions. Added hyperlink for One Call and State Law Directory. Segregated evidence of sewer or storm drains in USC list. Removed Sam Moyers and added Andrew McDonald as author.
26 September 2014	13	Andrew McDonald/Tony Tremblay	Added Exhibit 1. Definitions and 30-inch tolerance zone. Clarified use of 811 or state one call as a reliable line of evidence. Added best practice to cover backfilling of pre-cleared boreholes. Updated USC list to cover soft dig termination depths and PM review.
23 February 2015	14	Tony Tremblay	Page number correction

Revision Date	Revision Number	Standard Developed/Reviewed by or Revised By	Reason for change
10 May 2016	15	Denis Balcer/Sharon Lingle/Alec MacAdam/Andrew McDonald/Tony Tremblay/Julie Santaniello	ES and Section 4.2 - define subsurface intrusive work; clarify employees providing oversight of utility contractors, Arcadis requirements of operating and interpreting results of utility clearance equipment, and utility clearance before all subsurface intrusive work. Sections 1 and 5.8- changed submarine to submerged. Section 4.1 – added contacting public utility companies to help clear utilities. Section 4.2 – Clarified requirement to complete one year of utility clearance-related experience. Section 4.2 and 4.3 - Added discussion on aboveground activities causing subsurface disturbances. Added responsibility to clear overhead utilities when heavy equipment will be used and to evaluate use of a spotter. Added that repairs to damaged utilities need to be verified as competent and complete. Section 5.2 – Clarified reliable lines of evidence for each subsurface intrusive work point and degrees of certainty. Added all work within 30-inch Tolerance Zone needs Corp H&S preapproval. Section 5.6 and Exhibit 1- Clarify subsurface intrusive work and activity and exemptions for subsurface intrusive work. Section 5.6.1 – Add requirement to evaluate aboveground activities that may lead to subsurface disturbances that may cause damage to shallow underground utilities or structures.

Revision Date	Revision Number	Standard Developed/Reviewed by or Revised By	Reason for change
10 May 2016	15	Denis Balcer/Sharon Lingle/Alec MacAdam/Andrew McDonald/Tony Tremblay/Julie Santaniello	Section 5.7.2 – added non-electric overhead utilities and structures other than power lines need to be identified and marked if working in that area. Section 9 – Changed reviewer from Tony Tremblay to Julie Santaniello. Exhibit 1 – added definitions of Utility Strike, Daylighting, Potholing, Subsurface Intrusive Work, Subsurface Intrusive Activities, and Utility Bank. HSS and Supplements placed on new Arcadis headers. Updated Supplement revision numbers to be consistent with HSS. Supplement 2 revised. Utility Clearance and Structures Checklist and Utility Strike Investigation Form revised.
17 March 2017	16	Alec MacAdam/Julie Santaniello	Hyperlink updates; minor formatting; Utility Clearance and Structures Checklist revised.
13 May 2020	17	Alec MacAdam/Denis Balcer/Greg Mason/Julie Santaniello	Updated HSS format. Combined HSS Supplements, revised HSS sections, revised the Utility & Structures Checklist, added Exhibit 2 - Acronyms and Abbreviations.

EXHIBIT 1 - DEFINITIONS

Aboveground Utilities - For the purpose of this procedure, aboveground utilities include, but are not limited to: any aboveground line, pipe, conduit, system, or facility used for producing, storing, conveying, transmitting or distributing communication or telecommunications signals, electricity, gas, liquid, petroleum and petroleum products, coal slurry, hazardous liquids or gases, water under pressure, steam, sanitary sewage, storm water, or other materials, liquids, or gases.

Daylighting – exposing underground utilities or structures through soft dig technology/clearance prior to completing subsurface intrusive activities.

e.g. - Exempli gratia. Latin for “for the sake of example.” Use it to introduce one or more examples.

Excavation - Any man-made cut, cavity, trench, or depression, in an earth surface formed by earth removal into which a person can bodily enter.

I.e. - I.e. is the abbreviation for “id est” and means “in other words” or “in essence”.

Kilovolt (kV) - One kilovolt is equal to 1,000 volts (v), which are the potential difference that would move one ampere of current against one ohm of resistance. The kilovolt is a multiple of the volt, which is the SI derived unit for voltage.

Overhead Utilities and Structures – Overhead water lines, overhead pipe chases, ceilings in buildings.

Potholing – exposing underground utilities or structures through soft dig technology/clearance prior to completing subsurface intrusive activities.

Subsurface Intrusive Activities – For the purposes of this procedure, subsurface intrusive activities include, but are not limited to excavations, vertical drilling, installing grounding rod, soil sampling, etc.,

Subsurface Intrusive Work – Is any work or activity that breaks the plane of the ground surface. Exemptions include soil sampling using a non-conductive sampling tool to a depth of 6 inches below ground surface (bgs), placement of survey flagging to a depth of 6 inches bgs, and placement of non-conductive survey stake(s) to a depth of 6 inches bgs).

Subsurface Utilities - For the purposes of this procedure, subsurface utilities include, but are not limited to: any underground line, pipe, conduit, system, or facility used for producing, storing, conveying, transmitting or distributing communication or telecommunications signals, electricity, gas, liquid, petroleum and petroleum products, coal slurry, hazardous liquids or gases, water under pressure, steam, storm water, or sanitary sewage; underground storage tanks; tunnels and cisterns; and septic tanks and lines.

Utility Bank – a structure containing two or more conduits. A conduit is a single enclosure containing one or more facilities.

Utility Strike – An unplanned contact of a utility (i.e., overhead utilities, buildings, structures, aboveground utilities, underground utilities. or submerged utilities) during the course of work that results in; damage requiring repairs, making a report to the utility owner, or requiring further assessment to evaluate the potential for damage.

Utility Tolerance Zone – The area within 30 inches measured radially (e.g. extending in all directions) from the outside diameter of a located/marked utility in which special care is to be taken. If the centerline of the utility is marked, the diameter of the utility or utility bank/trench must be incorporated into the 30 inches. This area must be hand cleared with non-mechanized equipment. Once the utility has been exposed, if mechanized equipment is planned for use within the Arcadis 30-inch Tolerance Zone of the utility, such activity must receive pre-approval by Corporate H&S, to mitigate or accept the risk associated with the planned work. See Figure 1 – 30-inch Tolerance Zone.

Exhibit 2 – Acronyms and Abbreviations

ANA	Arcadis North America
Arcadis	Arcadis U.S. Inc.
ARC	Arcadis
APM	Associate Project Manager
APL	Acoustic Pipe Location
AKA	Also Known As
BGS	Below Ground Surface
cm	Centimeter
EM	Electromagnetic
ft.	Feet
GPR	Ground Penetrating Radar
HS	Health and Safety
H&S	Health and Safety
HSS	Health and Safety Standard
HAZWOPER	Hazardous Waste Operations and Emergency Response
HSFS	Health and Safety Field Safety
HSCS	Health and Safety Construction Safety
https	Hypertext transfer protocol secure
in.	Inch
kV	Kilovolt
m	Meter
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PIV	Post Indicator Valve
PUL	Private Utility Locator
PM	Project Manager
RF	Radio Frequency

RFD	Radio Frequency Detection
SOP	Standard Operating Procedure
TM	Task Manager
TZ	Tolerance Zone
UXO	Unexploded Ordinance

Exhibit 2 Figure 1 – Arcadis Tolerance Zone Illustration

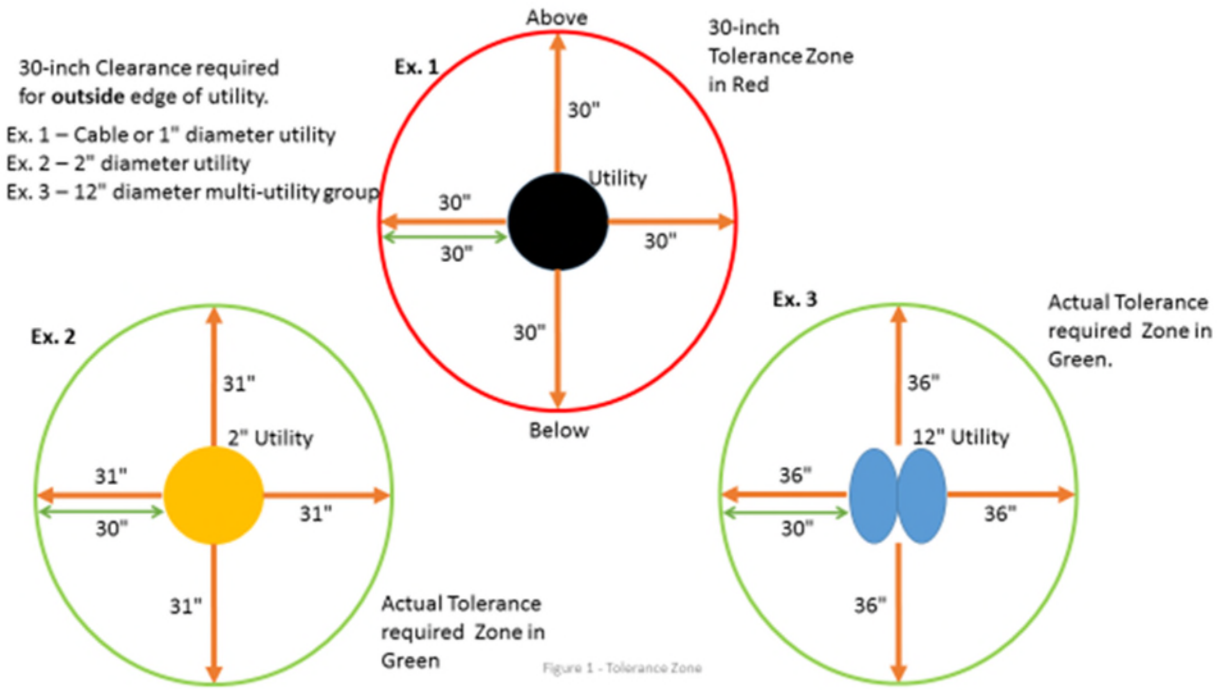
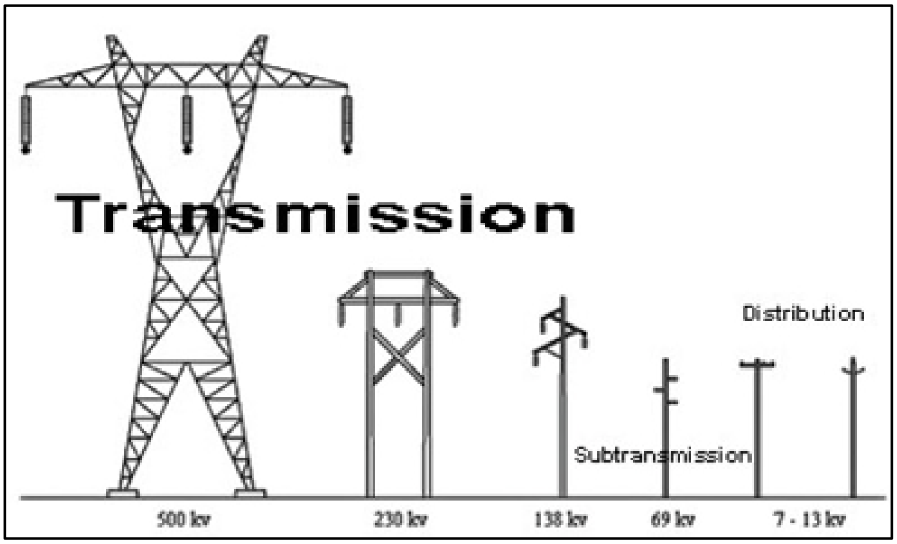
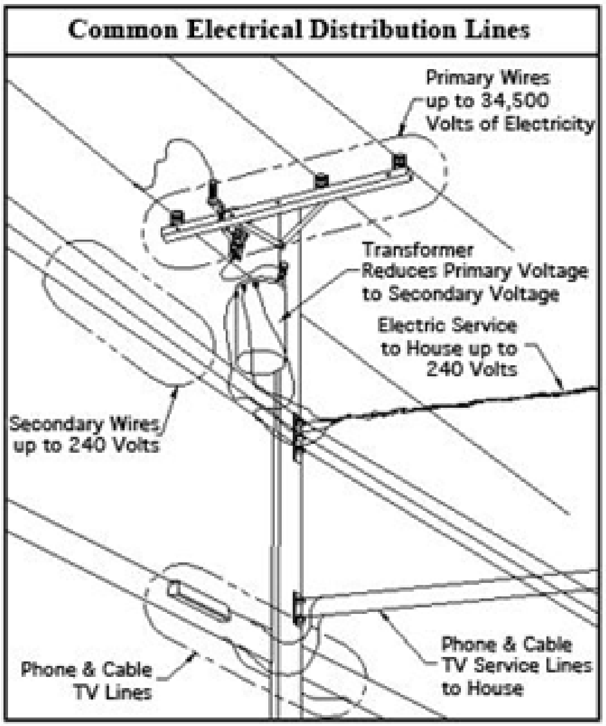


Exhibit 3 – Overhead Power Utility Illustrations





Attachment F

BNSF H&S Requirements

Contractor Safety Orientation

provided by

CONTRACTOR ORIENTATION

Contractor Safety Action Plan Sections

1. BNSF Safety Vision
2. Overview
3. General Information
4. Contractor Credential Requirements
5. Job Safety Briefings
6. Regulatory Training Programs
7. Federal Railroad Administration (FRA) Roadway Worker Requirements
8. Compliance Affirmation

Please note: Only sections 3 & 8 require input.

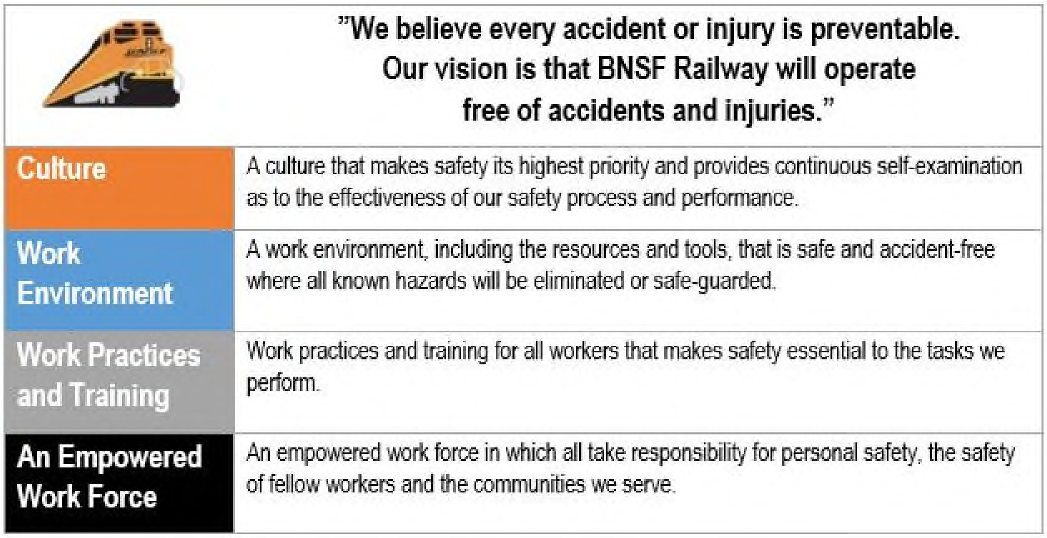
Appendix

A. Personal Protective Equipment (PPE)
B. Vehicle Operations
C. Fire Safety
D. Incident & Injury Form

☎ **BNSF 24-hour Emergency**
1-800-832-5452

1. BNSF Safety Vision

The BNSF Safety Vision establishes our fundamental values, a unity of purpose and projects a clear image of the future that has the best interests of all its people at heart.



"We believe every accident or injury is preventable. Our vision is that BNSF Railway will operate free of accidents and injuries."

Culture	A culture that makes safety its highest priority and provides continuous self-examination as to the effectiveness of our safety process and performance.
Work Environment	A work environment, including the resources and tools, that is safe and accident-free where all known hazards will be eliminated or safe-guarded.
Work Practices and Training	Work practices and training for all workers that makes safety essential to the tasks we perform.
An Empowered Work Force	An empowered work force in which all take responsibility for personal safety, the safety of fellow workers and the communities we serve.

2. Overview

The purpose of a Safety Action Plan (SAP) is to have a structured approach for maintaining safe work activities. Well-developed plans and proper training helps workers understand their roles and responsibilities, which results in fewer and less severe injuries and less equipment damage. General Contractors may submit a SAP including subcontractors or require each subcontractor to submit their own SAP.

REQUIREMENT

The Safety Action Plan must be available as follows:

1. One copy per company uploaded to Contractor Orientation at www.bnsfcontractor.com
2. Site-specific versions provided to the BNSF Project Manager or Employee in Charge (EIC)
3. Site-specific versions maintained with each work group on BNSF property

3. General Information

Company Name:

Arcadis-us

Contractor who is the main point of contact on BNSF property:

Sam Moyers	Director of Transportation Sa	18656212117	sam.moyers@arcadis.com

BNSF employee who is contractor’s main point of contact:

CHARLES.THOMAS@BNSF

Work Site Location:

Addressed in Site Specific S

Type of Work to be Performed:

Addressed in Site Specific S

Contract Type:

● Primary/General Contractor
○ Subcontractor

Will your subcontractor(s) complete their own Safety Action Plan or are you covering them on your SAP?

Not Covered

List any subcontractors you will have working on behalf of your company on BNSF property:

Subcontractor 1: *(Required)*

Addressed in Site Specific S	Addressed in Site Specific S	

Subcontractor 2:

Subcontractor 3:

Subcontractor 4:

Subcontractor 5:

Addtional Subcontractors:

List any specific training or qualifications
your employees will have based on the work they will perform.

Addressed in Site Specific SAP or HASP

Other:

If contractors are utilized, their names and contact information will be in the site specific SAP or HASP for the project.

Requirement

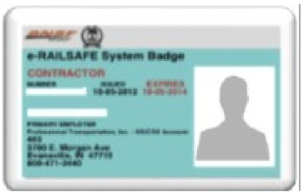
Current copies of Safety Data Sheets (SDSs) for hazardous materials **must** be provided to the BNSF Project Manager or EIC **and** be maintained on-site.

4. Contractor Credential Requirements

BNSF Contractor Orientation

Contractors and subcontractors must complete Contractor Orientation at www.bnsfcontractor.com to gain an understanding of the information needed to work safely on BNSF property. After completion of the orientation modules, contractors will receive a BNSF Contractor badge. This badge displays the modules completed, expiration date, and must be made available upon request.

eRailSafe Background Verification



Contractors and subcontractors must complete the eRailSafe background verification before entering BNSF property or having access to BNSF information systems. Each approved eRailSafe applicant will receive a photo ID badge, which must be worn visibly on their person. www.erailsafe.com

5. Job Safety Briefings

The Contract employer **must** ensure their workers receive Job Safety Briefings at the start of each work shift **and** as needed during the course of the day; e.g. personnel changes, weather changes, and/or changes in assignments.

- Job Safety Briefings will include Emergency Preparedness Information and summarize the findings of Risk Assessment activities.
- In addition to critical safety and response preparation, Job Safety Briefings provide information on potential exposures in the work environment, discussion about the best ways to minimize risk to exposure, and potential cues to pause the work.

Begin each shift with a

JOB SAFETY BRIEFING

1. LIFE-SAVING PROCESSES & EMERGENCY PREPAREDNESS

BNSF 24-hour Emergency
1-800-832-5452

Who is **CPR** qualified?

Who is **First Aid** qualified?

Where is the **defibrillator**?

Where is the **First Aid Kit**?

Is there **cell, radio** and/or **land line contact**?

If not, who will establish it?

Who will create written **directions to job site** to use in case of emergency (latitude/longitude recommended)?

What are the **emergency numbers**?

- **Medical**
- **Fire**
- **Police**

Who will **make the emergency call**?

Who will **meet emergency personnel**?

2. DISCUSS THE TASK AT HAND	How will weather conditions, crew experience levels, equipment and processes **affect the task** to be performed?
3. IDENTIFY THE EXPOSURES	What are the **exposures present** for the task to be performed?
4. DISCUSS WAYS TO MINIMIZE RISK	How do we **control risk** for each exposure?
5. IDENTIFY CUES TO PAUSE THE WORK	What are the **cues for pausing** the work to rebrief?

Weather, location, schedules and equipment can change in a moment's notice—changing the level of risk.

One briefing at the beginning of the shift is often not enough to ensure everyone is aware of changes throughout the day.

When you notice that things have changed, pause and choose safety.

Pause the work
Assess conditions
Understand the risk
Strategize a safer plan
Execute the plan

Consider the exposures below and how you might protect yourself and your workers.

	LIFE-SAVING PROCESSES
	Life-Saving Processes are proactive processes we consistently perform that may help protect us from the most critical risks.
	EXPOSURES
	Line of Fire/Release of Energy is an exposure that exists when a person or an object may be unexpectedly struck between two objects coming together. To mitigate risk to this exposure, avoid placing your body in a position to be hit, cut, struck or sprayed if something shifts, moves, releases or travels unexpectedly.
	Pinch Point is an exposure that exists when a person places his/her fingers or toes between objects that could crush them if the object came together unexpectedly.
	Ascending/Descending is an exposure that exists in environments where moving from one level to another may be necessary. Mitigate risk to this exposure by using three-point contact, avoiding jumping from one level to another, using hand rails on stairs and looking before stepping when climbing and going from one place to another.
	Walking/Path of Travel exposure is an exposure along a path of travel that could cause a slip, trip or fall. Look in your path of travel before moving, scan the path, use designated pathways when walking and take the safest route available to mitigate this exposure.

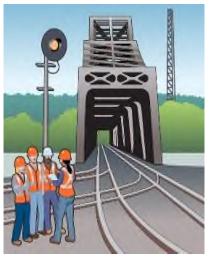
6. Regulatory Training Programs

Contract companies are responsible to ensure their workers and subcontractors are properly trained to meet all regulatory requirements prior to beginning work for BNSF. Examples include:

- Arc Flash/Electrical Worker
- Fall Protection
- Lead Safety

- Asbestos
- Confined Space
- DOT Training
- Environmental/Hazardous Waste
- Excavatoin (Trenching/Shoring)
- FRA Bridge Worker Safety
- FRA Roadway Worker
- Hazard Communications
- Hearing Conservation
- Lockout/Tagout
- Personal Protective Equipment
- Respiratory Protection
- Other Safety Training Programs

7. Federal Railroad Administration (FRA) Roadway Worker Requirements



Per the FRA, Roadway Worker duties include inspection, construction, maintenance or repair of track, bridges, roadway, signal and communication systems, electric traction systems, roadway facilities or roadway maintenance machinery on or near track or with the potential of fouling a track, and other personnel directly involved with their protection.

For contractors or subcontractors performing Roadway Worker duties as defined above,

1. Contractor and subcontractor companies must provide these workers annual FRA Roadway Worker Protection (RWP) training, **and** these contract workers must be able to provide current RWP training documentation. *RWP concepts should be reinforced in Job Safety Briefings.*
2. Contractor and subcontractor companies must ensure they are in compliance with the FRA Part 219 Drug & Alcohol Testing requirements and the FRA Part 243 Training, Qualification, and Oversight requirements. Contact the FRA at rrswebinquiries@dot.gov with any questions.

8. Compliance Affirmation

The following section serves as your company's Compliance Affirmation to this document:

Name: Sam Moyers

Title: Director of Transportation Sa

Date: 2022-01-04

REQUIREMENT

Don't forget:

1. One SAP per company uploaded to Contractor Orientation at www.bnsfcontractor.com
2. Site-specific SAP to the BNSF Project Manager or Employee in Charge (EIC)
3. Site-specific SAP with each work group

Thank you for completing your Safety Action Plan!

Appendix

A. Personal Protective Equipment (PPE)

PPE compliance is strictly enforced as per Section 21 of BNSF Safety Rules. Your contract may require a variety of work and tasks in different environments, and all workers must have the proper PPE while on BNSF property.

All individuals must have the appropriate PPE when on BNSF property, including:

- Eyewear & Face Protection
- Steel-toed boots/anti-slip footwear
- Hard Hat
- Hearing Protection
- Gloves/Hand Protection
- High-Visibility, ANSI Class II or III vest (based on type of work performed)

Other specialty PPE as identified/required by BNSF Safety Rules for task at hand.

B. Vehicle Operations

Vehicle Operation Guidelines

Every day, there is a wide variety of vehicles operating safely and without incident. However, we must remember that we work in an unforgiving environment.

Identify Exposures and Discuss the Best Ways to Minimize Risk

Line of Fire/Release of Energy

- Obey all traffic control signs and be aware of current surroundings at all times to avoid being in the line of fire from other vehicle traffic
- When at non-public crossings, stop before crossing the track(s), unless the vehicle is foul of a previously crossed track. Yield to trains, engines, rail cars, and on-track equipment before proceeding across the track(s).
- Identify and comply with proper clearance requirements prior to operating vehicles between tracks.

Ascending Descending

- Use caution when boarding or disembarking vehicles. Verify stable footing before getting in or out of the vehicle.
- Do not place your feet where your eyes have not been.

Pinch Point

- Keep fingers away from door hinges, and feet/toes away from door edges to prevent them from being crushed if door shuts/slams unexpectedly.
- Use the door handles or latches when opening and closing doors.

Life-Saving Processes

- Know and obey local, state and federal laws and vehicle operation regulations, both on and off company property
- Wear seat belts while operating or riding in equipment or vehicles that are equipped with them, as required.
- While driving, do not use cellular phones or similar handheld devices for voice communications in other than hands-free mode. Do not read or manually enter text messages.
- Use headlights any time the vehicle is moving.

What should be done before operating any vehicle and why?

- A thorough pre-use inspection of the vehicle should be performed with proper documentation and correction of any defects found to ensure that vehicles are in optimally safe condition.
- Operators must be trained and authorized for the vehicle that they will be using, where required. Every driver must carry a valid driver’s license.
- When driving a car or truck, workers are expected to comply with posted speed limits and operate the vehicle in a safe and careful manner.
- Studies show that seat belts save lives. Workers must wear seat belts while operating or riding in vehicles on BNSF property.

What is the safest way to back up a vehicle?

It’s best to position the vehicle to avoid backing up, if possible. If backing up is necessary, inspect the areas to the rear before beginning the movement to ensure that no people or obstructions are in the path.

- Position someone near the back of the vehicle to guide the movement, when possible.
- Sound the horn (three short blasts) in vehicles not equipped with back-up alarms.
- Stop if the person guiding the movement disappears from view.

What are the proper procedures for parking safely?

- Avoid parking on an incline, if possible. If parking on an incline is unavoidable, the driver should set the emergency brake and take other precautions to prevent the vehicle from rolling unexpectedly.
- Do not park so that vehicle is fouling a track or roadway. If fouling is necessary to perform duties, do so only if proper protection has been established.

C. Fire Safety

Before performing hot work tasks in right-of-way areas, work groups must perform a **thorough Fire Safety Risk Assessment,** ensure the **proper precautions** are in place, confirm that **specific fire-fighting tools are available** and establish **an emergency plan** to help prevent fires from being started by hot work activity.

What hazards may be present when performing hot work tasks in right-of-way areas?

Hand welding, cutting and grinding operations result in sparks or slag that can readily ignite a fire. In addition, serious injury can occur should clothing ignite.

What precautions can be taken when performing these operations to help prevent fires?

- Use protective screens or blankets to contain errant sparks or slag.
- Wet down the immediate work area and surrounding area before work begins.
- Make saw and torch cuts to the centers of track and direct small-scale grinding sparks to ballast to better contain sparks and slag.

What steps must be taken before work begins in right-of-way areas?

Before performing hot work activities, work groups must conduct a **Fire Safety Risk Assessment** to:

- Determine current fire conditions, including whether local work restrictions are in effect and/or whether special permits are required.
- Establish the response capabilities of the local fire agency.

What factors should be considered when doing a Fire Safety Risk Assessment?

A thorough fire safety risk assessment must take into consideration factors such as:

- Vegetation Type
- Rainfall
- Relative humidity
- Temperature
- Wind speed/direction
- Time of day of work activities
- Type and extent of work actvities

How does weather factor into fire safety during hot work tasks?

- Each work group must complete a **fire risk assessment** before work begins. This assessment should include considerations such as weather conditions and the use of a wind meter to determine wind speed. Hot work operations **should not** be conducted when wind speeds exceed 30 mph.

What elements must an Emergency Preparedness Plan include?

- Verify that Emergency Preparedness plans contain contacts and response times for responding fire agencies, as well as directions to the work site.
- Identify and communicate escape routes.
- Mechanically clear and/or apply herbicides along right-of-way areas to inhibit the growth of vegetation that provides fuel for fires.
- Comply with local fire agency requirements. Be sure to clear low spots, areas around culverts, etc. of vegetation that could provide fuel for fires.

D. Incident & Injury Form

NON-EMPLOYEE PERSONAL INJURY DATA COLLECTION

Please complete this form and provide to the BNSF supervisor, who will input this information into the EHS Star system. For questions call (817) 352-1267 or Safety.IncidentReporting@BNSF.com

Accident City/State: ____________________ **Date:** ______________ **Time:** __________

Line Segment/Mile Post: ____________ **County:** ______________

Temperature: ____________________ **Weather:** ____________

Name (Last/First/MI): ____

Job Title: ____________________ **Age:** _____ **Gender:** ____

Company: ____

eRailSafe Badge Number: ______________ **Expiration Date:** ____________________

BNSF Contractor Badge Number: ____________ **Expiration Date:** ____________________

Injury: ____________________ **Body Part:** ____________________
(e.g., laceration) (e.g., hand)

Description of accident (include how accident occurred, potential cause, etc.):

____

____

____

Work activity in progress at time of accident: ____________________

Tools, machinery, or hazardous materials involved in accident: ____________________

____

Treatment Received (include medications):

____

____

____

Dr. Name: ____________________ **Date:** ____________________

Dr. Street Address: ______________ **City:** ____________ **State:** _____ **Zip:** ______

Treatment Facility Name: ____

Treatment Facility Street Address: ____________ **City:** ____________ **State:** _____ Zip: ______

Diagnosis: ____

THIS REPORT IS PART OF BNSF'S ACCIDENT REPORT PURSUANT TO THE ACCIDENT REPORTS STATUTE AND, AS SUCH SHALL NOT "BE ADMITTED AS EVIDENCE OR USED FOR ANY PURPOSE IN ANY SUIT OR ACTION FOR DAMAGES GROWING OUT OF ANY MATTER MENTIONED IN SAID REPORT…." 49 U.S.C. § 20903. See 49 C.F.R. § 225.7(b).

ENVIRONMENTAL DEPARTMENT QUICK REFERENCE GUIDE
WORKING AROUND TRACK AND IN YARDS

Regulation(s)
- FRA Track and Safety Compliance Manual, Volume 3

Corporate Rule
- Employee Safety Rules S1.6.2, S13.1

Key Definitions
- Fouling Track - Fouling a track means the placement of an individual in such proximity to a track that the individual could be struck by a moving train or other on-track equipment, or in any case is within four feet of the nearest rail. FRA

Procedures

- Employees are prohibited from fouling a track, including in a yard, except when duties require it and safeguards are utilized.
- Always conduct a safety briefing before doing work near tracks and when tasks or situations change.
- Know your track protection!
- Always ask yourself: **Do I need to foul the track? Is it safe to foul the track? How do I determine if it is safe to foul the track?**

- When crossing or fouling tracks:
    - **Do not cross within 25 feet of the end of standing equipment** unless the appropriate protection has been established.
    - **Do not cross in front of approaching equipment** unless you are sufficiently ahead of the equipment to cross safely.
    - **Do not walk between rails or foul the track,** except when duties require and proper protection is provided. Use caution during bad weather and when visibility is impaired.
- When crossing over rail equipment, such as locomotives or cars:
    - Obtain positive confirmation that the equipment will not be moved.

    - Cross only through cars with a crossover platform and preferably with handholds.
    - Do not step on the coupler or uncoupling lever.

- Always identify exposures and look to minimize risks when working around track. It is important to consider and identify exposures present for a given task. While there are multiple exposures present when duties require fouling a track, some of the most common are listed below and should be covered during the safety briefing.

Line of Fire/Release of Energy

  - When working near tracks, only walk between rails or foul the track when duties require.
  - Before fouling track, determine whether it is safe to do so.
  - If the track is occupied, ensure the appropriate protection has been provided for the task to be performed.
  - Be aware of your surroundings at all times (including movement on adjacent tracks) to ensure that you are not in the line of fire from unexpected movement.
  - Verify tracks intended for railcar or engine movement are clear of obstructions before removing the appropriate protection to allow the movement.

Life-Saving Processes

  - When working near track, always remember to follow and use the most critical procedures and brief with co-workers about these procedures.
  - When parking or spotting equipment next to tracks, use the clearance lines to ensure equipment is parked a safe distance from the track.

Ascending/Descending

  - Use caution when stepping off equipment to avoid stepping into the foul of an adjacent track. Never get on or off moving equipment, except in an emergency to prevent injury.

Walking/Path of Travel

  - Conditions such as weather, lighting and range of vision can affect your safe path of travel or the ability to visually check all equipment. For example, equipment can appear to be farther away than it actually is during periods of darkness. Snow and rain can obscure vision, and create slip, trip or fall hazards.

- To minimize risk when working near track:
  - Remain alert and attentive. **Always expect the movement of trains, locomotives, cars or other equipment at any time, on any track and in either direction.**
  - Look in both directions, watch for moving equipment on adjacent tracks, and cross in front of approaching equipment only when sufficiently ahead of the movement to do so.
  - Don’t lose focus of movement on adjacent tracks.

Appendix D

Arcadis Technical Guidance Instructions

SOP - SAMPLE CHAIN OF CUSTODY

Rev: #2

Rev Date: April 29, 2020

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	April 19, 2017	All	Re-write to COC only	Richard Murphy
1	May 23, 2017	4	Add: Guidance on use of previous version of SOP.	Peter Frederick
		9	Add: Info on COCs for multiple shipping containers	
		7	Modify: Move letter i. to letter m. and change to "when appropriate"	
2	April 29, 2020	4	Remove obsolete link	Lyndi Mott
		11	Remove obsolete link	

APPROVAL SIGNATURES

Prepared by:		05/23/2017
	Peter C. Frederick	Date:
Technical Expert Reviewed by:		05/29/2020
	Lyndi Mott (Technical Expert)	Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) describes the general Chain of Custody (COC) procedures and guidance instructions for samples collected from project sites that are relinquished from Arcadis' possession.

COC is defined as the maintenance of an unbroken record of possession of an item from the time of its collection through some analytical or testing procedure. COC is typically documented by a written record of the collection, possession, and handling of samples collected from a project location. Each sample will be tracked by a documented record that efficiently documents the individuals who were responsible for the sample during each successive transfer of that sample to various recipients beyond Arcadis' possession. This information can be used to legally establish the integrity of the samples and therefore the analytical results derived from the samples. This information can be used in addition to other records and documentation regarding the samples, such as field forms, field logs, and photographs.

A sample is considered under custody if:

- It is in your possession; or
- It is in your view, after being in your possession; or
- It was in your possession and then you then locked it up to prevent tampering; or
- It is in a designated secure area.

Continued use of previous version of SOP:

Although not recommended, Arcadis program-, project-, and client-teams may be able to use the previous version of this SOP provided that it meets all of the quality expectations of Arcadis and client, and meets applicable regulatory requirements. It is up to the program, project, and/or client-team leader to determine whether it is appropriate to adopt the current SOP or to continue using the previous version.

However, all new work not associated with the previous version of this SOP must be performed with the current version of the SOP.

When adopting this new SOP, users of the previous versions must be aware that specific handling, packing, and shipping procedures and guidance has been removed and that those should be addressed within program or project plans (e.g. QAPPs, Work Plans, SAPs, etc.) or in a more detailed SOP or TGI specific to that sampling activity, whether related to media, constituent/analyte, client, state, etc.

In addition, adopting this new SOP will require users to refer to the Arcadis DOT Safety Program for procedures and guidance on the determination and handling, packing, and shipping of samples that are or may be considered hazardous materials.

3 PERSONNEL QUALIFICATIONS

Arcadis personnel performing work under the purview of this SOP will have received appropriate training and have field experience regarding the collection of samples from project locations. Arcadis personnel will have all other applicable and appropriate training relevant to the sampling work and project site.

4 EQUIPMENT LIST

The following list provides materials that may be required for each COC. Project reporting and documentation requirements must be reviewed with the CPM prior to execution of work. Additional materials, tools, equipment, etc. may be required, and project staff are required to verify with the CPM and/or Technical Expert what specific equipment is required to complete the COC.

- Indelible ink pen (preferably either black or blue ink);
- COC form (**Appendix A**) from either Arcadis, laboratory receiving and analyzing the samples, or other applicable and appropriate entity for the work performed;
- When appropriate, such as for litigation or expert testimony work, custody seals or tape.

5 CAUTIONS

One way in which the law tries to ensure the integrity of evidence is by requiring proof of the chain of custody by the party who is seeking to introduce a particular piece of evidence.

A proper chain of custody requires three types of affirmations: (1) affirmation that a sample is what it purports to be (for example, soil collected from a specified location and depth); (2) affirmation of continuous possession by each individual who has had possession of the sample from the time it is collected until the time it is analyzed or held by a laboratory; and (3) affirmation by each person who has had possession that sample remained in substantially the same condition and not contaminated or affected by outside influences from the moment one person took possession until the moment that person released the evidence into the custody of another (for example, affirmation that the sample was stored in a secure location where no one but the person in custody had access to it).

Proving chain of custody is necessary to "lay a foundation" for the samples in question, by showing the absence of alteration, substitution, or change of condition.

Ensure that appropriate sample containers with applicable preservatives, coolers, and packing material are planned for and provided at the site at the time of sample collection.

Understand the offsite transfer requirements of the samples for the facility at which samples are collected.

If overnight courier service is required schedule pick-up or know where the drop-off service center is located and the hours of operation.

An Arcadis employee appropriately trained at the correct level of internal hazardous materials/DOT (Department of Transportation) shipping must complete an Arcadis shipping determination to address applicable DOT and IATA (International Air Transport Association) shipping requirements. Review the applicable Arcadis procedures and guidance instructions for sample packaging, and labeling. Prior to using air transportation, confirm air shipment is acceptable under DOT and IATA regulations.

The person relinquishing possession of the samples or other member of the project team should contact the final recipient of the samples to confirm receipt and review any special provisions on the COC or questions that they may have.

6 HEALTH AND SAFETY CONSIDERATIONS

Follow the health and safety procedures outlined in the project/site Health and Safety Plan (HASP) as well as other applicable H&S requirements, such as:

- Arcadis Hazardous Material/DOT handling, packaging, and shipping training
- Project site-specific H&S training
- Client-specific H&S training
- Constituent-specific H&S training
- Media-specific H&S training

7 PROCEDURE

Collected samples must be uniquely identified, and properly documented, containerized, labeled with unique identifier, possessed in a secure manner during remainder of sampling event, packaged, and shipped to recipient laboratory.

Sample Identification

The method of sample identification depends on the type of measurement or analyses performed. In some cases, in-situ measurements of existing conditions and/or sample location must be made during sample collection. These data will be recorded directly on field forms, logbooks, or other project record data sheets used to permanently retain this information for the project file. Examples of location identification information includes: latitude/longitudinal measurements, compass directions, well number, building number, floor number, room name, or proximity to a site feature unique to the site. Examples of in-situ measurements are pH, temperature, conductivity, flow measurement, or physical condition of the media being sampled. Physical samples collected are identified by a unique identifying number or code on a sample tag or label. These physical samples are removed from the sample location and transported to a laboratory for analyses.

In some cases, before samples are placed into individual containers and labeled as individual samples, samples may be separated into portions depending upon the analytical methods and required duplicate or triplicate analyses to be performed.

When completing a COC for samples, personnel must complete the following:

1. Written COCs must be completed with indelible ink (preferably either black or blue colored ink).
2. Written COCs must be completed using legible printed writing, and not cursive writing.
3. All entry fields on the COC form must be completed. If information is not applicable for a specific entry field, personnel will either put “N/A” or use a strike-out line or dash like “-----------“ to indicate no applicable information is needed for that field.
4. Use of quotation marks or lines/down arrows to represent repetitive/duplicative text in similar fields.
5. Regardless of the type or specific COC form, the following pertinent information must be provided on the COC form:
    a. Arcadis project number
    b. Arcadis project name
    c. Project location, including street address, city, state, building number, providing as much detail as appropriate
    d. Recipient laboratory contact and sample receiving shipping location information
    e. Entities’/persons’ contact information for who will be receiving analytical results
    f. Name of sampler, i.e. person collecting sample and relinquishing possession of samples to the next entity in the chain of custody
    g. Date of sample collection

    h. If appropriate for the sample media, contaminant/constituent of concern, or analytical method, document time of sample collection using standard military time
    i. Sample analytical method(s)
    j. Turnaround time required for analyses and/or reporting
    k. Instructions to laboratory regarding handling, timing, analyses, etc. as applicable and appropriate
    l. Printed name and signature of the individual person who collected the samples and relinquishing possession of the samples
    m. If appropriate or when documentation of the specific sample collection method will influence how the laboratory handles, prepares, or analyzes the samples, document the sample collection methodology used for collecting the samples (e.g. ASTM D5755)

6. The following additional specific information will be entered on the COC form, regardless of what type of COC is being used:
    a. <u>Unique Sample Identifier</u> – The sample identifier (ID) must be unique to the individual sample it is applied to. The information in which the sample ID conveys is determined by the CPM, Technical Expert, and/or other project team members in advance of sample collection so that sample identification is consistently applied for the project. The sample nomenclature may be dictated by a specific client, program, or project database and require unique identification for each sample collected for the project. Consult with the CPM and/or Technical Expert for additional information regarding sample identification.

       The sample ID could convey specific information regarding the sample to aid personnel in recognizing what the sample represents, or they may be arbitrary so as to facilitate the anonymity of the sample location, media, constituent of concern, project site, etc.

       Examples of unique identifiers include:

        1. Well locations, grid points, or soil boring identification numbers (e.g., MW-3, X-20, SB-30). When the depth interval is included, the complete sample ID would be “SB-30 (0.5-1.0) where the depth interval is in feet. Please note it is very important that the use of hyphens in sample names and depth units (i.e., feet or inches) remain consistent for all samples entered on the chain of custody form. DO NOT use the apostrophe or quotes in the sample ID.
        2. Sample names may also use the abbreviations “FB,” “TB,” and “DUP” as prefixes or suffixes to indicate that the sample is a field blank, trip blank, or field duplicate, respectively.

    b. List the date of sample collection. All indicated dates must be formatted using either mm/dd/yy (e.g., 03/07/09) or mm/dd/yyyy (e.g. 03/07/2009).
    c. When appropriate for the analytical procedure used, list the local time that the sample was collected. The time value should be presented using military format. For example, 3:15 P.M. should be entered as 15:15.

d. Samples should be indicated to be either “Grab” or “Composite”. Grab samples are collected from only one unique location at one specific point in time.

e. Composite samples are a group of individual samples that are combined for analysis in their totality. Composite samples need to be documented if they are either collected from a number of different locations over a broader area to be representative of the entire area being sampled, or if they are representative of a single location over an extended period of time.

f. If used, preservatives for the individual sample will be noted.

g. The requested analytical method(s) that the samples are being analyzed for must be indicated. As much detail, as necessary, should be presented to allow the analytical laboratory to properly analyze the samples. For example, polychlorinated biphenyl (PCB) analyses may be represented by entering “EPA Method 8082 – PCBs” or “EPA PLM 600-R93-116.” In cases where multiple analytical methods and/or analytical parameters are required for an individual sample, each method should be indicated for the sample (e.g., EPA 8082/8260/8270 or EPA PLM/400-point count).

h. If there are project-specific sample analytes to be reported, they should be specifically listed for each individual sample (e.g., 40 CFR 264 Appendix IX).

i. The total number of containers for each analytical method requested should be documented. This information may be included under the parameter or as a total for the sample.

j. When necessary, note which samples should be used for site specific matrix spikes.

k. Indicate special project-specific requirements pertinent to the handling, shipping, or analyses. These requirements may be on a per sample basis such as “extract and hold sample until notified,” or may be used to inform the laboratory of special reporting requirements for the entire sample delivery group (SDG).

l. Indicate turnaround time (TAT) required for samples on COC. If individual samples have differing TATs, the different TATs for each sample or groups of samples must be clearly indicated.

m. Provide contact name and phone number in the event that problems are encountered when samples are received at the laboratory. The person relinquishing possession of the samples or other member of the project team should contact the final recipient of the samples to confirm receipt and review any special provisions on the COC or questions that they may have.

n. If available, attach the Laboratory Task Order or Work Authorization forms.

o. The “Relinquished By” field must contain the signature of the Arcadis person who relinquished custody of the samples to the next entity in the chain of custody, which may be another person, the shipping courier, or the analytical laboratory.

p. Dates and times must be indicated using the following format:

   1) Date: either mm/dd/yy e.g., 01/01/17 OR mm/dd/yyyy e.g., 01/01/2017

   2) Time: use military format, e.g. 9:30 a.m. is 0930 and 9:30 p.m. is 2130

   q. The “Received By” section is signed by sample courier or laboratory representative who received the samples from the sampler or it is signed upon laboratory receipt from the overnight courier service.

4. When more than one page of the COC form is required to complete the total number of samples, use as many sheets as necessary to accurately and clearly document the samples and information. Some COCs may have a standard first page/cover page, and subsequent pages may not contain all the detailed fields as the first page/cover page. Ensure that any subsequent pages convey all of the necessary and pertinent information for each individual sample as required in this procedure document.
5. Pages of the COC must retain a page count of the total number of pages; e.g., Page 1 of 3, Page 2 of 3, Page 3 of 3.
6. Upon completing the COC forms, forward the original signed COC with the sample package. Ensure that the original COC form is secured with the sample package so that it remains with the physical samples for the duration of transport and handling to its final destination and ensure that the COC form will not be become damaged or rendered unreadable due to sample breakage/leakage if stored inside the sample shipping container or outside influences if COC is stored in an outside plastic pouch to the container.
7. If you’ve collected enough samples that would require more than one container to ship them all to the same laboratory or location, then each separate/individual container that contains any number of samples must have a separate COC representing only those samples contained within that specific container. For example, if you have 3 total shipping containers for all of your samples, you must have a total of 3 separate, individual COCs for each of the 3 containers representing only those samples in their representative container. Thus, every container holding samples must have its own, individual COC.
8. If electronic chain of custody (eCOC) forms are utilized, ensure that the requirements of this procedure and guidance instructions are followed to the extent possible. Verify that proper signature and COC procedures are maintained with the CPM and/or Technical Expert when using eCOC.

8 WASTE MANAGEMENT

Not Applicable.

9 DATA RECORDING AND MANAGEMENT

The original signed COC shall be submitted with the samples. Copies of COC records will be transmitted to the CPM or designee at the end of each day unless otherwise directed by the CPM. The sampling team leader retains copies of the chain of custody forms for filing in the project file. Record retention shall be in accordance with client- and project-specific requirements and Arcadis policies, the most stringent will apply.

10 QUALITY ASSURANCE

COC forms will be legibly completed in accordance with this procedure and guidance instruction document, as well as other applicable and appropriate project documents such as Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP), Work Plan, or other project guidance documents.

COC records will be reviewed by the CPM or their appropriate designee for completeness and accuracy to the applicable requirements. Non-conformances will be noted and corrected in a timely manner on the copies retained by Arcadis as well as contacting the ultimate receiving entity for correction to the originally signed COC in their possession.

11 REFERENCES

Arcadis Client Document Retention Guide

Arcadis Transportation Safety Program requirements, procedures, and guidance instructions

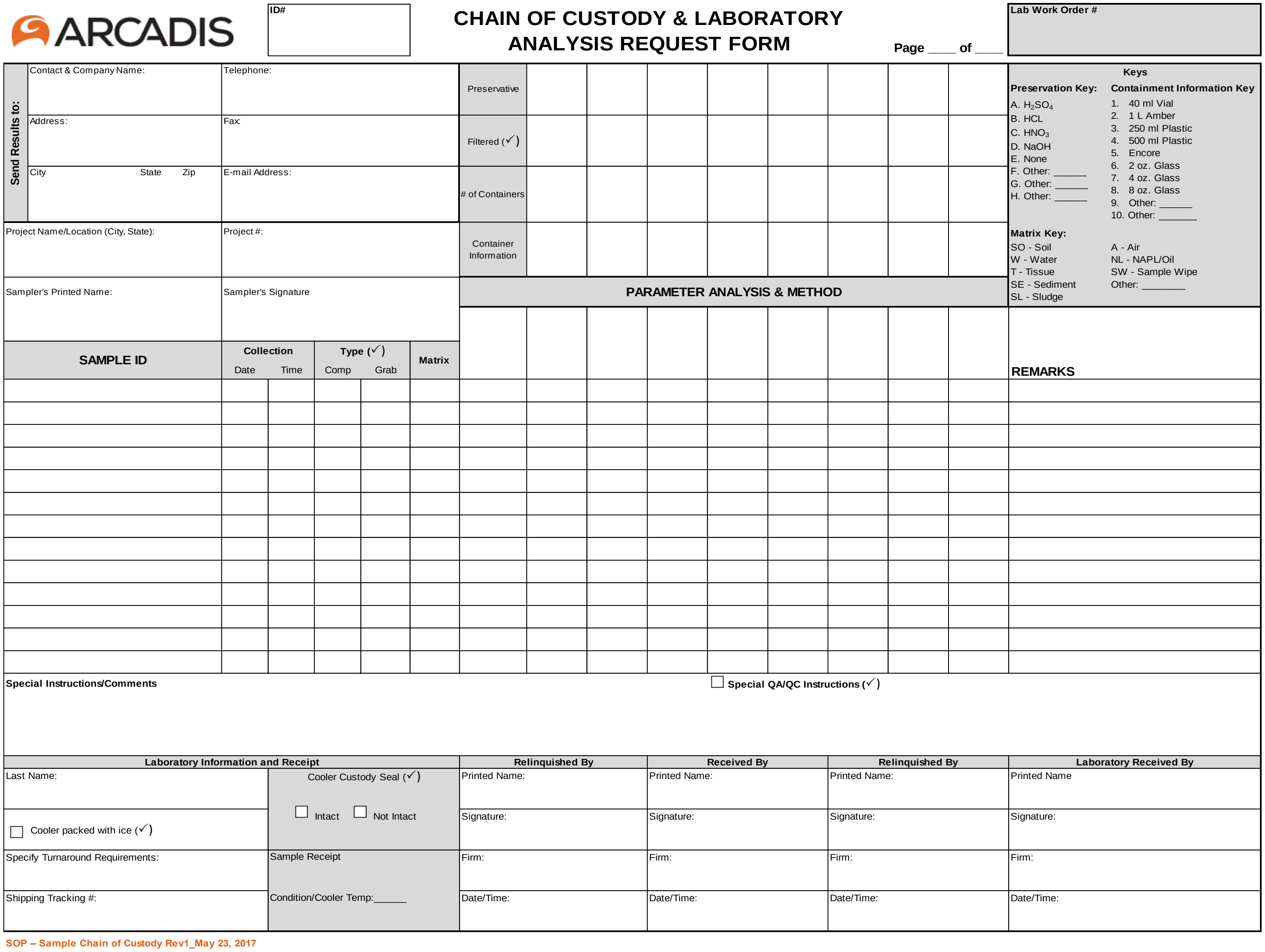
EPA Samplers' Guide – Contract Laboratory Program Guidance for Field Samplers, EPA document EPA-540-R014-013 October 2014

EPA Region III – *Sample Submission Procedures for the Office of Analytical Services and Quality Assurance (OASQA) Laboratory Branch* revision 13.0 January 29, 2014

EPA Region I Office Environmental Measurement and Evaluation – *Standard Operating Procedures for Chain of Custody of Samples* revision 1 March 25, 2002

EPA Region IV Science and Ecosystem Support Division *Operating Procedure for Sample and Evidence Management* January 29, 2013

APPENDIX A
Chain of Custody Form



ARCADIS

ID#

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Page ____ of ____

Lab Work Order #

Send Results to:	Contact & Company Name:	Telephone:
	Address:	Fax:
	City State Zip	E-mail Address:
Project Name/Location (City, State):		Project #:
Sampler's Printed Name:		Sampler's Signature

Preservative									
Filtered (✓)									
# of Containers									
Container Information									

PARAMETER ANALYSIS & METHOD

Keys

Preservation Key:
A. H_2SO_4
B. HCL
C. HNO_3
D. NaOH
E. None
F. Other: ______
G. Other: ______
H. Other: ______

Containment Information Key
1. 40 ml Vial
2. 1 L Amber
3. 250 ml Plastic
4. 500 ml Plastic
5. Encore
6. 2 oz. Glass
7. 4 oz. Glass
8. 8 oz. Glass
9. Other: ______
10. Other: _______

Matrix Key:

SO - Soil	A - Air
W - Water	NL - NAPL/Oil
T - Tissue	SW - Sample Wipe
SE - Sediment	Other: ________
SL - Sludge	

SAMPLE ID	**Collection**		**Type (✓)**		**Matrix**										**REMARKS**
	Date	Time	Comp	Grab											

Special Instructions/Comments

☐ **Special QA/QC Instructions (✓)**

Laboratory Information and Receipt		**Relinquished By**	**Received By**	**Relinquished By**	**Laboratory Received By**
Last Name:	Cooler Custody Seal (✓)	Printed Name:	Printed Name:	Printed Name:	Printed Name
☐ Cooler packed with ice (✓)	☐ Intact ☐ Not Intact	Signature:	Signature:	Signature:	Signature:
Specify Turnaround Requirements:	Sample Receipt	Firm:	Firm:	Firm:	Firm:
Shipping Tracking #:	Condition/Cooler Temp:______	Date/Time:	Date/Time:	Date/Time:	Date/Time:

SOP – Sample Chain of Custody Rev1_May 23, 2017

ARCADIS
Design & Consultancy
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built assets

TGI – Soil Description

Rev: 4

Rev Date: June 14, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	May 20, 2008	17	Original SOP	Joe Quinnan Joel Hunt
	1	September 2016	15	Updated to TGI	Nick Welty Patrick Curry
	2	February 16, 2018	15	Updated descriptions, attachments and references in text	Nick Welty Patrick Curry
	3	April 15, 2022		Minor description edits, intro of grain-size K analysis, revised boring log template	Matt McCaughey Patrick Curry
	4	June 14, 2022		Updated date on cover page and header. Updated revision number from 3 to 4. Updated reference throughout document from ASTM D2488-06 to ASTM D-2488.17 . Change “25% silt and clay; 15% pebbles” to “20% silt and 20% clay” on page 10 of 23. Updates made to Section 8.2.1 Changed reference to Appendix B to Appendix A	

Approval Signatures

Prepared by: 6/14/2022

Matthew C. McCaughey

Matthew C. McCaughey, PG (Preparer) Date

Reviewed by: 6/14/2022

Patrick Curry, PG (Subject Matter Expert) Date

1 Introduction

This Arcadis Technical Guidance Instruction (TGI) describes proper soil description procedures based on visual inspection and testing of soil cores and samples. This document has been developed to emphasize field observation and documentation of details required to:

- Make hydrostratigraphic interpretations guided by depositional environment/geologic settings
- Provide information needed to understand the distribution of constituents of concern; properly design wells, piezometers, and/or additional field investigations; and develop appropriate remedial strategies.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

This TGI should be followed for unconsolidated material unless there is an established client-required specific procedure or regulatory-required specific procedure. In cases where there is a required specific procedure, it should be followed and should be referenced and/or provided as an appendix to reports that include soil classifications and/or boring logs. When following a required non-Arcadis procedure, additional information required by this TGI should be included in field notes with client approval.

This TGI incorporates elements from various standard systems such as ASTM D-2488-17, Unified Soil Classification System, Burmister and Udden Wentworth. However, none of these standard systems focus specifically on contaminant hydrogeology and remedial design. Therefore, although each of these systems contain valuable guidance and information related to correct descriptions, strict application of these systems can omit information critical to our clients and the projects that we perform.

This TGI includes the following attachments:

- **Attachment A –** Field Soil Description Guide
- **Attachment B –** Particle Size System Comparison
- **Attachment C –** Description of Logging Terms
- **Attachment D –** Blank Boring Log
- **Attachment E –** Completed Boring Log

This TGI does not address details of health and safety; drilling method selection; boring log preparation; sample collection; or laboratory analysis. Refer to other Arcadis procedure, guidance, and instructional documents, the project work plans including the quality assurance project plan, sampling plan, and health and safety plan (HASP), as appropriate.

4 Personnel Qualifications

Soil descriptions should only be performed by Arcadis personnel or authorized sub-contractors with a degree in geology or a geology-related discipline. Field personnel will complete training on the Arcadis soil description TGI in the office and/or in the field under the guidance of an experienced field geologist with at least 2 years of prior experience applying the Arcadis soil description method.

5 Equipment List

The following equipment should be taken to the field to facilitate soil descriptions:

- Field book, field forms or digital devices to record soil descriptions
- Field book for supplemental notes
- This TGI for Soil Descriptions and any project-specific procedure, guidance, and/or instructional documents (if required)
- Field card showing Wentworth scale
- Munsell® soil color chart
- Tape measure divided into tenths of a foot
- Stainless steel knife or spatula
- Hand lens
- Water squirt bottle
- 4-ounce glass jars with lids (for collecting soil core samples)
- Personal protective equipment (PPE), as required by the HASP
- Digital camera

- Folding table

6 Cautions

Drilling and drilling-related hazards including subsurface utilities are discussed in other procedure documents and site-specific HASPs and are not discussed herein.

Soil samples may contain hazardous substances that can result in exposure to persons describing soils. Routes for exposure may include dermal contact, inhalation and ingestion. Refer to the project specific HASP for guidance in these situations.

7 Health and Safety Considerations

Field activities associated with soil sampling and description will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. Know what hazardous substances may be present in the soil and understand their hazards. Always avoid the temptation to touch soils with bare hands, detect odors by placing soils close to your nose, or tasting soils.

8 Procedure

8.1 General Procedures

- Select the appropriate sampling method to obtain representative samples in accordance with the selected sub-surface exploration method, e.g., split-spoon or Shelby sample for hollow-stem drilling, acetate sleeves for direct push, bagged core for sonic drilling, etc.
- Proceed with field activities in required sequence. Although completion of soil descriptions is often not the first activity after opening sampler, identification of stratigraphic changes is often necessary to select appropriate intervals for field screening and/or selection of laboratory samples.
- Set up boring log field sheet.
    - Determine the proper units of measure. Drillers in both the US and Canada generally work in feet due to equipment specifications. Field geologists typically record drilling depths, core recovery, and sample intervals in feet and grain size in millimeters
    - Use the Arcadis standard boring log form (**Attachment D**). *Note that as of April 2022, several digital logging applications are available through the FieldNow™ program and the Fulcrum app. A future revision of this TGI, likely in early 2023, will emphasize digital logging methods and field boring log forms will no longer be acceptable. FieldNow is discussed further in Section 10.*
    - The boring log template includes a graphic log of the primary soil texture to support quick visual evaluation of grain size. The purpose of the graphic log is to quickly assess relative soil permeability. Note, for poorly sorted soils (e.g., glacial till), the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability. For example, for a dense sand/silt/clay till, the graphic log would reflect the silt/clay, rather than sand.

  - Record depths along the left-hand side at a standard scale to aid in the use of this tool.
- Examine each soil core (this is different than examining each sample selected for laboratory analysis) and record the soil conditions in accordance with guidelines provided in Section 8.2.
- At the end of the boring, record the amount of drilling fluid used (if applicable) and the total depth logged.
- At a minimum, a written or digital boring log should be prepared with the following information:
  - Describe type of surface material (asphalt, grass, topsoil, gravel, etc.)
  - Describe the type of fill or non-native soils and estimated depth to native soils
  - Record sample intervals (soil cores, environmental and/or geotechnical samples)
  - Describe soil conditions in accordance with this TGI
  - Record moisture content and estimated depth to water table or saturated zone
  - Record the total depth and document why drilling was stopped (refusal, target depth achieved, etc.)

8.2 Soil Description Procedures

The standard soil description order is presented below.

- Depth
- PRIMARY TEXTURE
- Principal and Minor Components with Descriptors
  - % Modifiers and grain size fraction
  - Angularity for coarse sand and larger particles
  - Consistency or Density
  - Plasticity for silt and clay
  - Dilatancy for silt and silt-sand mixtures
- Sorting
- Moisture Content
- Color
- Notes

Depth. To measure and record the depth below ground surface (bgs) of top and bottom of each stratum, the following information should be recorded.

- Measured depth to the top and bottom of sampled interval. Use starting depth of sample based upon measured tool length information and the length of sample interval.
- Length of sample recovered, not including slough (material that has fallen into hole from previous interval), expressed as fraction with length of recovered sample as numerator over length of sampled interval as denominator (e.g., 36/60 for 36 inches recovered from 5-ft [60-inch] sampling interval).
- Thickness of each stratum measured sequentially from the top of recovery to the bottom of recovery.
- Any observations of sample condition or drilling activity that would help identify whether there was loss from the top of the sampling interval, loss from the bottom of the sampling interval, or compression of the sampling interval. Examples: 14/24, gravel in nose of spoon; or 36/60 bottom 12 inches of core empty.

Determination of Components. Obtain a representative sample of soil from a single stratum. If multiple strata are present in a single sample interval, each stratum should be described separately. More specifically, if the sample is from a 2-foot-long split-spoon where strata of coarse sand, fine sand and clay are present, then the resultant description should be of the three individual strata unless a combined description can clearly describe the interbedded nature of the three strata. Example: SAND, fine; with interbedded lenses of Silt and Clay, ranging between 1 and 3 inches thick.

Identify principal component and express volume estimates for minor components on logs using the following standard modifiers.

Modifier	Percent of Total Sample (by volume)
and	36 – 50
some	21 - 35
little	10 - 20
trace	<10

Determination of components is based on using the Udden-Wentworth particle size classification (see below) and measurement of the average grain size diameter. Each size class differs from the next larger class by a constant ratio of ½. Due to visual limitations, the finer classifications of Wentworth's scale cannot be distinguished in the field and the subgroups are not included. Visual determinations in the field should be made carefully by comparing the sample to the Soil Description Field Guide (**Attachment A**) that shows Udden-Wentworth scale or by measuring with a ruler.

The following table summarized the modified Udden-Wentworth Scale for grain size classification. Note that gravel is a size category encompassing the granule, pebble, cobble, and boulder size classes.

Udden-Wentworth Scale (Modified by Arcadis, 2008)				
Size Category	**Size Class**	**Millimeters**	**Inches**	**Standard Sieve #**
Gravel (Cobble)	Boulder	256 – 4096	10.08+	
	Large cobble	128 - 256	5.04 -10.08	
	Small cobble	64 - 128	2.52 – 5.04	
Gravel (Pebble)	Very large pebble	32 – 64	0.16 - 2.52	
	Large pebble	16 – 32	0.63 – 1.26	
	Medium pebble	8 – 16	0.31 – 0.63	
	Small pebble	4 – 8	0.16 – 0.31	No. 5 +
	Granule	2 – 4	0.08 – 0.16	No.5 – No.10

Sand	Very coarse sand	1 -2	0.04 – 0.08	No.10 – No.18
	Coarse sand	½ - 1	0.02 – 0.04	No.18 - No.35
	Medium sand	¼ - ½	0.01 – 0.02	No.35 - No.60
	Fine sand	1/8 -¼	0.005 – 0.1	No.60 - No.120
	Very fine sand	1/16 – 1/8	0.002 – 0.005	No. 120 – No. 230
Fines	Silt (subgroups not included)	1/256 – 1/16	0.0002 – 0.002	Not applicable (analyze by pipette or hydrometer)
	Clay (subgroups not included	1/2048 – 1/256	0.00002 – 0.0002	

Identify components as follows. Remove particles greater than very large pebbles (64-mm diameter) from the soil sample. Record the volume estimate of the greater than very large pebbles. Examine the sample fraction of very large pebbles and smaller particles and estimate the volume percentage of the pebbles, granules, sand, silt and clay. Use the jar method, visual method, and/or wash method (Appendix X4 of ASTM D2488) to estimate the volume percentages of each category.

Sieve and hydrometer grain-size analysis can be used to vet the visual description, as well as used to estimate hydraulic conductivity. Lab or field sieve analysis is advisable to characterize the variability and facies trends within each hydrostratigraphic unit. It is recommended that sieve-hydrometer analysis be performed on representative samples from each soil type to estimate the fraction of each grain size category using ASTM D422 Standard Test Method for Particle-Size Analysis of Soils. If desired sieve sizes can be specified to follow the Udden-Wentworth classification (U.S. Standard sieve sizes 6; 12; 20; 40; 70; 140; and 270) to retain pebbles; granules; very coarse sand; coarse sand; medium sand; fine sand; and very fine sand, respectively.

Several empirical formulas provide a reliable means of estimating hydraulic conductivity (K) from grain-size distribution data, provided that the formation does not contain abundant fines that result in cohesive or plastic behavior or include cobble-sized grains (Payne et al. 2008). Grain-size analysis can help bracket the permeability of hydrostratigraphic units (HSUs) and identify order-of-magnitude spatial variations in K. Arcadis has completed modifications to the Excel-based program HydroGeoSieveXL (Devlin 2015) to process sieve data quickly and estimate K. The tool calculates estimated K values from grain-size data using 15 different empirical formulas. A decision matrix then selects which of the formulas is relevant for the soil type and calculates an average K.

Principal Component. The principal component is the size fraction or range of size fractions containing the majority of the volume. Examples: the principal component in a sample that contained 55% small to medium pebbles would be “PEBBLES, small to medium”; or the principal component in a sample that was 20% fine sand, 30% medium sand and 25% coarse sand would be “SAND, fine to coarse” or for a sample that was 40% silt and 45% clay the principal component would be “CLAY and SILT”.

The boring log form (**Appendix D**) includes a graphic log to visually illustrate a relative estimate of soil permeability. To use the graphic log, place an ‘X’ or shade the appropriate column for the primary soil texture. If the soils have a high percentage of a secondary soil texture (i.e., when the ‘and’ modifier’ is used), it’s acceptable to mark off the appropriate column for the secondary soil texture in this instance. However, care should be used to avoid marking off the columns for other minor soil textures because doing so will make it difficult to determine the relative soil permeability of the poorly sorted soils.

As noted above, for poorly sorted soils such as glacial till, the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability.

Minor Component(s). The minor component(s) are the size fraction(s) containing less than 50% volume. Example: the identified components are estimated to be 60% medium sand to granules, 20% silt and 20% clay – there are two identified minor components: silt and clay.

Include a standard modifier to indicate percentage of minor components (see particle size table) and the same descriptors that would be used for a principal component. An example of minor constituents with modifiers include: some silt and clay, low plasticity; little medium to large pebbles, sub-round.

8.2.1 Secondary Descriptors

The following are the descriptors used outside of the principal and minor components. Note that plasticity should be provided as a descriptor for clay and clay mixtures. Dilatancy should be provided for silt and silt mixtures. Angularity should be provided as a descriptor for pebbles and coarse sand.

Angularity. Describe the angularity for coarse sand and larger particles in accordance with the table below (ASTM D-2488-17). Figures showing examples of angularity are available in ASTM D2488-17 and the Arcadis Soil Description Field Guide (**Appendix A**).

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Sub-Angular	Particles are like angular description but have rounded edges
Sub-Rounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges.

Plasticity. Describe the plasticity for silt and clay based on observations made during the following test method (ASTM D-2488-17).

- As in the dilatancy test (described below), select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material, adding water, if necessary, until it has a soft, but not sticky, consistency.
- Shape the test specimen into an elongated pat and roll by hand on a smooth surface or between the palms into a thread about 1/8 inch (3 mm) in diameter. If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation. Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 inch. The thread will crumble when the soil is near the plastic limit.

Description	Criteria
Non-plastic	A 1/8-inch (3 mm) 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 rerolled 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 rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Dilatancy. Describe the dilatancy for silt and silt-sand mixtures using the following field test method (ASTM D-2488-17).

- From the specimen, select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material adding water, if necessary, until it has a soft, but not sticky, consistency.
- Smooth the ball in the palm of one hand with a small spatula.
- Shake horizontally, striking the side of the hand vigorously with the other hand several times.
- Note the reaction of water appearing on the surface of the soil.
- Squeeze the sample by closing the hand or pinching the soil between the fingers, and not the reaction as none, slow, or rapid in accordance with the table below. The reaction is the speed with which water appears while shaking and disappears while squeezing.

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 of the specimen during shaking and disappears quickly upon squeezing

Note that silt and silt-sand mixtures will be non-plastic and display dilatancy. Clay mixtures will have some degree of plasticity but do not typically react to dilatancy testing. Therefore, the tests outlined above can be used to differentiate between silt-dominated and clay-dominated soils.

Sorting. Sorting is the opposite of grading, which is a commonly used term in the USCS or ASTM methods to describe the uniformity of the particle size distribution in a sample. Well-sorted samples are poorly graded and poorly sorted samples are well graded. <u>Arcadis prefers the use of sorting for particle size distributions and grading to describe particle size distribution trends in the vertical profile of a sample or hydrostratigraphic unit because of</u>

the relationship between sorting and the energy of the depositional process. For soils with sand-sized or larger particles, sorting should be determined as follows:

Description	Criteria
Well Sorted	the range of particle sizes is limited (e.g., the sample is comprised of predominantly one or two grain sizes)
Poorly Sorted	A wide range of particle sizes are present

You can also use sieve analysis to estimate sorting from a sedimentological perspective; sorting is the statistical equivalent of standard deviation. Smaller standard deviations correspond to higher degree of sorting (see Remediation Hydraulics, 2008).

Consistency or Density. This can be determined by standard penetration test (SPT) blow counts (ASTM D-1586) obtained when using hollow-stem auger drilling methods and a split spoon sampling device. Otherwise, some field tests are available as outlined below. When drilling with hollow-stem augers and split-spoon sampling, the SPT blow counts and N-value is used to estimate density. The N-value is the blows per foot for the 6” to 18” interval. For example, for a 24-inch split spoon soil core, the recorded blows per 6-inch interval are: 4/6/9/22. Since the second interval is 6” to 12”, the third interval is 12” to 18”, the N value is 6+9, or 15. Fifty blow counts for less than 6 inches is considered refusal. In recent years, more common drilling methods include rotary-sonic or direct push. When blow counts are not available, density is determined using a thumb test. Note however, the thumb test only applies to fine-grained soils.

Fine-grained soil – Consistency

Description	Criteria	Blow Counts (6-12 to 12-18-inch split spoon interval)
Very soft	Easily penetrated several inches by thumb	N-value < 2
Soft	Easily penetrated one inch by thumb	N-value 2-4
Medium Stiff	Indented about ½ inch with much effort	N-value 5-8
Stiff	Indented with ¼ inch with great effort	N-value 9-15
Very Stiff	Readily indented by thumbnail	N-value 16-30
Hard	Indented by thumbnail with difficulty	N-value > than 30

Coarse-grained soil – Density

Description	Criteria	Blow Counts (6-12 to 12-18-inch split spoon interval)
Very loose Loose Medium dense Dense Very dense	Density classification of coarse-grained soils is only required when blow counts from standard penetration tests are performed during hollow-stem auger drilling	N-value 1- 4 N-value 5-10 N-value 11-30 N-value 31- 50 N-value >50

Moisture Content. Moisture content should be described for each soil sample in accordance with the table below (percentages should not be used unless determined in the laboratory). *Note that some drilling methods (e.g., sonic) can compress and dry out the sample during drilling. Therefore, it can be difficult to determine if a sample is saturated, or merely moist. In this case, care should be taken to try and determine a static water level within the borehole by measuring depth to water through the drill casing, if possible.*

Description	Criteria
Dry	Absence of moisture, dry to touch, dusty
Moist	Damp but no visible water
Wet	Visibly free water

Color. Color should be described using simple basic terminology and modifiers based on the Munsell system. Munsell alpha-numeric codes are required for all samples. If the sample contains layers or patches of varying colors this should be noted, and all representative colors should be described. The colors should be described for moist samples. If the sample is dry, it should be wetted prior to comparing the sample to the Munsell chart.

Notes. Additional comments should be made where observed and should be presented as notes with reference to a specific depth interval(s) to which they apply. Some of the significant information that may be observed includes the following.

- Odor - You should not make an effort to smell samples by placing near your nose since this can result in unnecessary exposure to hazardous materials. However, odors should be noted if they are detected during the normal sampling procedures. Odors should be based upon descriptors such as those used in NIOSH “Pocket Guide to Chemical Hazards”, e.g., “pungent” or “sweet” and should not indicate specific chemicals such as “phenol-like” odor or “BTEX” odor.
- Structure
- Bedding planes (laminated, banded, geologic contacts).
- Presence of roots, root holes, organic material, man-made materials, minerals, etc.
- Mineralogy

- Cementation
- NAPL presence/characteristics, including sheen (based on client-specific guidance).
- Reaction with HCl - typically only used for special soil conditions, such as caliche environments.
- Origin, if known (Lacustrine; Fill; etc.).

8.3 Example of Soil Descriptions

The standard generic description order is presented below.

- Depth
- PRIMARY TEXTURE
- Principal and Minor Components with Descriptors
    - % Modifiers and grain size fraction
    - Angularity for coarse sand and larger particles
    - Consistency or Density
    - Plasticity for silt and clay
    - Dilatancy for silt and silt-sand mixtures
- Sorting
- Moisture Content
- Color
- Notes

10-15 feet CLAY, trace silt, trace small to very large pebbles, subround to subangular up to 2" diameter; medium to high plasticity, stiff, moist, dark grayish brown (10YR 4/2). NOTE: Lacustrine; laminated 0.1 to 0.2" thick, laminations brownish yellow (10YR 4/3).

10 -15 feet SAND, medium to very coarse, little granules to medium pebbles, subround to subangular, trace silt; poorly sorted, wet, grayish brown (10YR5/2).

Unlike the first example where a density of cohesive soils could be estimated, this rotary-sonic sand and pebble sample was disturbed during drilling (due to vibrations in a loose sand and pebble matrix) so no density description could be provided. Neither sample had noticeable odor so odor comments were not included.

9 Waste Management

Project-specific requirements should be identified and followed. The following procedures, or similar waste management procedures are generally required.

Water generated during cleaning procedures will be collected and contained onsite in appropriate containers for future analysis and appropriate disposal. PPE (such as gloves, disposable clothing, and other disposable equipment) resulting from personnel cleaning procedures and soil sampling/handling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or a covered roll-off box for appropriate disposal.

Soil materials will be placed in sealed 55-gallon steel drums or covered roll-off boxes and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

10 Data Recording and Management

10.1 Digital Data Collection Process Overview

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

10.2 Digital Data Collection Tools for Soil Descriptions

Arcadis is transitioning from the use of paper forms to a digital soil description logging process using web-based FieldNow applications accessible on field tablets and smart phones. Company-wide roll out of a FieldNow application for soil descriptions is targeted by the end of 2022.

Paper forms are included in Revision 3 (April 2022) of this Soil Description TGI. Specifically, a blank boring log and completed boring log are provided in **Attachment D** and **Attachment E**. Additional guidance and examples of the digital data collection tools for soil descriptions will be provided in the next revision to this TGI.

10.3 Additional Guidance

The general logging scheme for soil descriptions is described in this document. Depending on project data quality objectives, specific soil description parameters that are not applicable to project goals may be omitted at the project manager’s discretion. In any case, use of consistent procedures is required.

Completed logs and/or logbook will be maintained in the task/project field records file. Digital photographs of typical soil types observed at the site and any unusual features should be obtained whenever possible. Photographs should include a ruler or common object for scale. Photo location, depth and orientation must be recorded in the daily log or logbook and a label showing this information in the photo is useful.

For projects involving soil logging and soil sampling, the soil sample should be recorded on the Arcadis boring log form and the field logbook based on Data Quality Objectives for the task/project.

11 Quality Assurance

Soil descriptions should be completed only by appropriately trained personnel. Descriptions should be reviewed by an experienced field geologist for content, format and consistency. Edited boring logs should be reviewed by the original author to assure that content has not changed.

12 References

ASTM D-1586, Test Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D-2488-17, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

ASTM D422, 63rd Edition, 1972 - Standard Test Method for Particle-Size Analysis of Soils.

Devlin, J.F. 2015. HydroGeoSieve XL: an Excel-based tool to estimate hydraulic conductivity from grain-size analysis. Hydrogeology Journal, DOI 10.1007/s10040-015-1255-0.

Folk, Robert L. 1980. Petrology of Sedimentary Rocks, p. 1-48.

Payne, F. C., Quinnan, J. A., & Potter, S. T. 2008. Remediation Hydraulics. Boca Raton: FL: CRC Press.

United States Bureau of Reclamation. Engineering Geology Field Manual. United States Department of Interior, Bureau of Reclamation. http://www.usbr.gov/pmts/geology/fieldmap.htm.

Munsell® Color Chart – available from Forestry Suppliers, Inc.- Item 77341 “Munsell® Color Soil Color Charts.

Field Gauge Card that Shows Udden-Wentworth scale – available from Forestry Suppliers, Inc. – Item 77332 “Sand Grain Sizing Folder.”

NIOSH Pocket Guide to Chemical Hazards.

Attachment A

Soil Field Reference Guide

The purpose of this attachment is to present a field reference guide for use during soil logging. Field staff are encouraged to bring a laminated copy of this reference guide into the job site.

ON THE ORIGINAL DRAWING.
USE TO VERIFY FIGURE
REPRODUCTION SCALE

SOIL DESCRIPTION FIELD GUIDE (APRIL, 2022; REV. 3.0)

ARCADIS Design & Consultancy for natural and built assets

FINE-GRAINED SOILS

Description	Criteria
	Descriptor - Plasticity
Nonplastic	A 1/8-inch (3 mm) 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 rerolled 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 rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.
	Descriptor - Dilatancy
No Dilatancy	No visible change when shaken or squeezed.
Slow	Water appears slowly on the surface of soil during shaking and does not disappear or disappears slowly when squeezed.
Rapid	Water appears quickly on surface of soil during shaking and disappears quickly when squeezed.
Minor Components with Descriptors	
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Consistency
Very soft	N-value < 2 or easily penetrated several inches by thumb.
Soft	N-value 2-4 or easily penetrated 1 inch by thumb.
Medium stiff	N-value 5-8 or indented about 1/2 inch by thumb with great effort.
Stiff	N-value 9-15 or indented about 1/4 inch by thumb with great effort.
Very stiff	N-value 16-30 or readily indented by thumb nail.
Hard	N-value > than 30 or indented by thumbnail with difficulty.
Color using Munsell	
Geologic Origin (if known)	
Other	

EXAMPLE OF SOIL DESCRIPTION AND PHOTO

10-15 feet CLAY, trace silt, trace small to very large pebbles, subround to subangular up to 2" diameter; medium to high plasticity, stiff, moist, dark grayish brown (10YR 4/2). NOTE: Lacustrine; laminated 0.1 to 0.2" thick, laminations brownish yellow (10YR 4/3).

DESCRIPTION ORDER

Depth Interval
PRIMARY TEXTURE (e.g., SAND)
Principal and Minor Components with Descriptors:
- % Modifiers and grain size fraction
- Angularity coarse sand and larger
- Consistency or Density
- Plasticity for silt and clay
- Dilatancy for silt and silt-sand

Sorting for granular sediments
Moisture Content
Color
Other NOTES

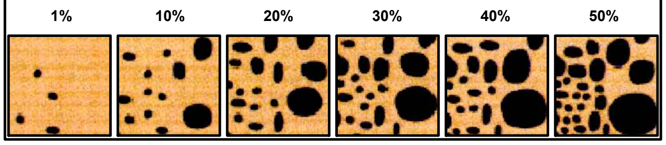
MINOR COMPONENTS % MODIFIERS

Modifier	Percent of Total Sample (by volume)
and	36 - 50
some	21 - 35
little	10 - 20
trace	<10

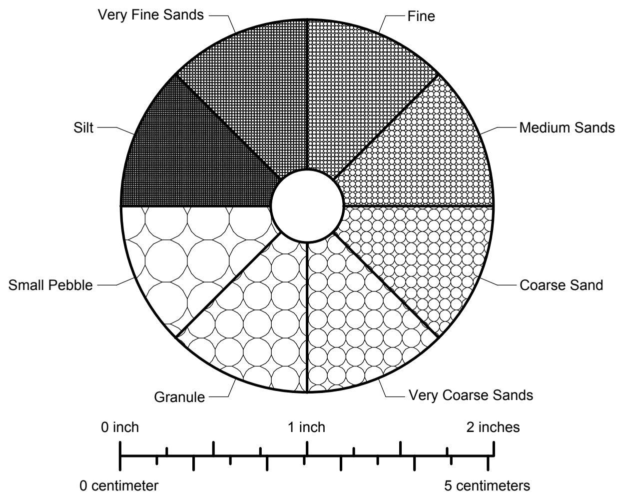
UDDEN-WENTWORTH SCALE

Fraction	Sieve Size	Grain Size	Approximate Scale
Boulder		256 - 4096 mm	Larger than volleyball
Large Cobble		128 - 256 mm	Softball to volleyball
Small Cobble		64 - 128 mm	Pool ball to softball
Very Large Pebble		32 - 64 mm	Pinball to pool ball
Large Pebble		16 - 32 mm	Dime size to pinball
Medium Pebble		8 - 16 mm	Pencil eraser to dime size
Small Pebble	No. 5+	4 - 8 mm	Pea size to pencil eraser
Granule	No. 10 - 5	2 - 4 mm	Rock salt to pea size
Very Coarse Sand	No. 18 - 10	1 - 2 mm	See field gauge card
Coarse Sand	No. 35 -18	0.5 - 1 mm	See field gauge card
Medium Sand	No. 60 - 35	0.25 - 0.5 mm	See field gauge card
Fine Sand	No. 120 - 60	0.125 - 0.25 mm	See field gauge card
Very Fine Sand	No. 230 - 120	0.0625 - 0.125 mm	See field gauge card
Silt and Clay. See SOP for description of fines	Not Applicable	<0.0625 mm	Analyze by pipette or hydrometer

PARTICLE PERCENT COMPOSITION ESTIMATION



GRAPH FOR DETERMINING SIZE OF PARTICLES



FOR COARSE-GRAINED SOILS

Description	Criteria
	Descriptor - Angularity
Angular	Particles have sharp edges and relatively planar sides withunpolished surfaces.
Subangular	Particles are similar to angular but have rounded edges.
Subround	Particles have nearly planar sides but have well-roundedcorners and edges.
Round	Particles have smoothly curved sides and no edges.
Minor Components with Descriptors	
	Sorting **Cu= d60/d10**
Well Sorted	Near uniform grain-size distribution Cu= 1 to 3.
Poorly Sorted	Wide range of grain size Cu= 4 to 6.
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Density
Very loose	N-value 1 - 4
Loose	N-value 5 - 10
Medium Dense	N-value 11 - 30
Dense	N-value 31 - 50
Very dense	N-value >50
Color using Munsell	
Geologic Origin (if known)	
Other	
	Cementation
Weak Cementation	Crumbles or breaks with handling or little finger pressure.
Moderate Cementation	Crumbles or breaks with considerable finger pressure.
Strong Cementation	Will not crumble with finger pressure.
	Reaction with Dilute HCl Solution (10%)
No Reaction	No visible reaction.
Weak Reaction	Some reaction, with bubbles forming slowly.
Strong Reaction	Violent reaction, with bubbles forming immediately.

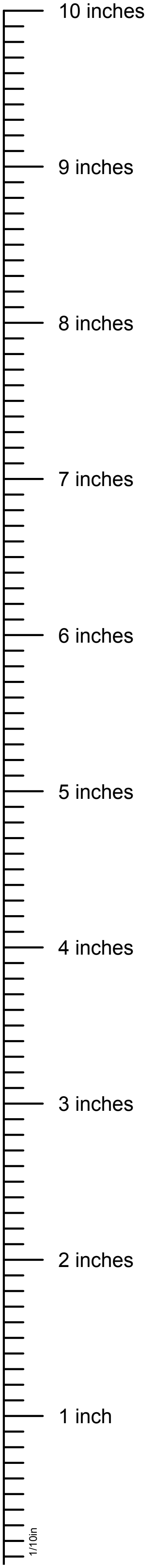
EXAMPLE OF SOIL DESCRIPTION AND PHOTO

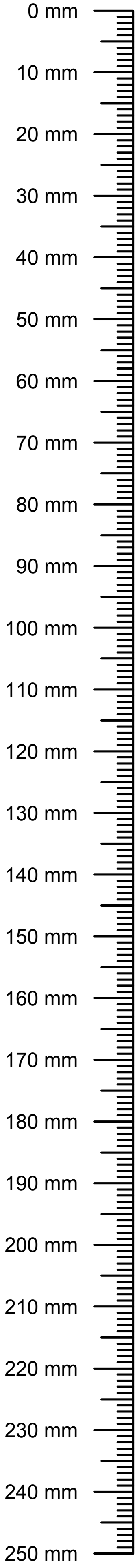
10 -15 feet SAND, medium to very coarse, little granules to medium pebbles, subround to subangular, trace silt; poorly sorted, wet, grayish brown (10YR 5/2).

ON THE ORIGINAL DRAWING.
USE TO VERIFY FIGURE
REPRODUCTION SCALE

SOIL DESCRIPTION FIELD GUIDE (APRIL, 2022; REV. 3.0)

ARCADIS Design & Consultancy for natural and built assets





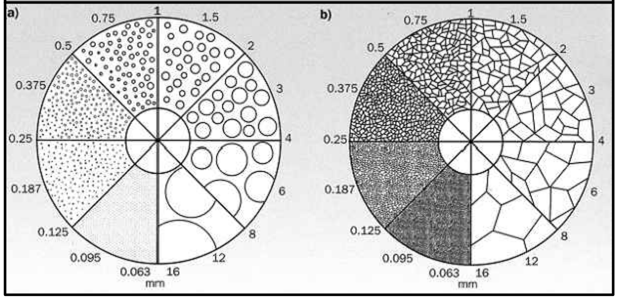
VARIATIONS IN SOIL STRATIGRAPHY

Term	Thickness of Configuration
Parting	0 - to 1/16-inch thickness.
Seam	1/16 - to 1/2-inch thickness.
Layer	1/2 - to 12-inch thickness.
Stratum	> 12-inch thickness.
Pocket	Small erratic deposit, usually less than 1 foot in size.
Varved Clay	Alternating seams or layers of sand, silt, and clay (laminated).
Occasional	≤ 1 foot thick.
Frequent	> 1 foot thick.

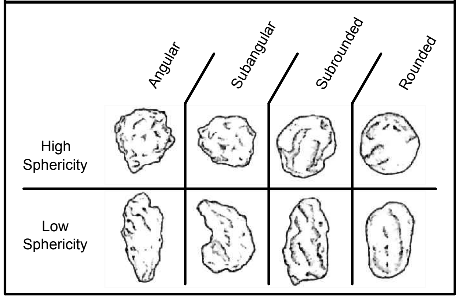
SOIL STRUCTURE DESCRIPTIONS

Term	Description
Homogeneous	Same color and appearance throughout.
Laminated	Alternating layers < 1/4 inch thick.
Stratified	Alternating layers ≥ 1/4 inch thick.
Lensed	Inclusions of small pockets of different materials, such as lenses of sand scattered through a mass of clay; note thickness.
Blocky	Cohesive soil can be broken down into small angular lumps, which resist further breakdown.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear to be polished or glossy, sometimes striated.

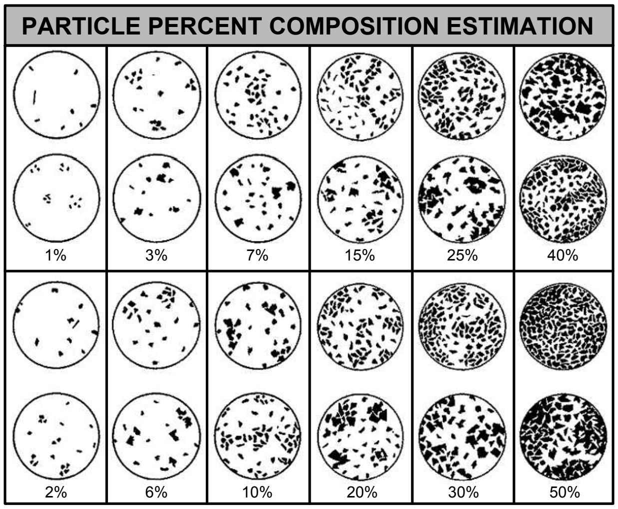
GRAPH FOR DETERMINING SIZE OF PARTICLES



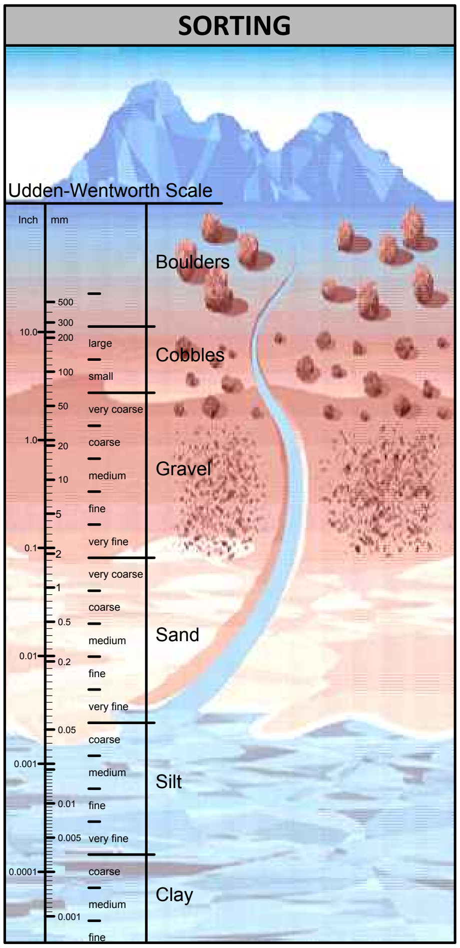
ANGULARITY CHART



PARTICLE PERCENT COMPOSITION ESTIMATION



SORTING



SETTLING TABLE (SILT/CLAY)

Diameter of Particle (mm)	<0.625	<0.031	<0.016	<0.008	<0.004	<0.002	<0.0005
Depth of Withdrawal (cm)	10	10	10	10	5	5	3
Time of Withdrawal	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec
Temperature (Celsius)							
20	00:00:29	00:01:55	00:07:40	00:30:40	00:61:19	04:05:00	37:21:00
21	00:00:28	00:01:52	00:07:29	00:29:58	00:59:50	04:00:00	
22	00:00:27	00:01:50	00:07:18	00:29:13	00:58:22	03:54:00	
23	00:00:27	00:01:47	00:07:08	00:28:34	00:57:05	03:48:00	
24	00:00:26	00:01:45	00:06:58	00:27:52	00:55:41	03:43:00	33:56:00
25	00:00:25	00:01:42	00:06:48	00:27:14	00:54:25	03:38:00	
26	00:00:25	00:01:40	00:06:39	00:26:38	00:53:12	03:33:00	
27	00:00:24	00:01:38	00:06:31	00:26:02	00:52:02	03:28:00	
28	00:00:24	00:01:35	00:06:22	00:25:28	00:50:52	03:24:00	31:00:00
29	00:00:23	00:01:33	00:06:13	00:24:53	00:49:42	03:10:00	
30	00:00:23	00:01:31	00:06:06	00:24:22	00:48:42	03:05:00	

Attachment B

Particle Size System Comparison

The purpose of this attachment is to illustrate how the Udden-Wentworth particle sizes and descriptive terms compares to other particle size systems.

When in the field, it is a customary practice to compare current soil descriptions to historical soil boring logs for reference purposes. When reviewing boring logs prepared by others, field staff should first note the particle size system used and recognize these particle size systems may differ. This will avoid confusion when cross referencing between historical and new boring logs and when reviewing existing geologic cross-sections.

For example, a well-sorted sand with grain sizes ranging from 1 to 2 mm should be classified as a very coarse sand by the Udden-Wentworth system. As shown in this attachment, the same particle size would be classified as a medium sand by the United Soil Classification System. The later system has fewer particle size grades and in general, is less descriptive than the Udden-Wentworth system.

PARTICLE SIZE SYSTEM COMPARISON

System Name | **Used By** | **Grain size distribution in millimeters (mm)**

Udden-Wentworth

Remediation Geologists and Engineers

								Pebbles				Cobbles	
		V. Fine	Fine	Medium	Coarse	V. Coarse	Granule	Small	Medium	Large	V. Large	Small	Large
CLAY	SILT	SAND					GRAVEL						
0.039	0.065	0.125	0.25	0.5	1	2	4	8	16	32	64	128	256
	1/16	1/8	1/4	1/2									

United Soil Classification System

Geotechnical Engineers

		Fine	Medium	Coarse	Fine	Coarse	
CLAY	SILT	SAND			GRAVEL		COBBLE
	0.074	0.42	2	4.75	19	75	300

U.S. Dept. of Agriculture

Soil Scientists

		V. Fine	Fine	Medium	Coarse	V. Coarse	
CLAY	SILT	SAND					GRAVEL
0.002	0.05	0.10	0.25	0.5	1	2	75

Remediation Hydraulics 2008, page 195): The Udden-Wentworth scale is preferred "...because the geometric progression of grain-size diameter also reflects relationships that are important when considering the erosion and deposition of sediments during the depositional process. The correlation between increasing grain size and degree of sorting and permeability is the most important, as permeability structure is responsible for the mobile and immobile porosity within aquifer systems. "

Attachment C

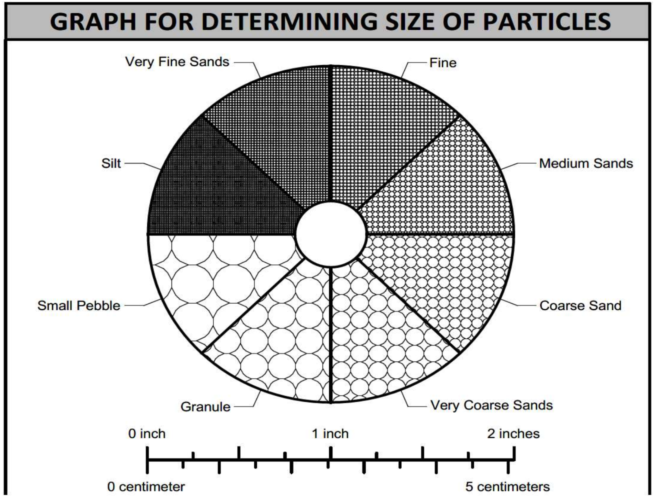
Description of Soil Logging Terms

The purpose of this attachment is to concisely define the soil logging terms used when filling out boring logs. During report preparation, project staff could use this sheet as an index placed in front of the completed boring logs. Also, it can serve as a supplemental reference sheet during field activities.

Description of Logging Terms

Note: Soil descriptions based on Arcadis Technical Guidance and Instructions (TGI) procedures. Key terms defined below.

GRAPH FOR DETERMINING SIZE OF PARTICLES



Udden Wentworth Soil Sizes

Boulder	> 256 mm
Large Cobble	128 to 256 mm
Small Cobble	64 to 128 mm
Very Large Pebble	32 to 64 mm
Large Pebble	16 to 32 mm
Medium Pebble	8 to 16 mm
Small Pebble	4 to 8 mm
Granule	2 to 4 mm
Very Coarse Sand	1 to 2 mm
Coarse Sand	0.5 to 1 mm
Medium Sand	0.25 to 0.5 mm
Fine Sand	0.125 to 0.25 mm
Very Fine Sand	0.062 to 0.12 mm
Silt/Clay	<0.065 mm

Primary Texture *(e.g. CLAY, SILT, SAND, GRANULE, PEAT, MUCK, FILL, etc.)*

List particle size with the highest percentage per sample interval (e.g. SAND)

Always CAPITALIZE the primary texture

Follow primary texture with a comma followed by grain-size descriptors, etc.

Minor Texture

And	(36 to 50%)
Some	(21 to 35%)
Little	(10 to 20%)
Trace	(>10%)

Angularity

Angular	Sharp edges
Sub-Angular	Rounded edges
Sub-Rounded	Well-rounded
Rounded	Smooth curved edges

Sand Density (Blow Counts/ft)

Very Loose	0-4
Loose	5-10
Medium Dense	11-30
Dense	31-50
Very Dense	<50

Silt/Clay Consistency (Blow Counts/ft)

Very Soft	0-2,	thumb easily penetrates several inches
Soft	3-4,	thumb easily penetrates one inch
Medium Stiff	5-8,	thumb indents 0.5 in. with much effort
Stiff	9-15,	thumb indents 0.25 in. with great effort
Very Stiff	16-30,	thumbnail is readily intended

Sorting

Well Sorted	1 to 3 Particle Sizes
Poorly Sorted	4+ Particle Sizes

Moisture Content

Dry	Dry to touch
Moist	No visible water
Wet	Visible free water

Plasticity (for silts and clays)

Non-Plastic	3 mm thread can not be rolled
Low Plasticity	3 mm thread can barely be rolled
Medium Plasticity	3 mm thread can easily and quickly rolled, but not rerolled
High Plasticity	3 mm thread can be rolled slowly, but can be rerolled

Dilatancy (for silts and silt-sand mixtures)

None	No visible change in the specimen
Slow	Water appears slowly during shaking / disappears slowly or not at all upon squeezing
Rapid	Water appears quickly during shaking / disappears quickly upon squeezing

Example Description

10 -15 feet SAND, medium to very coarse, little granules to medium pebbles, subround to subangular, trace silt; poorly sorted, wet, grayish brown (10YR5/2).

Attachment D

Blank Boring Log

The purpose of this attachment is to present a blank field form for use during soil logging. A digital version (Microsoft Excel) of this field form is available from the authors (upon request). If project specific modifications to this boring log template are warranted, please contact the Site Investigation Community of Practice leader for further assistance.

BORING LOG

ARCADIS

Boring ID: ____________________
Project Name: ______________________________
Page: ______/______
Permit ID: ____________________
Date Started: ____________________
Ground Elevation: ____________________
Site Address: ____________________
Date Completed: ____________________
Vertical Datum: ____________________
City, State: ____________________
Total Depth: ____________________
Northing: ____________________
Drilling Co: ____________________
Depth to Water: ____________________
Easting: ____________________
Driller: ____________________
Hole Diameter: ____________________
Horizontal Datum: ____________________
Drilling Method: ____________________
Core Device: ____________________
Prepared by: ____________________
Boring Status: ____________________
Drilling Fluid: ____________________
Reviewed by: ____________________

Drilling Information				**Graphical Log for Primary Texture**											**Soil Description (Udden-Wentworth System)**	**Field Notes**
Drilling Depth (ft bgs)	**Core Interval (ft)**	**Core Recovery (inches)**	**Vapor Reading (ppm)**	**Fines**		**Sand**					**Gravel**				Depth Interval (ft), PRIMARY TEXTURE, Principal and Minor Components with Descriptors (% modifiers and grain size fraction, angularity for coarse sand and larger, consistency/density, plasticity for silt and clay, dilatancy for silt/silt-sand); Sorting, Moisture Content, Color. NOTES: *Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)*	Driller's Observations, Geologic Formation, Field Screening Results, Sample Interval etc.
				clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder		

BORING LOG

ARCADIS

Boring ID: ____________________ **Project Name:** ________________________________ **Page:** ______/______

Drilling Information				Graphical Log for Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	Vapor Reading (ppm)	Fines		Sand					Gravel				Depth Interval (ft), PRIMARY TEXTURE, Principal and Minor Components with Descriptors (% modifiers and grain size fraction, angularity for coarse sand and larger, consistency/density, plasticity for silt and clay, dilatancy for silt/silt-sand); Sorting, Moisture Content, Color. NOTES: *Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)*	Driller's Observations, Geologic Formation, Field Screening Results, Sample Interval etc.
				clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder		

Attachment E

Completed Boring Log

The purpose of this attachment is to provide an example of a completed boring log for reference purposes to field staff. The example provided is for a soil boring completed outside the waste mass of a closed municipal landfill near Baltimore, Maryland. The objective of the drilling program was to determine the depth to groundwater to determine the appropriate depth interval to install a soil gas monitoring well and groundwater monitoring well across the first water-bearing zone. The site geology consists of unconsolidated sediments of the Mid-Atlantic Coastal Plain, specifically the Upper Patapsco formation. These sediments were deposited in a moderate gradient fluvial environment during the Cretaceous period. The landfill was constructed into a regional clay confining unit.

BORING LOG

ARCADIS

Boring ID: MW-08
Permit ID: MD-PG-100
Site Address: 100 Landfill Road
City, State: Baltimore, Maryland
Drilling Co: Earth Matters
Driller: Rod E. Piper
Drilling Method: Direct-push/hollow-stem
Boring Status: completed as well

Project Name: Acme Landfill
Date Started: 7/18/2018
Date Completed: 7/18/2018
Total Depth: 35 ft below ground
Depth to Water: 19 ft below ground
Hole Diameter: 2-inch
Core Device: 5-foot macrocore sampler
Drilling Fluid: none

Page: 1 / 1
Ground Elevation: 50.5 ft
Vertical Datum: NAVD 88, feet
Northing: 123456.79
Easting: 123456.79
Horizontal Datum: NAD 83 feet, MD State
Prepared by: Sandy Pebbles
Reviewed by: Clay Brown

Drilling Information				Graphical Log for Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel					
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	VOC Vapor Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth Interval (ft), PRIMARY TEXTURE, Principal and Minor Components with Descriptors (% modifiers and grain size fraction, angularity for coarse sand and larger, consistency/density, plasticity for silt and clay, dilatancy for silt/silt-sand); Sorting, Moisture Content, Color. NOTES: *Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)*	Driller's Observations, Geologic Formation, Field Screening Results, Sample Interval etc.
0 to 1	0-5	43.2/60	< 1												0-0.5 ft, topsoil with organics	Grass covered area
1 to 2			< 1				X								0.5-5 ft, SAND, fine, trace silt, trace pebble, round; poorly sorted, moist, yellowish brown (7.5 YR 5/8). NOTE: some cementation, does not react with HCl	continuous macro-core logging
2 to 3			< 1				X									
3 to 4			< 1				X									cemented sand @3.6-4 ft
4 to 5			< 1				X									
5 to 6	5-10	40.8/60	< 1				X	X	X						5-10 ft, SAND, fine to coarse, round to subround; well sorted, moist, light to strong brown (7.5 YR 6/4 to 7.5 YR 5/6).	
6 to 7			< 1				X	X	X							
7 to 8			< 1				X	X	X							
8 to 9			< 1				X	X	X							
9 to 10			< 1				X	X	X							
10 to 11	10-15	36/60	< 1				X	X	X						10-12.5 ft, same as above with trace silt	
11 to 12			< 1				X	X	X							
12 to 13			< 1				X	X	X							
13 to 14			< 1				X	X	X						12.5 to 15 ft, same as above, color change to pink (7.5 YR 7/3) and reddish yellow (7.5YR 6/8)	
14 to 15			< 1				X	X	X							
15 to 16	15-20	55.2/60	< 1						X	X					15-18.9 ft, SAND, coarse to very coarse, round to subround; well sorted, moist, strong brown (7.5YR 5/6) to reddish yellow (7.5YR 6/6)	
16 to 17			< 1						X	X						
17 to 18			< 1						X	X						
18 to 19			< 1		X	X	X								18.9-22.7 ft, SAND, very fine to fine, and SILT, coarse to very coarse, poorly sorted, wet, light gray (7.5YR 7/1)	water table encountered @ 18.9 ft
19 to 20			< 1		X	X	X									
20 to 21	20-25	36/60	< 1		X	X	X									
21 to 22			< 1		X	X	X									
21 to 23			< 1		X	X	X									
23 to 24			< 1	X	X										22.7-25 ft, CLAY and SILT, high plasticity, soft to stiff at 25 ft, dry to moist, light gray (2/5YR 7/1) w/ red mottling (2.5YR 4/6)	Middle Patapsco Confining Unit
24 to 25			< 1	X	X											
25 to 26	25-30	30/60	< 1	X	X										25-31.1 ft, CLAY and SILT, high plasticity, stiff; dry to moist, light gray (2/5YR 7/1) with red mottling (2.5YR 4/6)	
26 to 27			< 1	X	X											
27 to 28			< 1	X	X											
28 to 29			< 1	X	X											
29 to 30			< 1	X	X											
30 to 31	30-35 ft	60/60	< 1	X	X											
31 to 32			< 1		X											
32 to 33			< 1		X											
33 to 34			< 1		X										31.1-35 ft, SILT, low plasticity, high dilatancy; wet, gray (7.5YR 7/1)	End of direct-push boring @ 35 ft
34 to 35			< 1		X											

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TGI – Soil Drilling and Sample Collection

Rev: #2

Rev Date: April 8, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	October 11, 2018	All	Updated and re-written as a TGI	Marc Killingstad
	1	May 12, 2020	None	Review – no changes necessary	Marc Killingstad
	2	April 8, 2022	All	Updated to new format and minor content (e.g., PFAS)	Chris Shepherd/Marc Killingstad

Approval Signatures

Prepared by: 4/8/2022

Chris Shepherd (Preparer) Date

Reviewed by: 4/8/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to any and all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM. All deviations or omissions should be documented.

2 Intended Use and Responsibilities

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3 Scope and Application

This Technical Guidance Instruction (TGI) describes general drilling procedures and the methods to be used to field screen and collect soil samples for laboratory analysis in unconsolidated or weakly consolidated sediments. For soil description procedures, please refer to the *TGI - Soil Description*. For monitoring well installation in granular aquifers, please refer to the *TGI - Monitoring Well Installation*. For per- and polyfluoroalkyl substances (PFASs) drilling and soil sampling procedures, please refer to: *TGI – PFAS-Specific Drilling and Monitoring Well Installation, TGI – Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*, and *TGI – Equipment and Reagent Blank Sample Collection for PFAS Analysis*.

Overburden (unconsolidated sediments) drilling is commonly performed using the hollow-stem auger drilling method. Other drilling methods suitable for overburden drilling, which are sometimes necessary due to site-specific geologic conditions, include: direct-push, drive-and-wash, spun casing, rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and hand tools may also be used. Drilling within consolidated materials such as fractured rock is commonly performed using water-rotary (coring or tri-cone roller bit), air rotary or rotasonic methods. For guidance when drilling in consolidated materials (i.e., bedrock), please refer to *the TGI – Bedrock Core Collection and Description.*

The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling depths, targeted chemicals, site or regional geologic knowledge, types of sampling to be conducted, required sample quality and volume, and cost.

Field screening of soil samples is commonly performed using a photoionization detector (PID) and/or a flame ionization detector (FID). These instruments are used to measure relative concentrations of volatile organic compounds (VOCs) for the selection of samples for further laboratory or field analysis. Field screening for dense non-aqueous phase liquids (DNAPL) may be performed using hydrophobic dye (Oil Red O or Sudan IV), which is pertinent at chlorinated solvent sites.

Collection of soil samples for laboratory analysis may be performed using a variety of techniques including grab samples, undisturbed cores, and composite or homogenized samples. Samples may require homogenization across a given depth interval, or several discrete grabs (usually five) may be combined into a composite sample. Samples for VOC analysis will not be homogenized or composited and are collected as discrete grab samples.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). Some lubricants (e.g., vegetable oil-based lubricants) may be acceptable, if the constituents won't interfere with the analyses.

4 Personnel Qualifications

Arcadis field personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or state/federal regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as identified in the site-specific Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. The HASP will also identify any access control requirements.

Prior to mobilizing to the field, Arcadis field personnel will review and be thoroughly familiar with relevant site-specific documents including but not limited to the task-specific work plan or field implementation plan (FIP), Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. Personnel responsible for overseeing drilling operations will have at least 16 hours of prior training overseeing drilling activities with an experienced geologist, environmental scientist, or engineer with at least 2 years of prior experience.

Arcadis personnel directing, supervising, or leading soil sampling activities will have a minimum of 1 year of previous environmental soil sampling experience. Field employees with less than 6 months of experience will be accompanied by a supervisor (as described above) to ensure that proper sample collection techniques are employed.

Additionally, the Arcadis field team will review and be thoroughly familiar with documentation provided by equipment manufacturers and become familiar with the operation of (i.e., hands-on experience) all equipment that will be used in the field prior to mobilization.

5 Equipment List

The following materials will be available, as required, during soil boring drilling, field screening, andsampling activities:

- Site-specific HASP and health and safety documents identified in the HASP
- FIP/work plan that includes site map with proposed boring locations, fieldsampling plan (with corresponding depths, sample analyses, sample volume required, and sample holding time), and previous boring logs (as available)
- Appropriate personal protective equipment (PPE), as specified in the HASP
- Including but not limited to disposable chemical resistant gloves and Level D PPE
- Traffic cones, delineators, and caution tape as appropriate for securing the work area as specified in the Traffic Safety Plan (TSP)
- Photoionization detector (PID), flame ionization detector (FID) or other air/soil screening equipment, asneeded, in accordance with the HASP or workplan
- Sampling equipment:
- Drilling equipment required by *ASTM D1586*, when performing split-spoon sampling including clean sample sleeves
- Disposable plastic liners, when drilling with direct-push equipment
- Stainless steel hand auger and stainless-steel spade if using manual methods
- Appropriate soil sampling equipment (e.g., stainless steel spatulas/spoons/bowls, knife)
- Sealable plastic bags (e.g., Ziploc®)

- Air-tight sample containers and 8-oz. glass Mason jars or driller's jars
- Aluminum foil
- Appropriate sample blanks (trip blank supplied by the laboratory), as specified in the FSP
- Soil sample containers and labels (supplied by the laboratory) appropriate for the analytical method(s) with preservative, as needed (parameter-specific)
- Sample labels
- Indelible ink pens
- Engineer's ruler or survey rod
- Plastic sheeting (e.g., Weatherall Visqueen)
- Appropriate transport containers (coolers) with ice and appropriate labeling, packing, and shipping materials
- Decontamination equipment (buckets, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels) in accordance with the *TGI for Groundwater and Soil Sampling Equipment Decontamination*
- Forms/notes:
    - Tablet with digital forms, etc., if appropriate
    - Appropriate soil boring log (**Attachment 1**)
    - Chain-of-custody forms
    - Field notebook
    - Digital camera (or smart phone with camera)
- Drums or other containers appropriate for soil and decontamination water, as specified by the site investigation-derived waste (IDW) management plan, and appropriate drum labels

6 Cautions

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service in accordance with the work plan, client requirements, and Arcadis guidance. See appropriate guidance forproper utility clearance protocol. Work will be performed in accordance with the Arcadis *Utility Location and Clearance Health and Safety Standard* and the *Utilities and Structures Checklist* will be completed before beginning any intrusive work.

Prior to beginning field work, the project technical team will ensure that all field logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.) and task objectives are clearly understood by all team members. An internal call with the project technical team to review the FIP/work plan scope and objectives is strongly recommended prior to mobilization to ensure that the field work will be effectively and efficiently executed.

Some regulatory agencies have specific requirements regarding borehole abandonment and grout mixtures. Determine whether the oversight agency has any such requirements prior to finalizing the drilling plan.

If DNAPL is known or expected to exist at the site, refer to the project specific documents (e.g., DNAPL Contingency Plan) for additional details regarding drilling to reduce the potential for inadvertent DNAPL remobilization.

Similarly, if light non-aqueous phase liquid (LNAPL) is known or expected to be present as "perched" layers above the water table, refer to the DNAPL Contingency Plan. Follow the general provisions and concepts in the DNAPL contingency plan during drilling above the water table at known or expected LNAPL sites.

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions. Water used for drilling, decontamination of drilling/sampling equipment, or grouting boreholes uponcompletion will be of a quality acceptable for project objectives. Testing of water supply will be considered.

Specifications of materials used for backfilling the borehole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPL is likely to be present or in groundwater with high salinity. In these situations, neat cement grout is preferred.

Store and/or stage empty and full sample containers and coolers out of direct sunlight. Sample container threads should be wiped down with a clean, nonabrasive material (e.g., paper towels) to better ensure the sample container is properly sealed. Be careful not to over-tighten lids with Teflon® liners or septa. Over-tightening can impair the integrity of the seal and cancause the glass to shatter and create a risk for hand injuries.

NOTE: *Field logs and some forms are considered to be legal documents. All field logs and forms will therefore be filled out in indelible ink. Do not use permanent marker or felt-tipped pens for labels on sample container or sample coolers. Permanent markers could introduce volatile constituents into the samples.*

NOTE: *An Arcadis employee that is appropriately trained at the correct level of internal hazardous materials/DOT (Department of Transportation) shipping must complete an Arcadis shipping determination to address applicable DOT and IATA (International Air Transport Association) shipping requirements. Review the applicable Arcadis procedures and guidance instructions for sample packaging and labeling. Prior to using air transportation, confirm air shipment is acceptable under DOT and IATA regulations.*

7 Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Review all site-specific and procedural hazards as they are provided in the HASP, and review Job SafetyAnalysis (JSA) documents in the field each day prior to beginning work.

Prior to drilling, utility clearance must be performed (see Section 5). Appropriate personal protective equipment (PPE) will be worn at all times in line with the task and thesite-specific HASP.

Working outside at sites with suspected contamination may expose field personnel to hazardous materials such as contaminated groundwater or NAPL (e.g., oil). Other potential hazards include biological hazards (e.g., stinging insects, ticks in long grass/weeds, etc.), and potentially the use of sharp cutting tools (scissors, knife). Only use non-toxic peppermint oil spray for stinging insect nests. Review client-specific health and safety requirements, which may preclude the useof fixed/folding-blade knives and use appropriate hand protection.

If thunder or lightning is present, discontinue drilling and sampling until 30 minutes have passed after the last occurrence of thunder or lightning.

8 Procedure

The procedures for drilling and the methods to be used to field screen and collect soil samples for laboratory analysis are presented below:

8.1 Drilling Procedures

8.1.1 Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area.
    a. Verify utilities were cleared (see Section 5) and use soft dig technique to clear borehole, if applicable
    b. Clean sampling equipment in accordance with the FIP/work plan prior to drilling
2. Advance boring to target depth:
    a. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) using the appropriate tooling (e.g., split-barrel sampler) and sample containers
        i. Split-barrel or drive-ahead samples are obtained during drilling
        ii. A common sampling method that produces high-quality soil samples with relatively littlesoil disturbance is described in *ASTM D1586 – Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils* (ASTM D1586).
    b. Always change disposable gloves before handling the sampling equipment
    c. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
    e. Rotasonic drilling produces soil cores that, for the most part, are relatively undisturbed, but note that when drilling in consolidated or finer-grained sediment the vibratory action during core barrel advancement may create secondary fractures or breaks. The core is retrieved by vibrating the soil/rock into a separate core bag, typically in 5-foot or 10-foot increments. The soil cores may consolidate or expand during retrieval, depending on soils, etc.
    f. Dual-rotary removes cuttings by compressed air or water/mud and allow only a

generalassessment of geology unless separate coring tools and techniques are used

   g. Decontaminate equipment between samples in accordance with the FIP/work plan (or equivalent)

3. Describe each soil sample as outlined in the appropriate project records (refer to the description procedures outlined in the *TGI - Soil Description*)
   a. Record descriptions on the soil boring log (**Attachment 1**) and/or field notebook
   b. When possible, photo document the samples (e.g., soil cores, split-barrels)
   c. During soil boring advancement, document all drilling events in field notebook, including blow counts (i.e., the number of blows from a soil sampling drive weight [140 pounds] required to drive the split-barrel sampler in 6-inch increments) and work stoppages
   d. Blow counts will not be available if rotasonic, dual-rotary, or direct-push methods are used; however, if standard penetration testing is required during rotasonic drilling, an automatic drop hammer may be used in conjunction with the method to switch from core barrel advancement to standard penetration testing
   e. If soils are screened with a PID/FID or another instrument, document the measurement in accordance with the work plan
4. The drilling contractor will be responsible for obtaining accurate and representative samples, informing the supervising Arcadis geologist of changes in drilling pressure, drilling penetration rates, and keeping a separategeneral log of soils encountered, including blow counts
   a. The term “samples” means soil materials from particular depth intervals, whether or not portions of these materials are submitted for laboratory analyses
   b. Records will also be kept of occurrences of premature refusal due to boulders, construction materials that may have been used as fill, etc.
   c. Where a boring cannot be advanced to the desired depth, the boring will be abandoned, and an additional boring will be advanced at an adjacent location to obtain the required sample in accordance with the work plan
   d. Where it is desirable to avoid leaving vertical connections between depth intervals (e.g., if DNAPL or perched LNAPL are known or expected to exist at the site), the borehole will be sealed using cement and/or bentonite (see **Section 5** above)
   e. Multiple refusals may lead to a decision by the supervising geologist to abandon that sampling location

8.1.2 Direct-Push Method

The direct-push drilling method may also be used to complete soil borings. Examples of this technique include Geoprobe®, Diedrich Environmental Soil Probe (ESP) System, or AMS PowerProbe.

Environmental probe systems typically use a hydraulically operated percussion hammer.

Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow. The hammer provides the force needed to penetrate very stiff to medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual tube liner for samplingsoil (dual tube sampling system).

The outside diameter (OD) of the outer casing ranges from 2.25 to 6 inches and the OD of the inner sampling tube diameter ranges from 1.4 to 4.5 inches. The outer casing isolates overlying soil and permits the unit to continue to probe at depth. The dual tube sampling system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, a single rod system may be used that does notprovide a cased boring and which limits tremie-grouting from the bottom up.

Direct-push drilling can generally achieve target depths 100 feet or less depending on the site geology. The known or expected site conditions (e.g., presence of NAPL) will be evaluated when selecting the typeof direct-push sampling system to be employed.

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area
    a. Verify utilities were cleared (see Section 5) and use soft dig technique to clear borehole, if applicable
    b. Clean sampling equipment in accordance with the FIP/work plan prior to drilling
2. Advance soil boring to target depth.
    a. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) using clean/disposable sampling equipment (plastic liners)
    b. Always change disposable gloves before handling the sampling equipment
    c. Collect, document, and store samples for laboratory analysis as specified in theFIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
3. Decontaminate equipment between samples in accordance with the FIP/work plan (or equivalent)
4. Describe samples in accordance with the procedures outlined in **Step 3** under ***Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods*** above (refer to the description procedures outlined in the *TGI - Soil Description*)

8.1.3 Manual Methods

Manual methods may also be used to complete shallow soil borings. Examples of this technique include using a spade, spoon, scoop, hand auger, or slide hammer. Manual methods are typically used to collect surface soil samples (0 to 6 inches) or to complete soil borings/collect soil samples from a depth of 5 feet or less.

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area
2. Clear the ground surface of brush, root mat, grass, leaves, or other debris
3. Use a spade, spoon, scoop, hand auger, or slide hammer to collect a sample of the required depth interval
4. Use an engineer’s ruler or survey rod to verify that the sample is collected to the correct depth and

record the top and bottom depths from the ground surface

5. To collect samples below the surface interval, remove the surface interval first; then collect the deeper interval
    a. To prevent the hole from collapsing, it may be necessary to remove a wider section from the surface or use cut polyvinyl chloride (PVC) pipe to maintain the opening
    b. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) and transfer to the appropriate, laboratory-supplied container
    c. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
6. Decontaminate equipment between samples in accordance with the FIP/work plan (orequivalent)
7. Describe samples in accordance with the procedures outlined in **Step 3** under ***Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods*** above (refer to the description procedures outlined in the *TGI - Soil Description*)

8.2 Field Screening Procedures

8.2.1 PID and FID Screening

Soils are typically field screened with a PID or FID for a relative measure of the total VOCs at sites where VOCs are known or suspected to exist. PIDs and FIDs require calibration in accordance with the work plan(s) and manufacturer’s specifications and PIDs should be calibrated based on the target chemicals. The PID employs an ultraviolet lamp to measure VOCs and the ionizationenergy (IE) of the site constituents need to be considered when selecting the type of lamp (e.g., 10.6 eV, 11.7 eV) that will be used. In general, any compound with an IE lower than that of the lamp photons canbe measured. The FID has a wide linear range and responds to almost all VOCs.

Field screening is performed using one (or both) of the following two methods:

1. Upon opening the sampler, the soil is split open and the PID or FID probe is placed in the opening and covered with a clean, gloved hand. Such readings will be obtained at several locations along the lengthof the sample.
2. A portion of the collected soil is placed in a jar, which is covered with aluminum foil, sealed, and allowed to warm to room temperature (see below). After warming, the cover is removed, the foil is pierced withthe PID or FID probe, and a reading is obtained.

Prior to usage, the PID or FID must be calibrated according to the manufacturer's specifications at a minimum frequencyof once per day prior to collecting PID or FID readings. The PID will be calibrated to a benzene-related compound (isobutylene) or other appropriate gas, while the FID will be calibrated to methane. The time, date, and calibration procedure must be clearly documented in the field notebook and/or the calibration form.

If at any time the PID or FID results appear erratic or inconsistent with field observations, then the instrument will be recalibrated.

If calibration is difficult to achieve, then the PID's lamp will be checked for dirt or moisture and cleaned, or technical assistance will be required. Maintenance and calibration records will be kept as part of the field quality assurance program.

Initial PID readings will be recorded on the soil boring log (**Attachment 1**) and/or in the field notes. The soil sample will be separated from the slough material (if any) by using disposable gloves and a pre-cleaned stainless-steel spoon or tool.

For the second method, a representative portion of the sample will be placed in a pre-cleaned air-tight container (as quickly as possible to avoid loss of VOCs), filling the container half full to allow for the accumulation of vapors above the soil. An aluminum foil seal will be placed between the glass and cap and the cap will be screwed on tightly. Unless the screening will be performed immediately after the sample is placed in the container, the sample containers will be stored in a cooler chilled to approximately4ºC until screening can be performed.

The headspace of the container will be measured using a PID or FID as follows:

1. Samples will be taken to a warm workspace and allowed to equilibrate to room temperature for atleast one hour.
2. Prior to measuring the soil vapor headspace concentration, the container will be shaken.
3. The headspace of the sample will then be measured directly from the container by piercingthe aluminum foil seal with the probe of the PID or FID and measuring the relative concentration of VOCs in the headspace of the soil sample. The initial (peak) reading must be recorded.

8.2.2 NAPL Screening

To screen for the potential presence of non-aqueous phase liquid (NAPL) in soil, drilling procedures must allow for high-quality porous media samples to be taken. Split-barrel samplers or direct-push samplers will be collected continuously ahead of the auger, drill casing/rods, or probe rods. Upon opening each split-barrel sampler or direct-push plastic liner sleeve, the soil will immediately be evaluated for the presence of visible NAPL and odors. If suspected NAPL is immediately visible in the sample, its depth will benoted.

Additionally, the soil will be screened for the presence of organic vapors using a PID or FID, in accordance with the work plan, if applicable. During screening, the soil will be split open using a clean spatula or knife and the PID or FID probe will be placedin the opening and covered with a clean, gloved hand (**Method 1** above). Such readings will be obtained along the entire length of the sample. Alternatively, **Method 2** for PID/FID screening (outlined above) may also be performed. If the PID or FID examination reveals the presence of organic vapors above 100 parts permillion (ppm), the sample will undergo further detailed evaluation for visible NAPL.

The assessment for NAPL will include the following tests/observations:

- Evaluation for Visible NAPL Sheen or Free-Phase NAPL in Soil Sampler
    - NAPL sheen will be a colorful iridescent appearance on the soil sample
    - NAPL may also appear as droplets or continuous accumulations of liquid with a color typically ranging from yellow to brown to black, depending on the type of NAPL
    - Creosote DNAPL (associated with wood-treating sites) and coal tar DNAPL (associated with manufactured gas plant [MGP] sites) are typically black and have a characteristic, pungent odor
    - Pure chlorinated solvents may be colorless in the absence of hydrophobic dye. Solvents mixed

with oils may appear brown

  - Particular care will be taken to fully describe any sheens observed, staining, discoloration, droplets (blebs), or NAPL saturation

- Soil-Water Pan Test
  - A portion of the selected soil interval with the highest PID or FID reading above 100 ppm will be placed in a disposable polyethylene dish along with a small volume of potable or distilled water
  - The dish will be gently tilted back and forth to mix the soil and water, and the surface of the water will be viewed in natural light to observe the development of a sheen, if any
  - A small quantity of Oil Red O or Sudan IV hydrophobic dye powder should be added in accordance with the work plan, and the soil and dye will be manually mixed for approximately 30 to 60 seconds and smeared in the dish tocreate a paste-like consistency
  - A positive test result will be indicated by a sheen on the surface of the water and/or a bright red color imparted to the soil following mixing with dye
- Soil-Water Shake Test
  - A small quantity of soil (up to 15 cc) will be placed in a clear, colorless, jar containing an equal volume of potable or distilled water (40-mL vials are well suited to this purpose, but not required)
  - After the soil settles into the water, the surface of the water will be evaluated for a visible sheen under natural light
  - The jar will be closed and gently shaken for approximately 10 to 20 seconds
  - Again, the surface of the water will be evaluated for a visible sheen or a temporary layer of foam
  - A small quantity (approximately 0.5 to 1 cc) of Oil Red O or Sudan IV powder will be placed in the jar in accordance with the work plan
  - The sheen layer, if present, will be evaluated for a reaction to the dye (change to bright red color)
  - The jar will be closed and gently shaken for approximately 10 to 20 seconds
  - The contents in the closed jar will be examined under natural light for visible bright red dyed liquid inside the jar

- A positive test result will be indicated by the presence of a visible sheen or foam on the surface ofwater, a reaction between the dye and the sheen layer upon first addition of the dye powder, a bright red coating on the inside of the vial (particularly above the water line), or red-dyed droplets within the soil

NOTE: *If NAPL is obviously present upon opening the soil sampler or evaluating the soil sample within the split-spoon sampler or direct-push liner sleeve, it is not necessary to perform a soil-water pan test or soil-water shake test. In addition, it is not necessary to perform both a soil-water pan test and a soil-water shake test; either test method is acceptable. The pan test may be preferred in some circumstances because the presence of a sheen may be easier to see on a wider surface. Further, these tests will only be performed if specified in the work plan(s).*

NOTE: *When using hydrophobic dye in the tests above, color will be assessed outdoors under natural light during the period between sunrise and sunset, regardless of the degree of cloud cover. The hydrophobic dye Safety Data Sheets (SDS) will be incorporated into the HASP and reviewed prior to use and the dyes will be carefully handled and disposed in accordance with regulations, if applicable*.

8.3 Soil Sample Collection for Laboratory Procedures

If not specifically identified in the FIP/work plan, soil samples will be selected for laboratory analysis based on:

1. Their position in relation to identified source areas
2. The visual presence of source residues (e.g., NAPL or staining)
3. The relative levels of total VOCs based on field screening measurements
4. The judgment of the field coordinator
5. Moisture content or relative position with regard to apparent groundwater table/saturation

Samples designated for laboratory analysis will be placed in the appropriate containers.

Sample containers for VOC analysis will be filled first immediately following soil core retrieval to reduce loss of VOCs.

If samples will be collected for other analyses, a sufficient amount of the remaining soil willthen be homogenized as described below and sample containers will be filled for other parameters.

VOC samples will be collected as discrete samples using a small diameter core sampler (e.g., En Core® Sampler, Terra Core™ Sampler).

The En Core® Sampler is a disposable volumetric sampling device that collects, stores and delivers soil samples without in-field chemical preservation. The En Core® Sampler requires the use of a reusable T-handle.

The Terra Core™ Sampler is a one-time use transfer tool, designed to collect soil samples and transfer them to the appropriate containers for in-field chemical preservation (e.g., methanol).

The small diameter core samplers will be used according to the manufacturer's instructions (e.g., En Novative Technologies). Some regulatory agencies have specific requirements regarding VOC sample collection. Determine whether the oversight agency has specific requirements prior to commencing sampling and collect samples at appropriate interval as specified in the FIP/work plan (or equivalent). Samples may require homogenization across a given depth interval, or several discrete grabs (usually five) may be combined into a composite sample.

NOTE: *Samples for VOC and PFAS analysis will NOT be homogenized or composited and will be collected asdiscrete samples as described above.*

The procedure for mixing samples is provided below.

1. Mix the materials in a stainless steel (or appropriate non-reactive material) bowl using a stainless-steel spoon (or disposable equivalents)
   a. When dealing with large sample quantities, use disposable plastic sheeting and a shovelor trowel
   b. NOTE: *When preparing samples for metals analyses, do not use disposable aluminum(or metal tools or trays other than stainless steel), as it may influence the analytical results*
2. Flatten the pile by pressing the top without further mixing
3. Divide the circular pile by into four equal quarters by dividing out two diameters at right angles
4. Mix each quarter individually using appropriate non-reactive bowls, spoons and/or sheeting
5. Mix two quarters (as described above) to form halves, then mix the two halves to form a composite orhomogenized sample
6. Place composite or homogenized sample into specified containers
7. Remaining material will be disposed of in accordance with project requirements and applicableregulations
8. Sample containers will be labeled with sample identification number, date, and time of collection andplaced on ice in a cooler (target 4° Celsius)
9. Samples selected for laboratory analysis will be documented (chain-of-custody forms), handled, packed, and shipped in accordance with the procedures outlined in the FIP/work plan (or equivalent).

8.4 Soil Boring Abandonment

All soil borings need to be abandoned in accordance with ***TGI for Monitoring Well and Soil Boring Decommissioning***. See Attachment E of the TGI for specifics.

9 Waste Management

Investigative-Derived Waste (IDW) generated during drilling activities, including soil and excess drilling fluids (if used), and decontamination liquids, will be stored on site in appropriately labeled containers and disposed of properly. Disposable materials will be stored and disposed of separately. Containers must be labeled at the time of collection and will include date, location(s), site name, city, state, and description of matrix contained (e.g., soil, PPE). Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage,* the procedures identified in the FIP/work plan or QAPP as well as state-, federal- or client-specific requirements. Be certain that waste containers are properly labeled and documented in the field log.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Management of the original documents from the field will be completed in accordance with the site- specific QAPP.

In general, drilling activities will be documented on appropriate field/log forms as well as in a proper field notebook. All field data will be recorded digitally or with indelible ink. Field forms, logs/notes (including daily field and calibration logs), digital records, and chain-of-custody records will be maintained by the field team lead. Any deviations or omissions from this TGI should be documented.

Initial field logs and chain-of-custody records will be transmitted to the Arcadis CPM and Technical Lead at the end of each day unless otherwise directed by the CPM. The field teamleader retains copies of the field documentation.

Additionally, all documents (and photographs) will be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of drilling activities, soil descriptions, soil boring information, and quantities of materials used.

In addition, the locations of soil borings will be documented photographically and in a site sketch. If appropriate, a measuring wheel or engineer's tape will be used to determine approximate distances between important site features.

Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

11 Quality Assurance

Quality assurance procedures shall be conducted in accordance with the Arcadis Quality Management System or the site-specific QAPP.

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the appropriate TGI.

Field-derived quality assurance blanks will be collected as specified in the FIP/work plan and/or site- specific QAPP, depending on the project quality objectives. Typically, field rinse blanks (equipment blanks) will be collected when non-dedicated equipment (e.g., split-spoon sampler, stainless steel spoon) is used during soil sampling. Field rinse blanks will be used to confirm that decontamination procedures are sufficient and samples are representative of site conditions. Trip blanks for VOCs, which aid in the detection of contaminants from other media, sources, or the container itself, will be kept with the coolers and the sample containers throughout the sampling activities and during transport to the laboratory.

Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures. Calibrate instruments at the beginning of each day and verify the calibration at the end of each day. Record all calibration activities in the field notebook.

12 References

ASTM D1586 - *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*. ASTM International. West Conshohocken, Pennsylvania.

13 Attachments

Attachment 1. Soil Boring Log Form

Attachment 1

Soil Boring Log Form

BORING LOG

ARCADIS

Boring ID: ______________________
Permit ID: ______________________
Site Address: ______________________
City, State: ______________________
Drilling Co: ______________________
Driller: ______________________
Drilling Method: ______________________
Boring Status: ______________________

Project Name: ______________________
Date Started: ______________________
Date Completed: ______________________
Total Depth: ______________________
Depth to Water: ______________________
Hole Diameter: ______________________
Core Device: ______________________
Drilling Fluid: ______________________

Page: ______________________
Ground Elevation: ______________________
Vertical Datum: ______________________
Northing: ______________________
Easting: ______________________
Horizontal Datum: ______________________
Prepared by: ______________________
Reviewed by: ______________________

Drilling Information				**Primary Texture**											**Soil Description (Udden-Wentworth System)**	**Field Notes**
				Fines		**Sand**					**Gravel**					
Drilling Depth (ft bgs)	**Core Interval (ft)**	**Core Recovery (inches)**	**PID Reading (ppm)**	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.

BORING LOG

Boring ID: ____________ **Project Name:** ____________ **Page:** /

Drilling Information				Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	PID Reading (ppm)	Fines		Sand					Gravel				Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.
				clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder		

BORING LOG

Boring ID: ____________________ **Project Name:** ________________________________ **Page:** ____ / ____

Drilling Information				Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel					
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	PID Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.

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TGI – Monitoring Well Installation

Rev: 1

Rev Date: June 23, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	4/24/2017	All	Re-written as a TGI	Marc Killingstad Peter C. Frederick
	1	6/23/2022	All	Put into new template format, reviewed and made minor revisions	Whitney Plasket Marc Killingstad

Approval Signatures

Prepared by: Whitney L Plasket 4/7/2022

Whitney Plasket Date

Reviewed by: 4/7/2022

Marc Killingstad Date

1 Introduction

This Technical Guidance Instruction (TGI) describes methods used to install groundwater monitoring wells in unconsolidated aquifers. It is assumed that the monitoring well to be installed has been properly designed, including sizing of the filter pack and screen, the length of the screen, total depth of the well, material strength and compatibility and surface completion. Typical monitoring wells are constructed of manufactured screen and engineered filter pack and are generally suitable for formations with granular materials having a grain size distribution with up to 50% passing a #200 sieve and up to 20% clay-sized material. Monitoring wells installed in formations finer than this may not be able to produce turbidity free water.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

The monitoring well installation procedures set forth herein are consistent with the approach and methods presented in the American Society of Testing and Materials (ASTM) *D5092 – Standard Practice for Design and Installation of Groundwater Monitoring Wells* (ASTM D5092). As such, following this TGI in combination with proper well design (see appropriate TGI and/or consult with appropriate subject matter expert), well development (see appropriate TGI), groundwater sampling procedures (see appropriate TGI), and well maintenance and rehabilitation (see appropriate TGI and/or consult with appropriate subject matter expert), will result in a monitoring well suitable for: (1) collection of groundwater samples representative of the surrounding formation and free of artificial turbidity; (2) measurement of accurate groundwater levels; and (3) hydraulic testing of formation sediments immediately adjacent to the open interval of the well to assess hydraulic properties (e.g., slug testing).

Monitoring well boreholes in unconsolidated (overburden) materials are often drilled using the hollow-stem auger drilling method; however, other drilling methods are also suitable for installing overburden monitoring wells and may be appropriate given site-specific geologic conditions or project objectives. These methods include drive-and-wash, spun casing, rotosonic (sonic), dual-rotary (Barber Rig), and fluid/mud rotary with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe® or cone penetrometer) and driven well points may also be used in some cases within the overburden.

Monitoring wells to be installed within consolidated materials such as fractured bedrock are commonly drilled using air rotary, water-rotary (coring or tri-cone roller bit), or sonic drilling methods. For guidance when installing monitoring wells in consolidated materials, please consult the appropriate subject matter expert and, if available, the applicable guidance document.

The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling/well depths, site or regional geologic knowledge, type of monitoring to be conducted using the installed well, project objectives, and cost. Consultation with the appropriate subject matter expert is also strongly recommended.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). No polyvinyl chloride (PVC) glue/cement will be used in constructing or retrofitting monitoring wells that will be used for water-quality monitoring.

Coated bentonite pellets are generally not recommended because of potential chemical incompatibilities between the coating material and groundwater chemistry.

Specifications of materials to be installed in the borehole will be obtained prior to mobilizing onsite. These materials generally include:

- Well casing (length, material, and diameter);
- Well screen (length, material, diameter, and slot size);
- Grout (typically neat cement grout, which is 5-6 gallons of water per 94 lb. bag of Portland Type I/II cement *with no bentonite* but, as applicable, up to 5% bentonite can be added);
- Filter pack (filter pack type and fine sand seal type, as applicable); and
- Bentonite (type, as applicable/needed, non-coated pellets or tablets are generally preferred over chips).

Well materials will be inspected and, if needed, cleaned, or replaced prior to installation. The field task manager or field team lead will communicate with the drilling company ahead of time to make sure the materials meet the required specification for well construction.

NOTE: If installing monitoring wells for per- and polyfluoroalkyl substances please refer to *TGI for Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*.

4 Personnel Qualifications

Arcadis field personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or state/federal regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as identified in the site-specific Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. The HASP will also identify any access control requirements.

Prior to mobilizing to the field, Arcadis field personnel will review and be thoroughly familiar with relevant site-specific documents including but not limited to the field implementation plan (FIP)/task-specific work plan, Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. Personnel responsible for overseeing drilling operations will have at least 16 hours of prior training overseeing drilling activities with an experienced geologist, environmental scientist, or engineer with at least 2 years of prior experience.

Arcadis personnel directing, supervising, or leading well installation activities will have a minimum of 1 year of previous environmental monitoring well installation experience. Field employees with less than six months of experience will be accompanied by a supervisor (as described above) to ensure that proper well installation techniques are employed.

Additionally, the Arcadis field team will review and be thoroughly familiar with documentation provided by equipment manufacturers and become familiar with the operation of (i.e., hands-on experience) all equipment that will be used in the field prior to mobilization particularly the selected drilling method/rig.

Monitoring well installation activities will be performed by persons who have been trained in proper well installation procedures under the guidance of an experienced field geologist, engineer, or technician. Field sampling is typically performed for soil or bedrock characterization as part of monitoring well installation; therefore, field personnel will have undergone in-field training in soil or bedrock description and sample collection methods, as described in *TGI for Soil Drilling and Sample Collection, TGI for Bedrock Core Collection and Description, and TGI for Soil Description*.

5 Equipment List

The following materials may be required during soil boring and monitoring well installation activities:

- Site Plan with proposed soil boring/well locations;
- Field Implementation Plan (FIP)/Work Plan that includes site map with proposed well locations, well construction details (tabulated and drawings) which will include well casing material and size, well screen material and size, length of screen, target depth and screen interval, filter pack material, development methods, and previous boring logs (as available);
- Field Sampling Plan (FSP), and site-specific Health and Safety Plan (HASP);
- Personal protective equipment (PPE) as required by the HASP;

- Traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area, if such are not provided by drillers;
- Appropriate soil sampling equipment (e.g., stainless steel spatulas, knife);
- Soil and/or bedrock logging equipment as specified in the FIP/work plan or other appropriate project documents;
- Appropriate sample containers and labels;
- Drum labels as required for investigation derived waste handling;
- Insulated coolers with ice, when collecting samples requiring preservation by chilling;
- Photoionization detector (PID) or flame ionization detector (FID);
- Ziplock style bags;
- Water level or oil/water interface meter;
- Locks and keys for securing the well after installation;
- Decontamination equipment (bucket, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels);
- Engineer’s tape/measuring wheel;
- Weighted tape;
- Disposable bailers;
- Forms/notes:
    - Tablet with digital forms
    - Field notebook
    - Chain-of-custody forms
    - Digital camera (or smart phone with camera);
    - Appropriate field forms, consider including a photo of the well head and a Google Earth map showing the well location.

Prior to mobilizing to the site, Arcadis personnel will contact the drilling subcontractor or in-house driller (as appropriate) to confirm that appropriate sampling and well installation equipment will be provided. Specifications of the sampling and well installation equipment are expected to vary by project, and so communication with the driller is necessary to ensure that the materials provided will meet the project objectives. Equipment/materials typically provided by the driller could include:

- Drilling equipment required by the ASTM standard guidance document D1586, when performing split-spoon sampling;
- Disposable plastic liners (when drilling with direct-push equipment);
- Drums for investigation derived waste (IDW);
- Equipment to move IDW drums, if required;
- Drilling and sampling equipment decontamination materials;
- Decontamination pad materials, if required;

- Traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area, if required; and
- Well construction materials.

6 Cautions

- Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service. See Arcadis standard for proper utility clearance protocol.
- Prior to beginning field work, contact the project technical team (including Project Hydrogeologist) to ensure that all field procedures, logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.), and objectives are clearly understood by all team members.
- Some regulatory agencies require a minimum annular space between the well or permanent casing and the borehole wall. When specified, the minimum clearance is typically 2 to 3 inches on all sides (e.g., a 2-inch diameter well requires a 6-inch diameter borehole). In addition, some regulatory agencies have specific requirements regarding grout mixtures and well seal materials. Determine whether the oversight agency has any such requirements prior to finalizing the drilling and well installation plan. If installing a monitoring well into consolidated sediments, refer to regulatory agency rules regarding casing.
- The maximum screen length may also be dictated by regulatory agencies. If installing a monitoring well with greater than a 10-ft screen, refer to regulatory agency rules regarding screen length.
- If dense non-aqueous phase liquids (DNAPL) are known or expected to exist at the site, refer to the project specific documents for additional details regarding drilling and well installation to reduce the potential for inadvertent DNAPL remobilization. Similarly, if light non-aqueous phase liquids (LNAPLs) are known or expected to be present as “perched” layers above the water table, refer to the *DNAPL Contingency Plan*. Follow the general provisions and concepts in the DNAPL contingency plan during drilling above the water table at known or expected LNAPL sites.
- Avoid using drilling fluids or materials that could impact groundwater or soil quality or could be incompatible with the subsurface conditions. Water used for drilling and sampling of soil or bedrock, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be of a quality acceptable for project objectives. Consider testing of water supply as necessary.
- Similarly, consider the compatibility between the well materials and the surrounding environment. For example, PVC well materials are not preferred when DNAPL is present. In addition, some groundwater conditions leach metals from stainless steel or are corrosive to metal well materials, and some remedial technologies are incompatible with certain materials of construction. If questions arise, contact the CPM and Project Hydrogeologist/Technical Lead to discuss.
- Specifications of materials used for backfilling the borehole will be obtained, reviewed, and approved to meet project quality objectives. Bentonite is not recommended where DNAPLs are likely to be present or in groundwater with high salinity. In these situations, neat cement grout is preferred.
- As noted above, coated bentonite pellets are not recommended for monitoring well construction, as the coating could impact the water quality in the completed well.

- Heat of hydration during neat cement grout curing must be considered to avoid damage to PVC well materials. The annular space for a typical monitoring well is small enough that heat of hydration should not create excessive temperature increases which may damage PVC well material. However, washouts in the borehole can lead to thick accumulations of grout which can produce enough heat during curing to weaken and potentially damage PVC casing. If heat of hydration is a concern, contact the Project Hydrogeologist/Technical Lead to address the issue.
- Similarly, it is imperative that backfill volumes (filter pack and well seal) be estimated and then closely monitored to ensure that materials are not 'lost' to the formation. If estimated volumes do not reasonably match actual volumes, contact the Project Hydrogeologist/Technical Lead to address the issue.

7 Health and Safety Considerations

Field activities associated with monitoring well installation will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. The HASP may require that the drilling company provide their own HASP and/or Job Safety Analyses (JSAs).

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Review all site-specific and procedural hazards as they are provided in the HASP, and review Job SafetyAnalysis (JSA) documents in the field each day prior to beginning work.

Prior to drilling, utility clearance must be performed (see Section 6). Appropriate personal protective equipment (PPE) must always be worn in accordance with the task and the HASP.

Working outside at sites with suspected contamination may expose field personnel to hazardous materials such as contaminated groundwater or NAPL (e.g., oil). Other potential hazards include biological hazards (e.g., stinging insects, ticks in long grass/weeds, etc.), and potentially the use of sharp cutting tools (scissors, knife). Only use non-toxic peppermint oil spray for stinging insect nests. Review client-specific health and safety requirements, which may preclude the useof fixed/folding-blade knives and use appropriate hand protection.

If thunder or lightning is present, discontinue drilling and sampling until 30 minutes have passed after the last occurrence of thunder or lightning.

8 Procedure

The procedures for installing groundwater monitoring wells are presented below:

Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Sonic, and Dual-Rotary Drilling Methods

1. Prior to monitoring well installation, determine the expected volumes of filter pack and seal materials including grout (neat cement or cement-bentonite) and bentonite (if applicable).
2. Locate boring/well location, establish work zone, and set up sampling equipment decontamination area.
3. During well installation, record construction details, measurements, and tabulate materials used (e.g., screen and riser footages; filter pack volume; bags of cement/sand; volume of grout; etc.) in the field notebook as well as appropriate field forms.

4. Advance boring to desired depth.
   a. Collect soil and/or bedrock samples at appropriate interval(s), document, and store samples for laboratory analysis as specified in the FIP/Work Plan.
   b. Decontaminate equipment between samples in accordance with the *TGI for Groundwater and Soil Sampling Equipment Decontamination* or if installing monitoring wells for per- and polyfluoroalkyl substances please refer to *TGI for Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide* for both sampling and decontamination guidance.
   c. A common sampling method that produces high-quality soil samples with relatively little soil disturbance is described in *ASTM D1586 – Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils* (ASTM D1586). Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary.
   d. Sonic drilling produces soil cores that, for the most part, are relatively undisturbed, but note that when drilling in consolidated or finer-grained sediment the vibratory action during core barrel advancement may create secondary fractures or breaks.
   e. Dual-rotary removes cuttings by compressed air or water/mud and allow only a general assessment of geology.
5. Describe each soil sample as outlined in *TGI for Soil Description* and document descriptions in the field notebook and/or field tablet or field forms and photo document the samples. It should be noted that electronic logs must be backed up and transferred to a location accessible to other project team members as soon as feasible to retain and protect the field data. During boring advancement, document all drilling events in field notebook or field forms, including blow counts (number of blows required to advance split-spoon sampler in 6-inch increments) and work stoppages. Blow counts will not be available if sonic, dual-rotary, or direct-push methods are used.
6. Before installing a screen, it is important to confirm that the borehole has been advanced into the targeted saturated zone. This is particularly important for wells installed to monitor the water table and/or the shallow saturated zone, as the capillary fringe may cause soils above the water table to appear saturated. If one or more previously installed monitoring wells exist nearby, use the depth to water at such well(s) to estimate the water-table depth at the new borehole location.

   NOTE: *To verify that the borehole has been advanced into the saturated zone, it is necessary to measure the water level in the borehole. For boreholes drilled without using water (e.g., hollow-stem auger, cable-tool, air rotary, air hammer), verify the presence of groundwater (and/or LNAPL, if applicable) in the borehole using an electronic water level meter, oil-water interface probe, or a new/decontaminated bailer. For boreholes drilled using water (e.g., drive and wash, spun-casing with roller-bit wash, sonic, or water rotary with core or roller bit), monitor the water level in the borehole as it re-equilibrates to the static level.*

   In low-permeability units like clay, fine-grained glacial tills, shale, and other bedrock formations, it may be necessary to wait overnight to allow the water level to equilibrate. Document depth to water in the borehole on the appropriate field forms and field notebook. If there are questions concerning the depth of the well/screen interval, consult with the project technical lead prior to finalizing well depth/screen interval. To the extent practicable, ensure that the depth of the well below the apparent water table is deep enough so that the installed well can monitor groundwater year-round, accounting for seasonal water-table fluctuations. When in doubt, err on the side of slightly deeper well installation.

7. Upon completing the borehole to the desired depth, if a screened well construction is required, install the monitoring well by lowering the screen and casing assembly through the augers or casing. Monitoring wells typically will be constructed of 2-inch-diameter (although sometimes 4-inch), flush-threaded PVC or stainless steel slotted or wire wrapped well screen and blank riser casing. Smaller diameters may be used if wells are installed using direct-push methodology or if multiple wells are to be installed in a single borehole, according to the well design as outlined in the FIP/Work Plan. The screen length and other construction details will be specified in the FIP/Work Plan based on regulatory requirements and specific monitoring objectives. Monitoring well screens are usually 5 to 10 feet long, but the screen length will depend on the purpose for the well and the objectives of the groundwater investigation and will (in most cases) be determined prior to the field mobilization.

   NOTE: *The slot size and filter pack gradation will be predetermined in the Work Plan (or equivalent) or FSP and based on site-specific grain-size analysis (sieve analysis) or other geologic considerations or monitoring objectives. Consult the Project Hydrogeologist and/or subject matter expert if there are questions/concerns regarding the filter pack and slot size specified. If the screen slot size and filter pack have not been based on site-specific grain-size analysis, consider collecting soil samples during well installation so future wells can be properly designed.*

   NOTE: *A blank sump may be attached below the well screen if the well is being installed for DNAPL recovery /monitoring purposes. If so, the annular space around the sump may be backfilled with filter pack during placement around the well screen.*

8. A blank riser will extend from the top of the screen to the level specified in the FIP/Work Plan (e.g., approximately 2.5 feet above grade if a stick up or just below grade where a flush-mounted monitoring well is specified).

   NOTE: *For wells greater than 50 feet deep, placement of centralizers may be desired to assist in centering the monitoring well in the borehole during installation. Refer to the FIP/Work Plan and/or consult with the Project Hydrogeologist/Technical Lead.*

9. When the monitoring well assembly has been set, using a tremie place the washed silica filter pack in the annular space from the bottom of the boring to a height above the top of the screen as specified in the FIP/Work Plan (typically placed to at least 2 feet above the top of the well screen). The filter pack will be placed, and drilling equipment extracted in increments until the top of the sand pack is at the appropriate depth.

   NOTE: *It is very important to verify that the expected volume of filter pack matches with the actual amount placed. There can be differences due to irregularities in the borehole geometry. Washout of the borehole will result in the need for greater than calculated well materials. If a difference of more than 10% is noted, consult with the Project Hydrogeologist/Technical Lead. The filter pack will be consistent with the screen slot size and the soil particle size in the screened interval, as specified in the FIP/Work Plan.*

10. After placement of the filter pack, preliminary well development is recommended be performed to ensure that the filter pack settles and does not bridge within the annular space and to remove any fines accumulated in the well during installation. This typically entails gently surging the entire well screen to prevent filter pack material bridging and to settle the filter pack prior to well seal installation. For recommended procedures, please refer to the *TGI for Monitoring Well Development*. Monitor the placement of the filter pack (e.g., with a weighted tape measure) and, as necessary during preliminary development (i.e., settlement), add filter pack to ensure proper thickness/height above screen is attained.

11. Depending on the project-specific requirements and applicable federal/state/local regulations, a well seal comprised of either fine sand or hydrated bentonite will then be placed in the annular space above the filter pack, typically at a minimum of 2 feet thick—follow the specifications outlined in the FIP/Work Plan). If non-hydrated bentonite is used, allow sufficient time for hydration to occur (typically a minimum of 30 minutes, but follow manufacturer's recommendations and/or specifications outlined in the FIP/Work Plan). Potable water may be added to hydrate the bentonite if the seal is above the water table. Monitor the placement of the fine sand/bentonite seal (e.g., with a weighted tape measure).

    NOTE: *Coated bentonite pellets are generally not recommended for monitoring well construction because of potential chemical incompatibilities between the coating material and groundwater chemistry.*

12. During the extraction of the augers or casing, a neat cement or cement/bentonite grout will be placed in the annular space from the well seal to a depth as specified in the FIP/Work Plan (e.g., approximately 2 ft. below groundwater surface). It is recommended that grout be placed with a tremie pipe. Ensure that seal materials are mixed at the proper ratios with water following manufacturer's recommendations.

    NOTE: *If it is necessary to install a monitor well into a permeable zone below a confining layer (i.e., confined conditions), particularly if the deeper zone is believed to have water quality that differs significantly from the zone above the confining layer, then a telescopic well construction may be considered.*

    In this case, the borehole is advanced approximately 3 to 5 feet into the top of the confining layer (depending upon the thickness of the confining layer), and a permanent casing (typically PVC or stainless steel) is installed into the socket drilled into the top of the confining layer.

    The casing is then grouted in place. The preferred methods of grouting telescoping casings include (1) pressure-injection grouting using an inflatable packer installed temporarily into the base of the casing, such that grout is injected out the bottom of the casing until it is observed at ground surface outside the casing; (2) displacement-method grouting (also known as the Halliburton method), which entails filling the casing with grout and displacing the grout out the bottom of the casing by pushing a drillable plug, typically made of wood to the bottom of the casing, following by tremie grouting the remainder of the annulus outside the casing; or (3) tremie grouting the annulus surrounding the casing using a tremie pipe installed to the base of the borehole.

    In all three cases, the casing is grouted to the ground surface, and the grout is allowed to set prior to drilling deeper through the casing. Refer to the FIP/Work Plan, Project Hydrogeologist, and/or subject matter expert for the completion of non-standard monitoring wells, including telescopic wells.

13. Install the monitoring well surface completion as specified in FIP/Work Plan. Typical completions are a locking, steel protective casing (extended at least 1.5 feet below grade and 2 feet above grade) over the riser casing and secure with a neat cement seal. Alternatively, for flush-mount completions, place a steel curb box with a bolt-down lid over the riser casing and secure with a neat cement seal. In either case, the cement seal will extend approximately 1.5 to 2.0 feet below grade and laterally at least 1 foot in all directions from the protective casing and will slope gently away from the casing to promote drainage away from the well.

14. When an above-grade completion is used, the riser will be sealed using an expandable locking plug and the top of the well will be vented by drilling a small-diameter (1/8 inch) hole near the top of the well casing or through the locking plug, or by cutting a vertical slot in the top of the well casing. When a flush-mount installation is used, the riser will be sealed using an unvented, expandable locking plug.

15. Monitoring wells will be labeled as specified in the FIP/Work Plan. If not specified, use indelible ink or paint with the appropriate designation on both the inner and outer well casings and/or inside of the curb box lid. If called for, mark a consistent measuring point by cutting a V in the PVC casing or marking the measuring point in black.
16. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 9 below.
17. After completing well installation, finalize documentation and follow data management procedures outlined in Section 10 below.
18. For final well development guidance and procedures, please refer to the *TGI for Monitoring Well Development.*

Direct-Push Method

The direct-push drilling method may also be used to complete soil borings and install monitoring wells. Examples of this technique include the Diedrich ESP vibratory probe system, GeoProbe®, or AMS Power Probe® dual-tube system. Environmental probe systems typically use a hydraulically operated percussion hammer. Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow and provides the force needed to penetrate very stiff to medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual-tube liner for sampling soil. The outside diameter (OD) of the outer casing ranges from 1.75 to 2.4 inches and the OD of the inner sampling tube ranges from 1.1 to 1.8 inches.

The outer casing isolates shallow layers and permits the unit to continue to probe at depth. The double-rod system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, the inside diameter (ID) of the steel casing provides clearance for the installation of small-diameter (e.g., 0.75- to 1-inch ID) micro-wells.

If direct-push drilling has been determined to be a viable method for site conditions and project objectives, procedures for installing monitoring wells in soil using the direct-push method are described below.

1. Locate boring/well location, establish work zone, and set up sample equipment decontamination area.
2. Advance soil boring to designated depth, collecting samples at intervals specified in the FIP/Work Plan. Samples will be collected using dedicated, disposable, plastic liners. Collect and describe samples in accordance with the procedures outlined in Steps 4 and 5 above. Collect samples for laboratory analysis as specified in the FIP/Work Plan.
3. Upon advancing the borehole to the desired depth, install the micro-well through the inner drill casing. The micro-well will consist of approximately 1-inch ID PVC or stainless-steel slotted screen and blank riser. The filter pack, well seal, and neat cement/cement-bentonite grout will be installed as described, where applicable, in Steps 9 through 12 above.
4. Install surface completion (protective steel casing or flush-mount), as appropriate and as described in Steps 13 through 15 above.
5. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section 9 below.
6. After completing well installation, finalize documentation and follow data management procedures outlined in Section 10 below.

Driven Well Point Installation

If specified in the FIP/Work Plan, well points installed by pushing or driving using a drilling rig or direct-push rig (or hand-driven where possible) will typically consist of a 1- to 2-inch-diameter threaded steel casing with either 0.010- or 0.020-inch slotted stainless-steel screen. The screen length will vary depending on the hydrogeologic conditions of the site. The casings will be joined together with threaded couplings and the terminal end will consist of a steel well point. Because they are driven or pushed to the desired depth, well points do not have annular backfill materials such as sand pack or grout. Refer to the FIP/Work Plan and/or consult with the Project Hydrogeologist/Technical Lead and/or subject matter expert for specific guidance on drive point installation procedures/specifications.

9 Waste Management

IDW, including soil cuttings and excess drilling fluids (if used), decontamination liquids, and disposable materials (well material packages, PPE, etc.), will be placed in clearly labeled, appropriate containers, or managed as otherwise specified in the Work Plan (or equivalent), FSP, and/or IDW management guidance document.

Investigative-Derived Waste (IDW) generated during drilling activities, including soil and excess drilling fluids (if used), and decontamination liquids, will be stored on site in appropriately labeled containers and disposed of properly. Disposable materials will be stored and disposed of separately. Containers must be labeled at the time of collection and will include date, location(s), site name, city, state, and description of matrix contained (e.g., soil, PPE).

Waste will be managed in accordance with the *TGI for Investigation-Derived Waste Handling and Storage,* the procedures identified in the FIP/work plan or QAPP as well as state-, federal- or client-specific requirements. Be certain that waste containers are properly labeled and documented in the field log.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

If not using FieldNow®, all well drilling/installations activities will be documented on appropriate field/log forms as well as in a proper field notebook and/or Personal Digital Assistant (PDA) and/or tablet. All field data will be recorded digitally or with indelible ink. Field forms, logs/notes (including daily field and calibration logs), digital records, and chain-of-custody records will be maintained by the field team lead. Any deviations or omissions from this TGI will be documented.

Additionally, all documents (and photographs) should be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of well installation activities, soil descriptions, well construction specifications (screen and riser material and diameter, sump length, screen length and slot size, riser length, filter pack type and volume, type of well seal (fine sand or bentonite seal) and volume, type and volume of grout (neat cement or cement-bentonite), and other materials used.

Management of the original documents from the field will be completed in accordance with the site-specific QAPP. Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

Initial field logs and forms will be transmitted to the Arcadis CPM and/or Technical Lead at the end of each day unless otherwise directed by the CPM. The field team leader retains copies of the field documentation.

Locations of newly installed wells will be documented photographically and/or on a site sketch. If appropriate, a measuring wheel, engineer's tape, or handheld GPS will be used to determine approximate distances from key site features or estimated coordinates.

The well location, ground surface elevation, and inner and outer casing elevations will be surveyed using the method specified in the FIP/Work Plan. Generally, a local baseline control will be set up. This local baseline control can then be tied into the appropriate vertical and horizontal datum, such as the National Geodetic Vertical Datum (NGVD)of 1929 or North American Vertical Datum (NAVD) of 1988 and the State Plane Coordinate System. At a minimum, the elevation of the top of the inner casing used for water-level measurements should be measured to the nearest 0.01 foot. Elevations will be established in relation to the NGVD of 1929 or the NAVD of 1988. A permanent mark will be placed on top of the inner casing to mark the point for water-level measurements.

11 Quality Assurance

Quality assurance procedures will be conducted in accordance with the Arcadis Quality Management System or the site-specific QAPP. Refer to the QAPP or FIP/sampling plan/work plan for specific requirements.

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the appropriate TGI. All well construction materials will be inspected and cleaned (as necessary) prior to well installation.

Field-derived quality assurance blanks will be collected as specified in the FIP/work plan and/or site- specific QAPP, depending on the project quality objectives. Typically, field rinse blanks (equipment blanks) will be collected when non-dedicated equipment (e.g., split-spoon sampler, stainless steel spoon) is used during soil sampling. Field rinse blanks will be used to confirm that decontamination procedures are sufficient and samples are representative of site conditions. Trip blanks for VOCs, which aid in the detection of contaminants from other media, sources, or the container itself, will be kept with the coolers and the sample containers throughout the sampling activities and during transport to the laboratory.

Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures. Calibrate instruments at the beginning of each day and verify the calibration at the end of each day. Record all calibration activities in the field notebook.

12 References

American Society for Testing Materials (ASTM) D5092 - *Standard Practice for Design and Installation of Ground Water Monitoring Wells*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

American Society of Testing and Materials (ASTM) D1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

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TGI – Monitoring Well Development

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	1	4/12/2022	All	Updated to new format and some minor content changes	Marc Killingstad

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Prepared by:		4/12/2022
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Reviewed by:		4/12/2022
	Marc Killingstad (Subject Matter Expert)	Date

1 Introduction

This Technical Guidance Instruction (TGI) covers the development of screened wells used for obtaining representative groundwater information and samples from granular aquifers (i.e., monitoring wells).

Note: This TGI only applies to monitoring well development and not remediation (injection/extraction) well development.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

The objectives of monitoring well development are:

1. Repair damage to the borehole wall from drilling that can include clogging, smearing or compaction of aquifer materials;
2. Remove fine-grained sediment from the formation and filter pack that may result in high turbidity levels in groundwater samples;
3. To re-sort formation and filter pack material adjacent to the well screen;

4. To recover any drilling fluids (if used) that may affect the permeability of the formation and filter pack or alter the water quality around the well; and
5. To optimize the well efficiency and hydraulic communication between the well screen and the formation.

Successful monitoring well development is dependent on the following:

1. Hydrostratigraphy – Permeable formations containing primarily sand and gravel are more easily developed due to lower percentages of silt and clay material. Water in permeable formations can be moved in and out of the screen and/or through the formation easier than in less permeable deposits.
2. Well Diameter – Development tooling including brushes, surge blocks, pumps and jetting tools are more readily available for wells 4 inches in diameter and greater.
3. Well Design – Wells with filter packs and screens designed to match the formation through the analysis of formation sieve samples are easier to develop. An important aspect to well design is to minimize the size of the annular space between the formation and well screen. Adequate room must be allowed for the proper installation of well materials, but not too large as to prevent/reduce communication with the surrounding formation.
4. Drilling Methods – Different drilling methods result in varying amount of borehole damage and, therefore, impact the degree to which development will be successful.

Well development methods for monitoring wells include the following:

1. Bailing – Use of a bailer to remove water and sediment from the well casing. This technique does little to remove fines from the filter pack and may lead to bridging of sediment since the flow is in only one direction, toward the well screen. The most effective use of bailing during monitoring well development is in conjunction with other methods (e.g., surging/swabbing) to remove fines accumulated in the monitoring well between cycles of other development methods.
2. Pumping/over pumping – Use of a pump to remove water and sediment from the well casing, over pumping involves pumping the well at a rate that exceeds the design capacity of the well. Similar to bailing, this technique does little to remove fines from the filter pack and may lead to bridging of sediment since the flow is in only one direction, toward the well screen. Small diameter monitoring wells have the additional constraint on pump size and flow rates which further limit the effectiveness of this methodology.
3. Backwashing (rawhiding) – Consists of starting and stopping a pump intermittently to produce rapid pressure changes in a well. This method can produce better results than pumping alone since the procedure involves movement of the water in and out of the screen and formation. However, in many cases the surging action is not rigorous enough to fully develop the well and might be considered the final phase of development after a more rigorous method has been used. Again, small diameter monitoring wells have the additional constraint on pump size and flow rates which further limit the effectiveness of this methodology.
4. Surging/swabbing – Use of a mechanical surge block or swabbing tool to operate like a piston with an up and down motion. The downstroke causes a backwash action that breaks up bridged sediment and the upstroke pulls the dislodged sediment into the well. This method works well for both small and large diameter monitoring wells. Care should be taken on the downstroke so as not to force fines back into the formation, frequent pumping/purging during surging help to keep fines out of the well. Double surge blocks are recommended, and this is typically the most effective method for development of monitoring wells.

5. Jetting – Use of a tool fitted with nozzles that direct streams of water horizontally into well screens at high velocity. Due to the size of the tooling, this method is better suited for wells 4 inches in diameter and larger. The method is also more effective with wire-wrapped/continuous slot screens due to the increased open area. Jetting requires specialized equipment and concurrent pumping to prevent reintroducing fines into the filter pack. Additionally, depending on the configuration of the tool, jetting may require subsequent surging/pumping to remove fines dislodged in the filter pack and formation. Typically, jetting is not a preferred option for new well development but may be effective as part of a re-development/rehabilitation effort.

For most situations, surging/swabbing coupled with bailing or pumping to remove dislodged materials is recommended.

Final well development for properly designed and constructed monitoring wells may begin after the annular seal materials have been installed and allowed to cure, since these wells are designed to retain approximately 90% of the filter pack material. This cure time is typically at least 24 to 48 hours after the sealing materials have been installed.

This TGI is meant to provide a general guide for proper development of newly installed monitoring wells.

A site-specific field implementation plan (FIP) for well installation and development detailing the specific methods and tools is strongly recommended to provide site-specific instruction and guidance.

4 Personnel Qualifications

Generally, Arcadis field personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, and/or state/federal regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The HASP and other documents will identify other training requirements and access control requirements.

The designated Field Manager is responsible for periodic observation of field activities and review of field generated documentation associated with this TGI. The Field Manager is also responsible for implementation of corrective action if problems occur (e.g., retraining personnel, additional review of work plans and TGIs, variances to QC sampling requirements, issuing non-conformances, etc.).

Prior to mobilizing to the field, personnel will review and be thoroughly familiar with relevant site-specific documents including but not limited to the task-specific work plan or field implementation plan (FIP)/field sampling plan/work plan, Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Field personnel assigned to install and develop monitoring wells are responsible for completing their tasks in accordance with the specifications outlined in this TGI and other appropriate and relevant guidelines.

Monitoring well development activities will be performed by persons who have been trained in proper well development procedures under the guidance of an experienced field geologist, engineer, or technician.

5 Equipment List

Required equipment depends on the selected method and should be detailed in the site-specific FIP; however, the following are typically required.

- Approved site-specific Health and Safety Plan (HASP)
- Approved site-specific FIP which will include site map, well construction information/borehole information, and development plan
- Personal protective equipment (PPE) and health and safety equipment, as required by the HASP
- Field notebook and/or smart device (phone or tablet)
- Cleaning/decontamination equipment
    - Non-phosphate laboratory soap (Alconox or equivalent), brushes, clean buckets or clean wash tubs—new buckets or tubs will be purchased if it cannot be determined if the presentitems are clean
    - Distilled or de-ionized water for equipment decontamination
- Monitoring well keys
- Water-level meter
- Down-hole multiparameter water quality sonde (e.g., YSI)
- Plastic sheeting (e.g., Weatherall Visqueen) to protect all down-hole sampling equipment fromcontact with potential sources of contamination
- Well development forms/logs
- Well construction logs/diagrams
- Weighted tape (of sufficient length for maximum site depth)
- Turbidity meter
- Camera
- Watch/timing device

6 Cautions

Different USEPA regions and/or state regulatory agencies may stipulate deviations from this document. It is the responsibility of the Project Team (Project Manager and Technical Lead) to be fully aware of the requirements from the applicable regulatory framework.

Prior to beginning field work, the project technical team will ensure that all field logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.) and task objectives are clearly understood by all team members. An internal call with the project technical team to review the FIP/field sampling plan/work plan scope and objectives is strongly recommended prior to mobilization to ensure that the field work will be effectively and efficiently executed.

Where surging is performed to assist in removing fine-grained material from the sand pack, surging must be performed in a gentle manner. Excessive suction could promote fine-grained sediment entry into the outside of the sand pack from the formation.

Avoid using development fluids or materials that could impact groundwater or soil quality or could be incompatible with the subsurface conditions.

In some cases, it may be necessary to add potable water to a well to allow surging and development, especially for new monitoring wells installed in low permeability formations. Before adding potable water to a well, the Certified Project Manager (CPM) and/or Project Hydrogeologist must be notified, and the CPM shall make the decision regarding the appropriateness and applicability of adding potable water to a well during well development procedures. If potable water is to be added to a well as part of development, the potable water source should be sampled and analyzed for constituents of concern, and the results evaluated by the CPM prior to adding the potable water to the well. If potable water is added to a well for development purposes, at the end of development the well will be purged dry to remove the potable water, or if the well no longer goes dry then the well will be purged to remove at least three times the volume of potable water that was added

7 Health and Safety Considerations

Field activities associated with monitoring well development will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

Appropriate PPE will be worn at all times in line with the task and the site-specific HASP.

Review all site-specific and procedural hazards as they are provided in the HASP, and review Job Safety Analysis (JSA) documents in the field each day prior to beginning work.

Access to well locations may expose field personnel to hazardous materials such as contaminated groundwater or NAPL (e.g., petroleum hydrocarbons, chlorinated solvents). Other potential hazards include pressurized wells, stinging insects that may inhabit well heads, other biological hazards (e.g., ticks in long grass/weeds around wellhead), and potentially the use of sharp cutting tools (scissors, knife). Open well caps slowly and keep face and body away while allowing to vent any built-up pressure to vent. Only use non-toxic peppermint oil spray for stinging insect nests. Review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives and use appropriate hand protection.

Do not enter confined spaces unless following appropriate confined space entry procedures specified in the HASP.

If thunder or lightning is present, discontinue sampling until 30 minutes have passed after the last occurrence of thunder or lightning.

8 Procedure

As indicated above, for most monitoring wells, gentle surging coupled with bailing or pumping to remove dislodged sediment is recommended.

8.1 Preliminary Well Development

After installation of the primary filter pack around the monitoring well screen, preliminary well development is recommended be performed to ensure that the filter pack settles and does not bridge within the annular space. The preliminary well development steps are as follows:

1. Measure and record depth to water, total depth of well, and depth to top of the sand pack in the annulus.
2. Use steel or weighted bailer to remove any fines that have accumulated in the bottom of the well.
3. Lower an appropriately sized double-surge block into the screened portion of the well on a rigid pipe or high-density tubing and gently cycle up and down to force water in and out of the screen slots and formation. A two-foot throw is recommended (use tape or chalk marks on the pipe or tubing); however, the entire length of well screen must be gently surged.
4. Start above the screen and gently surge over two-foot intervals while working down to the screen bottom.

NOTE: Care must be taken not to surge the well too aggressively at this point as the casing is not well-supported and damage could occur. The objective is to create enough surging action to settle the primary filter pack and provide some preliminary removal of accumulated materials before final development.

NOTE: If possible, ensure that the developer surges the block upward faster than downward to pull the fines out of the filter pack, instead of forcing them back in (and allowing for proper settlement).

5. Monitor the total depth of the well periodically during surging to ensure that we are not pulling excessive amounts of filter pack through the screen and remove any debris accumulated in the well with a weighted bailer or pump.
6. Re-measure the top of the sand in the annulus to see if more sand pack is necessary. Remove any fines that have accumulated out of the well using a submersible pump or weighted bailer.

NOTE: If the monitoring well was drilled using mud rotary drilling methodology or if significant fines were encountered during the well installation, consider adding a commercially available 'mud' dispersant (e.g., AQUA-CLEAR PFD, Nu Well 220, etc.) as part of the preliminary development. This will help to break up the 'skin' along the borehole wall created by either the drilling fluid or smearing during drilling and assist in final development. Follow manufacturer's directions for dosing, and the mixture should be worked through the entire saturated screen interval by gently surging or brushing.

8.2 Final Well Development

After sufficient time has passed to allow for proper curing of the well seal/grout (i.e., 24 to 48 hours), final well development can be performed. Final well development steps are as follows:

1. Don appropriate PPE (as required by the site-specific HASP).
2. Place plastic sheeting around the well.
3. Clean all equipment entering each monitoring well, except for new, disposable materials that have not been previously used.
4. Open the well cover while standing upwind of the well, remove well cap. Insert PID probe approximately 4 to 6 inches into the casing or the well headspace and cover with gloved hand. Record the PID reading in

the field notebook. If the well headspace reading is less than 5 PID units, proceed; if the headspace reading is greater than 5 PID units, screen the air within the breathing zone. If the PID reading in the breathing zone is below 5 PID units, proceed. If the PID reading is above 5 PID units, move upwind from well for 5 minutes to allow the volatiles to dissipate. Repeat the breathing zone test. If the reading is still above 5 PID units, don the appropriate respiratory protection in accordance with the requirements of the HASP. Record all PID readings.

5. Obtain an initial measurement of the depth to water and the total well depth from the reference point at the top of the well casing. Record these measurements in the field logbook. It is recommended to use a weighted tape for the total well depth measurement.
6. The depth to the bottom of the well should be sounded and then compared to the completion form or construction diagram for the well. Any discrepancies should be reported immediately to the CPM and/or Project Hydrogeologist. If sand or sediment is present inside the well, it should first be removed by bailing. Do not insert bailers, pumps, or surge blocks into the well if obstructions, parting of the casing, or other damage to the well is suspected. Instead report the conditions to the CPM and/or Project Hydrogeologist and obtain approval to continue or cease well development activities.

NOTE: If the monitoring well was drilled using mud rotary drilling methodology or if significant fines were encountered during the well installation, it is recommended that a commercially available 'mud' dispersant (e.g., AQUA-CLEAR PFD, Nu Well 220, etc.) be included as part of the final well development to effectively break up the 'skin' along the borehole wall created by either the drilling fluid or smearing during drilling.

Per manufacturer's instructions, the general procedure for adding dispersant is as follows:

   i. *Determine volume of water in screen area and double the calculated volume to account for water in gravel pack and formation interface*
   ii. *Once the water volume is determined, calculate the required treatment volume of dispersant need per manufacturer's recommendations*
   iii. *Mix thoroughly before introducing into well*
   iv. *The preferable application method utilizes a tremie line with the product applied into the screened area*
   v. *Mixture should be thoroughly blended in well, then agitated via surging/swabbing/brushing repeatedly (e.g., every two hours) for a period of up to 24 hours*
   vi. *The dispersant should sit for at least 6 to 8 hours or overnight before continuing well development activities*

7. After allowing the dispersant to sit for the required time (if dispersant is used), start the mechanical development by lowering an appropriately sized double-surge block (or similar) into the well on a rigid pipe or high-density tubing.
   i. Surging should start above the screen to reduce the possibility of "sand-locking" the surge block. Initial surging should be with a long stroke and at a slow rate (20 to 25 strokes per minute)
   ii. After surging above the screen, the well should be cleaned via bottom-loading bailer, submersible pump, or inertia pump tubing with check valve to the bottom of the well

   iii. Begin surging at the lower end of the screen, gradually working upward, surging in 2-ft intervals until the entire screen has been developed.
   iv. Surge the well a minimum of 10 throws per 2-ft screen interval.
   v. Each interval may require several surge cycles to achieve the best development.
   vi. The entire length of well screen must be surged.
   vii. Ensure that the developer surges the block upward faster than downward to pull the fines out of the filter pack, instead of forcing them back in (and allowing for proper settlement)
   viii. measure total depth of the well periodically during surging to ensure that excessive amounts of sediment are not being pulled through the screen. Remove any debris accumulated in the well via simultaneous airlifting (if a combined tool is available) or with bailing/pumping.

8. After completing a cycle of surging, lower a bottom-loading bailer, submersible pump, or inertia pump tubing with check valve to the bottom of the well and gently bounce on the bottom of the well to collect/remove accumulated sediment, if any. Remove and empty the bailer, if used. Repeat until the bailed/pumped water is free of excessive sediment and contact at the bottom of the well feels solid. Alternatively, measurement of the well depth with a weighted tape can be used to verify that sediment and/or silt has been removed to the extent practicable, based on a comparison with the well installation log or previous measurement of total well depth.
9. After surging the well for a minimum of two cycles and removing excess accumulated sediment from the bottom of the well, re-measure the depth-to-water and the total well depth from the reference point at the top of the well casing. Record these measurements in the field log book.
10. Remove formation water by pumping/bailing.
   i. Where pumping is used, measure and record the pre-pumping water level.
   ii. Operate the pump at a relatively constant rate
   iii. Measure the pumping rate using a calibrated container and stopwatch, and record the pumping rate in the field log book
   iv. Measure and record the water level in the well at least once every 5 minutes during pumping
   v. Record any relevant observations in terms of color, visual level of turbidity, sheen, odors, etc.
   vi. Pump or bail until termination criteria specified in the site-specific FIP are reached
   vii. Record the total volume of water purged from the well

NOTE: The FIP may also specify a maximum turbidity requirement for completion of development. Unless otherwise specified the maximum turbidity should be 50 NTUs or less

11. While developing, take periodic water level measurements (at least one every five minutes) to determine if drawdown is occurring and record the measurements on the Well Development Log.
12. While developing, calculate the rate at which water is being removed from the well. Record the volume on the Well Development Log.
13. While developing, water is also periodically collected directly from the well or bailer discharge and readings taken of the indicator parameters: pH, specific conductance, and temperature. Development is

considered complete when the indicator parameters have stabilized (i.e., three consecutive pH, specific conductance, and temperature readings are within tolerances specified in the project work plans or within 10% if not otherwise specified), the extracted water is clear and free of fine sediment and most importantly, when acceptable volume of water has been removed and/or a sufficient amount of surging has been performed.

14. In certain instances, for slow recharging wells, the parameters may not stabilize. In this case, well development is considered complete when minimal amounts of fine-grained sediments are recovered, and an acceptable volume of water has been removed.
15. If the well goes dry, stop pumping or bailing. Note the time that the well went dry. After allowing the well to recover, note the time and depth to water. Resume pumping or bailing when sufficient water has recharged the well.
16. Contain all development water in appropriate containers.
17. When complete, secure the lid back on the well.
18. Place disposable materials in plastic bags for appropriate disposal and decontaminate reusable, downhole pump components and/or bailer

9 Waste Management

Investigation-Derived Waste (IDW), including purge water and decontamination liquids, will be stored on site in appropriately labeled containers and disposed of properly. Disposable materials will be stored and disposed of separately. Containers must be labeled at the time of collection and will include date, location(s), site name, city, state, and description of matrix contained (e.g., water, PPE). Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage*, the procedures identified in the FIP/field sampling plan/work plan or QAPP as well as state-, federal- or client-specific requirements. Be certain that waste containers are properly labeled and documented in the field log.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

All well development activities will be documented on appropriate log forms as well as in a proper field notebook and/or PDA. Additionally, all documents (and photographs) should be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site; times of arrival and departure; significant weather conditions; timing of well development activities; development method(s); observations of purge water color, turbidity, odor, sheen, etc.; purge rate; and water levels before, during, and after pumping.

Management of the original documents from the field will be completed in accordance with the site-specific QAPP. Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

Development activities will be documented on appropriate field logs as well as in a proper field notebook. All field data will be recorded digitally or with indelible ink. Field forms, logs/notes (including daily field and calibration logs), digital records, and chain-of-custody records will be maintained by the field team lead. Any deviations or omissions from this TGI should be documented.

Initial field logs and forms will be transmitted to the Arcadis CPM and/or Technical Lead at the end of each day unless otherwise directed by the CPM. The field team leader retains copies of the field documentation.

11 Quality Assurance

Quality assurance procedures will be conducted in accordance with the Arcadis Quality ManagementSystem or the site-specific QAPP. Refer to the QAPP or FIP/sampling plan/work plan for specific requirements.

12 References

American Society for Testing Materials (ASTM), Designation D5521-05. *Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers*. American Society for Testing Materials. West Conshohocken, Pennsylvania.

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TGI - Manual Water-Level and NAPL Monitoring

Rev: 2

Rev Date: April 5, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
0	0	October 11, 2018	All	Updated and re-written as TGI	Marc Killingstad Everett H. Fortner III
1	1	May 8, 2020	All	Updated and added NAPL gauging	Marc Killingstad Everett H. Fortner III Andy Pennington
2	2	April 5, 2022	All	Formatting and Revisions	Martha Wulftange

Approval Signatures

Prepared by: 4/5/2022

Everett H. Fortner III, PG (Preparer) Date

Reviewed by: 4/5/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This TGI describes the equipment, field procedures, materials, and documentation procedures to measure and record water-levels using an electronic water-level probe or an oil-water level indicator. This TGI also describes procedures for measuring in-well thicknesses of non-aqueous phase liquid (NAPL), both light and/or dense (LNAPLs and DNAPLs, respectively).

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

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3 Scope and Application

The objective of this Technical Guidance Instruction (TGI) is to describe procedures to measure and record water-levels (groundwater and surface-water) using manual water-level meters. Water levels may be measured using an electronic water-level probe or an oil-water level indicator from established reference points (e.g., top of casing). Reference points must be surveyed to evaluate fluid level elevations relative to a vertical datum (e.g., North America Vertical Datum of 1988 [NAVD88] relative to sea level). This TGI also describes procedures for measuring in well thickness of NAPL and DNAPLs.

Surface water-levels can be measured from stilling wells or fixed points (bridges, walls, etc.) and measuring from an established point of reference using a water-level meter. In some cases, surface water water-levels may be determined from a graduated stream gauge, attached to a pole located in open water with known elevation, without the use of a water-level meter.

The use of pressure transducers or other automated devices for the collection of groundwater elevation data will be subject of *TGI – Water-Level Monitoring using Pressure Transducers and TGI – Water-Level Measurements using Sonic Meters.*

4 Personnel Qualifications

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The HASP and other documents will identify other training requirements or access control requirements.

5 Equipment List

The following field equipment is suggested for water-level measurements:

- Site-specific Health and Safety Plan (HASP)
- Appropriate personal protective equipment (PPE) as specified in the HASP
- Electronic water-level indicator graduated in 0.01 ft. increments
- Electronic oil-water (interface) level indicator graduated in 0.01 ft. increments, if necessary
- Non-phosphate laboratory soap (Alconox or equivalent), brushes, clean buckets or clean wash tubs.
- Distilled or de-ionized (required for some sites) water for equipment decontamination
- Photoionization detector (PID) and/or organic vapor analyzer (optional)
- 150-foot measuring tape (or sufficient length for the maximum site depth requirement) – if required for total depth measurements of deeper wells
- Solvent (methanol/acetone/isopropyl alcohol) rinse – optional
- Spray bottle for solvent - optional
- Plastic drop cloth (e.g. Weatherall Visqueen) to place beneath the buckets or tubs to reduce potential for contamination of the tape or probe
- Tools and/or keys required for opening wells
- Well construction summary table and/or well construction logs
- Summary table of previous water-level measurements
- Field notebook and/or smart device (phone or tablet) or appropriate field forms (see Attachment 1).
- Indelible ink pen

6 Cautions

Electronic water-level indicators and oil-water interface probes may sometimes produce false-positive readings. For example, if the inside casing surface of the well or stilling tube has condensation above the water level, then an electronic water-level probe may produce a signal by contacting the sidewall of the well, rather than the true water-level surface. For accuracy, the electronic water-level probe and/or interface probe should be raised and lowered several times at the approximate depth where the instrument produces a tone indicating a fluid interface to verify consistent, repeatable results (three or more times). Additionally, some wells may be constructed with a sump. If local/regional groundwater levels have declined such that the water-level is below the base of the well screen, a sump may still contain water and provide an erroneous measurement. Therefore, possessing and comparing measurements with a well construction summary table or well construction log is recommended for proper reporting.

If the presence of a NAPL is known or suspected within specific wells, do not use an electronic water- level indicator. Use an oil-water interface probe instead. If NAPL presents ignition or explosion hazards, an intrinsically safe oil-water interface probe is required to be used with grounding and following the manufacturer’s instructions.

If the NAPL is known to be very viscous or problematic to gauge, the data quality will require additional consideration prior to measuring. Staff will consider the data quality objectives for the gauging activity – e.g., if quantifying NAPL thickness is necessary, or if assessing the presence/absence is sufficient.

Alternate NAPL measurement methods (such as using drop pipes or temporary coatings for down-well equipment) may be considered.

When measuring total well depths with an electronic water-level indicator, the measurement must have a correction factor applied for post processing or completed at the time of measurement that is equal to the length of the probe beneath the circuit closing electrodes (if applicable to the instrument). This is necessary because the tape distance markings are referenced to the electrode, rather than the end of the probe. Some newer instruments do not have an offset electrode and this correction factor is needed. In addition, total depth measurements are difficult with wells that have large water columns due to buoyancy issues. In addition, the total depth measurement will include notes that indicate a soft or hard bottom if recognized during the measurement.

Ensure that the type of electronic water-level indicator is compatible with the depth and diameter of the wells to be measured. Some smaller piezometers or larger diameter well stilling tubes will accommodate only smaller diameter probes.

7 Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Access to wells may expose field personnel to hazardous materials such as contaminated groundwater or oil. Other potential hazards include pressurized wells, stinging insects that may inhabit well heads, other biologic hazards (e.g. ticks in long grass/weeds around well head), and potentially the use of sharp cutting tools (scissors, knife). Appropriate personal protective equipment (PPE) will be worn during these activities. Only use non-toxic peppermint oil spray for stinging insect nests. Open well caps slowly and keep face and body away to allow to vent any built-up pressure. Field personnel will thoroughly review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives.

Obtaining measurements from active pumping wells requires knowledge of the construction and design, as the indicator probe and tape can become intertwined within down-well equipment (such as pump impellers) causing a serious health and safety hazard and equipment damage. Ensure that stilling wells have a perforated end and capped bottom to inhibit tape from extending into the downhole pump depth. If a stilling tube is not present or the still tube construction is not known, determine a conservative “not to exceed” measurement depth based on the top of pump depth with an added safety factor. If all information is not known, a water-level will not be taken from the pumping well until clarification on depths are available.

8 Procedure

Calibration procedures and groundwater level measurement procedures for electronic water-level indicators and oil-water indicators are described in the sections below. Calibration documentation can berequested from the rental or manufacturer.

Calibration Procedures

If the indicator requires length and markings verification is required by project data quality plan or other reasons, then the following steps may be used:

- Measure the lengths between each increment marker on the indicator with a measuring tape. The appropriate length of indicator measuring tape, suitable to cover the depth range for the wells of interest, will be checked for accuracy.
- If the indicator measuring tape is inaccurate, the probe will require to be sent back to the manufacturer or rental company. If a replacement can’t immediately be available, then an offset can be measured to correct the measurements.
- If multiple water-level indicators and/or oil-water interface probes are being used for an event, calibration of the multiple devices will be required by measuring a water-level at a single well contemporaneously with all indicators to be used and calculated correction factors provided for data processing (typical corrections are small and range from 0.01 to 0.03 foot).
- Equipment calibration will be recorded in the field logbook and/or smart device.

Water-Level Measurement Procedures

The general procedures to be followed for the collection of fluid level measurements and well depths from the monitoring wells are as follows:

- Check that the water-level/oil-water level indicator battery is functional, before mobilization and prior to each work day (e.g., turn power on and check that meter sounds when probe is lowered into a bucket of water – note that water-level meters will not work with low-electrical-conductivity liquids such as distilled water).
- Record instrument make, model, serial number, and (if present) Arcadis ID number in the field form or electronic field form.
- Don disposable nitrile gloves. Decontaminate the water-level/oil-water indicator, any attached tape and the spool with laboratory-grade soap and distilled water (see Initial Decontamination Procedures below). The spool requires caution with cleaning as it is not water-proof and can be damaged during cleaning.

- The top of the monitoring well will be cleaned with a clean rag to prevent loose particulate matter from falling into the well.
- Perform a well inspection (note that a well inspection form may be required to be filled out along with a photo to document the conditions).
- Place clean plastic sheeting on the ground next to the well.
- Unlock and/or open the monitoring well cover while standing upwind from the well (note that some wells may be under pressure and precaution should be taken with opening well caps – see Section 6).
- Measure the volatile organics present in the monitoring well head space with a PID and record the PID reading (if applicable and requirement for the site).
- Allow the water-level in the well to equilibrate with atmospheric pressure for a few minutes (check previous field forms or field books for equilibration time, if noted).
- Locate the measuring reference point that correlates to the survey point on the well casing. If one is not found, make a reference point by notching the highest and/or north point on the inner casing (or outer if an inner casing is not present) or mark with a permanent mark. All downhole measurements will be taken from the reference point. Document any changes or new reference point addition.
- Measure to the nearest 0.01 foot and record the height of the inner well casing and outer protective casing to ground level (note that some well pads are raised and are not at true ground surface).
- Lower the indicator probe into the center of the well until contact with the water surface is indicated by either an audible alarm or light. The sensitivity of the probe may need adjustment if the alarm or light is not strong signal. Use and install a tape guide (available from some manufacturers) to help with accuracy and provide protection with damaging the measurement tape. If a tape guide is not available, make sure that the tape does rub on the inner or outer casing which could fray and damage the tape.
- If an oil-water interface probe is being used to measure depth and thickness of NAPL, lower the interface probe into the center of the well until a contact with the NAPL surface is indicated by either audible alarm or light. The sensitivity of the probe may need adjustment if the alarm or light is not strong signal. To gauge the water level in a well which contains LNAPL (LNAPL-water interface), advance the interface probe past the LNAPL-water interface until the probe produces a solid audible alarm indicating water. While slowly retrieving the probe upward, the equipment will produce a different tone when the LNAPL-water interface is reached (typically this is a multiple alarm sound or flashing light). This level should represent the depth to water. The depth indicating the bottom of the water column and top of DNAPL layer, if any, is indicated by the multiple alarm signal or flashing light emitted by the interface probe.
- Hold the tape at the measuring point and repeat the measurement two more times.
- Read and record measurement to the nearest 0.01 foot. Check the measurement with previous measurements, if available, and note any anomalies/discrepancies; if significant, contact the project staff.

- Measure and record total depth of well (see Total Depth Measurement Procedures below); note that measurement of total depth is not always performed at wells containing LNAPL or DNAPL, in order to reduce decontamination of the instrument and reduce potential exposure to NAPL.
- Record all measurements (with date and time collected to the nearest minute) and note any inconsistencies/anomalies and relevant observations in the field notebook and/or smart device or appropriate field forms.
- Follow decontamination procedure outlined below before measuring subsequent wells (see
- Decontamina*tion after Water Level and Total Depth Measurements* below).
- Replace cap and lock the well when all activities are completed.

Total Depth Measurement Procedures

- Weighted tape or electronic water-level indicator can be used to measure the total well depth.
- Follow initial procedures noted above in Water-Level Measurements above.
- Lower indicator probe (or tape) until weighted end is resting on the bottom of the well. Raise indicator slowly until there is no slack in the tape. Gently estimate the bottom of the well by slowly raising and lowering the indicator: great care should be taken to avoid damaging the sensor on the probe. The operator may find it easier to allow the weight to touch bottom and then detect the 'tug' on the tape while lifting the weight off the well bottom.
- Because of tape buoyancy and weight effects encountered in deep wells with long water columns, it may be difficult to determine when the probe is in contact the bottom of the well and sediment in the bottom of the well can also make it difficult to determine total depth. Care must be taken in these situations to ensure accurate measurements.
- If total depth measurements are to be collected during low-flow sampling events, the measurement will be made only after low-flow sampling has been completed or at least 12 hours prior to initiating sample collection from the well, in order to minimize: 1) mixing of the stagnant water at the top of the well column with potential formation water underneath; and/or 2) agitation and subsequent entrainment of possible sediment collected at the well bottom).
- Read and record measurement to the nearest 0.1 foot. Please refer to the note regarding total depth measurements described in Section 5 Cautions above.
- Follow decontamination procedure outlined below before gauging the next well (see Decontaminationafter *Water Level, NAPL Level, and Total Depth Measurements* below).

Initial Decontamination

- Note that there may be project specific decontamination procedure documents that will be followed in lieu of the below procedures.
- Set up a decontamination station consisting of three clean buckets (e.g., 5-gallon buckets). The buckets should not be used to containerize purge water; they will be used for decontamination purposes only.
- Fill the first bucket with one gallon of distilled water (use deionized water if metals are a contaminant at the site) and add non-phosphate laboratory-grade soap. Fill the second bucket

with distilled water (use deionized water if metals are a contaminant at the site) and leave the third bucket empty. Place the drop cloth underneath.

- Unwind the entire tape from the spool into a bucket with non-phosphate laboratory-grade soap and distilled water; Brush the tape carefully to remove dirt and possible contamination, using a brush dedicated to the wash bucket.
- Carefully brush all dirt of the spool and wipe down with a soapy cloth or paper towel.
- Transfer the tape into the second bucket containing rinse water. Carefully brush the tape using a second brush, dedicated to the rinse bucket. Lift the tape out of the bucket and allow rinse water to drip off the tape.
- Transfer the tape to the third bucket. Wind the tape onto the spool while wiping excess water off the tape using a paper towel.

Decontamination after Water Level, NAPL Level, and Total Depth Measurements

- Set up a decontamination station consisting of three clean buckets, fill according to the initial decon procedure.
- Unwind the only the length of tape used for gauging from the spool into a bucket with laboratory-grade soap and distilled water. Brush the tape carefully to remove dirt and possible contamination, using a brush dedicated to the wash bucket.
- Continue as described above.
- Extra care should be taken to clean the probe after a total depth measurement. All sediment or dirt needs to be removed during decontamination.
- If an oil-water interface probe is used to gauge NAPL, a solvent may be necessary to remove all NAPL residue. After decontaminations steps above, use a spray bottle filled with chosen solvent (ex. isopropyl alcohol) and spray across all surfaces of the tape. Use paper towels to wipe off solvent and/or residue. This step may be repeated if necessary.

Notes:

- Collect equipment blanks if required by the work plan (minimum 1 per 20 samples or 1 per sampling event).
- Prepare new wash solution and rinse water when necessary (e.g., every 10 to 20 wells). The spent wash and rinse solution should be discharged according to site practices.
- The decontamination station may be expanded by adding extra rinse and/or detergent stations (i.e., solvent wash station) to the set up. The addition of more stations depends on the requirements of the work plan or the site-specific Field Sampling and Quality Assurance Plan and outlined in the project field plan or kick-off meeting.
- Small crates or washtubs are a possible substitute for the buckets. In any case, it is recommended to use containers with a lid.

9 Waste Management

Decontamination fluids, PPE, and other disposable equipment will be properly stored on site in labeledcontainers and disposed of properly. Be certain that waste containers are properly labeled and documented in the field log book. Review *TGI – Investigation Derived Waste Handling and Storage*, foradditional information and state- or client-specific requirements.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

If paper forms are used, fluid level measurements as well as all relevant observations should be documented in the field logbook, field forms and/or PDA as appropriate. The following information must be documented:

- Well or location identification;
- Measurement time;
- Total well depth or depth of the water body at the location;
- Depth to water and, where necessary, depth to NAPL.

Once all the data has been collected and recorded, all notes/forms/data must be uploaded to the appropriate project directory on the Arcadis server, and an email should be sent to the Task Manager and/or Technical Lead for notification. A summary of the work completed that day and any relevant observations noted (such as well inspections) during the daily activities as well as copies of the data mentioned above should be included with the email. The appropriate team member will review the datafor accuracy and provide feedback.

11 Quality Assurance

Suggested quality control measures are below; project teams may implement some or all of these at their discretion and based on project data quality needs.

- As described in the detailed procedure, the electronic water-level meter and/or oil-water interfaceprobe can be calibrated prior to use versus an engineer's rule to ensure accurate length demarcations on the tape or cable. The results will be recorded.
- Measurements will be completed three times, with the final measurement recorded.
- Fluid interface measurements will be verified by gently raising and lowering the instrument through each interface to confirm repeatable results.

- Field notes will be reviewed by the project team once the field data has been delivered.

12 References

Cunningham, W.L., and Schalk, C.W., comps., 2011. *Groundwater technical procedures of the U.S.Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 pp*.

U.S. Environmental Protection Agency, 2013. *SESD Operating Procedure, Groundwater level and WellDepth Measurement.* January 29.

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TGI – Low Flow Steady State Drawdown Testing

Rev: 0

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Version Control

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0	0	March 16, 2022	All	Initial	Everett Fortner

Approval Signatures

Prepared by:		3/16/2022
	Everett H. Fortner III, PG	Date
Reviewed by:		3/16/2022
	Marc Killingstad, PE	Date

1 Introduction

Groundwater zone hydraulic conductivity can be estimated with flow versus stable drawdown relationship using a constant low flow rate (generally less than 1 liter per minute) over a general period of 15 to 30 minutes. Low flow steady state drawdown testing is a procedure to provide the field data to assess these parameters.

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3 Scope and Application

The testing of a groundwater zone typically involves using groundwater monitoring wells. However, many tests require the tested groundwater zone to provide adequate yield and proper designed extraction well with multiple, properly spaced observations wells. Typical extraction constant-rate tests provide results that are more representative of bulk average groundwater zone characteristics than those predicted by single-well hydraulic tests (e.g., single-well extraction tests or slug tests). However, groundwater zones that are lower in permeable, yield, or that may lack the saturated thickness or well network require alternate methods such as single-well testing that can be completed with groundwater monitoring wells, piezometers, temporary well points within a drill stem, or discreet packer interval. In addition, the data for the testing can be collected while performing low flow groundwater sampling activities. The low flow steady state discharge and drawdown method utilizes flow rates that are analogous to low flow sampling methods and less than or equal to 1 liter per minute (L/min) (Robbins et al., 2009 and Aragon-Jose et al. 2011) in order to maintain/achieve a maximum drawdown of approximately 20 percent of the initial water column or packed interval over 15 minutes; however, the flow rate may be increased to as much as 4 L/min with more conductive groundwater zones that the low flow rate does not induce an appreciable drawdown response of greater than approximately 0.2 feet (Fortner et al., 2013). If a flow rate of greater than 1 L/min is required, a pressure transducer is recommended to record the drawdown response and the results should be considered approximate within an order of magnitude.

The resulting hydraulic conductivity estimates derived from testing data are comparable to slug testing results and as with other single well tests, are typically viewed as the lower bound of the hydraulic conductivity local to the testing well. The hydraulic conductivity is estimated using a series of steady state flow equations presented in Robbins et al., 2009 and Aragon-Jose et al. 2011 or with flow rates exceeding 1 L/min, additional flow equations from Cooper and Jacob, 1946 and Driscoll, 1986.

The low flow steady state discharge and drawdown method does not have the inherent issues with single-well pumping tests (often referred to as specific capacity testing) that use higher flow rates of greater than approximately 1 gallon per minute (gpm) within wells that are not designed for extraction such as monitoring wells. The higher stress single-well pumping tests induces bias due to excessive drawdown (well losses) within the pumping well compared to the actual drawdown within the groundwater zone. In addition, the testing often is not performed over a long enough duration to remove borehole storage to obtain a more representative drawdown.

To the extent possible, the hydraulic response to the low flow rate, via observed changes in water levels in the test well and observation wells, will be recorded with a pressure transducer/data logger (refer to *TGI – Water-Level Monitoring Using Data Logging Instruments*) as well as manually measured with an electronic water-level meter (refer to *TGI – Manual Water-Level and NAPL Monitoring*). However, manual water levels may be used alone. Flow rates will be maintained at a steady/consistent level throughout the duration of the test, flow rate estimated from past groundwater pumping information or development data, and checked/recorded frequently using a measurement device such as a graduate cylinder. After a sufficient duration of steady state drawdown (generally the steady state drawdown is defined as less than 0.03 feet of water level change over the test duration) is reached for approximately 15 to 30 minutes or based on the test design and/or consultation with the project hydrogeologist, pumping will cease, and recovery will be monitored until observed water level is within 95% of static (pre-test) conditions. A ball valve or check valve will be used to prevent back flow back through the testing for the recovery monitoring.

This TGI primarily focuses on unconsolidated aquifers (i.e., porous media). Tests completed in fill, fractured bedrock, and karst systems have unique challenges that require additional specific design that may include increased monitoring or additional analyses and are not specifically addressed in this TGI.

As with all hydraulic testing, proper test design and planning is necessary to perform a successful test. Therefore, it is strongly recommended that the project hydrogeologist develop a detailed field implementation plan (FIP) that clearly outlines the test objectives, specific steps/procedures to be performed, communication expectations and protocol, and health and safety requirements and review with field personnel prior to mobilization to the field.

4 Personnel Qualifications

Field personnel performing the extraction constant rate tests will have the following qualifications:

- Familiarity and competency with
    - quantitative hydrogeology,
    - understanding of the Project Site,
    - this TGI, and
    - the work scope (i.e., have reviewed the FIP or work plan with project hydrogeologist).
- Sufficient “hands-on” experience necessary to successfully complete the field work.
- Demonstrated familiarity with equipment required for this testing such as submersible pumps, flow rate measurement, and electronic data logging equipment (see TGI for Water Level Monitoring using Data Logging Instruments).
- Completed current health and safety training in accordance with the project health and safety plan (HASP) (e.g., 40-hour Hazardous Waste Operations training and site-specific training, as appropriate).

5 Equipment List

- Test well construction details
- Well development and/or other testing information such as past groundwater sampling data
- Work plan or FIP
- Electronic water-level meter(s) – calibrated individual and to each other if multiple used
- Appropriate data-logging pressure transducers – suitable for expected water column range and data logging capabilities (e.g., Solinst AquaVent [vented] with direct read cable for the test well, Solinst Level Logger Edge [non-vented] for observation wells)
- Pressure transducer communication equipment, manuals, and calibration certificates
- Laptop computer or other interface (tablet) with appropriate software installed for communication with pressure transducers
- Appropriate pump (e.g., variable speed submersible pump or peristaltic) capable of test design flow rates, depth to water, and with any associated flow controller
- Appropriate tubing
- Appropriate check-valve (i.e., back-flow preventer) or ball valve for tubing size
- Buckets or drums
- IDW containerization
- Approved decontamination detergent
- Potable water for decontamination
- Appropriate field forms/logs (electronic FieldNow® forms for pressure transducers, low flow groundwater sampling, manual water level collection or extraction constant rate testing may be used)
- Digital camera or smart phone
- Appropriate PPE (per project HASP)
- Tripod, winch, and suspension cable, if required for weight of pump and tubing
- Appropriate flow rate measuring equipment (e.g., graduated cylinder and stop watch)

- Shelter, table, and chairs, if needed

6 Cautions

- Pressure Transducers/Data Loggers
    - Verify and document that all rental instruments and water-level meters are in good working order (and calibrated with relevant documentation) prior to mobilization to the field.
    - Small-diameter pressure transducers (typically 0.5 to 0.75 in) are available that can cover a range of pressures.
    - Deploy the pressure transducer in the test well at a reasonable distance above the pump intake to prevent noise (over 1 foot, if available water column allows).
    - To prevent pressure transducer malfunction or damage, do not submerge pressure transducers in excess of the operating range and do not insert objects in the sensor opening (refer to manufacturer manuals).
    - For vented pressure transducers/data loggers, prior to field mobilization test functionality using a bucket or barrel filled with water. Submerge pressure transducer, accurately measure the water head above the pressure transducer, and compare the measurement to the reading. Document functionality testing results and resolve any non-conformances.
    - For non-vented transducers, which record a combined pressure of barometric and the water column above the pressure transducer, can be tested in the same fashion as the vented pressure transducer (outlined above). The water column above the pressure transducer can be checked by subtracting out current atmospheric pressure.
    - The pressure transducer will be set in the well at least 10 minutes prior to recording start to allow the instrument to thermally equilibrate with groundwater and allow for any cable stretching.
    - The water level will be collected from the test well at a minimum of 15 minutes after equipment is installed in the well. If the water level is not stable (i.e., change of less than or equal to 0.03 feet over the pre-test period, additional time may be required to ensure equilibrium).
    - Only linear logging will be used to record data: do not use logarithmic or head-change logging settings to record data. These other measurement settings have caused issues in the past and, therefore, will not to be used since most current data loggers have sufficient data memory for linear logging.
    - When deployed, the pressure transducer cables will be secured at the wellhead to prevent movement that would affect measurements. Mark a reference point on the down-hole transducer cable or securing line and check regularly to detect slippage. For larger diameter wells, loop the cable and use tape to secure cable to well outer casing.
- Data Recording and Management
    - All data management and recording devices (i.e., laptop computer(s), pressure transducers and other time-measurement devices) will be synchronized so that the time (using 24-hour military format) of each reading, electronic and manual, can be referenced to the exact minute and hour that pumping started.
    - Data management is crucial to prevent data loss. Use caution not to overwrite any previously recorded files and remember, electronic data backup is always necessary. A significant job loss

occurs if data is accidently overwritten or lost. As soon as testing has been completed or at intervals as directed in the field implementation plan, immediately back up data on a laptop computer, a flash drive kept in a safe location (e.g., back pack), and uploaded nightly to the project data server (i.e., SharePoint) to reduce the risk of data loss (e.g., computer failure) in the field.

- Flow Rate
    - Flow rates will be measured using a graduate cylinder, appropriate graduate bucket or in-line flow meter.
    - The flow meter chosen for the test will have an adequate flow rate range capable of accurately measuring the expected flow rates and appropriately sized for the discharge piping.
- Equipment Care
    - Keep sensitive electronic equipment away from heat and devices that generate significant magnetic fields. For example, do not place pressure transducers near electric power generators or electric pump motors or store in vehicles when high temperatures are anticipated. Likewise, radio signals may cause pressure transducers or computers to malfunction.
- Decontamination
    - Make sure all equipment that enter the test and observation wells (e.g., pump, water-level meter, pressure transducer) is properly decontaminated before and after use. If testing multiple wells, start with the least contaminated and progress to the most contaminated. Please refer to the TGI – Groundwater and Soil Sampling Equipment Decontamination.
- Weather
    - Verify that heavy rainfall (greater than a quarter of an inch) has not occurred within 48 hours and is not expected during testing. Recharge will influence groundwater levels that cannot be corrected during post-test analysis providing unreliable results. If weather conditions are questionable, check with project hydrogeologist for direction.

7 Health and Safety Considerations

The site-specific HASP will be used to verify that the extraction constant rate tests are conducted in a safe manner and will include appropriate Job Safety Analyses (JSAs). The following specific health and safety issues will be considered when conducting pumping tests:

Appropriate PPE with minimum of Level D must be worn to avoid contact with site chemicals of concern during extraction constant rate testing.

Electrical hazards evaluated (e.g., extension cords, power distribution centers and generators)

Well covers must be carefully removed to avoid potential contact with insects or animals. Well caps are recommended be vented or tethered to avoid potential eye injury in case of gas buildup in the well is expected. Well covers are also a potential lifting hazard and pinch point hazard.

Pressurization or vacuum hazards associated with pipes and fittings will be considered during extraction constant rate test planning and implementation.

Downhole equipment assemblages (pump and piping) may be too heavy for hand deployment and may require the use of a tripod, winch or crane truck.

8 Procedure

1. Prior to mobilization: review field implementation plan with project hydrogeologist; review HASP, assemble appropriate forms and site data (e.g., well construction details); and order/test/calibrate all equipment.
2. Initiate and fill out field forms/logs (electronic FieldNow® forms for pressure transducers, low flow groundwater sampling, manual water level collection or extraction constant rate testing may be used)
3. All time measurement documentation will be in 24-hour time.
4. Measure water-levels and total well depth in test well.
5. Install pressure transducer (if applicable):
    a. Ensure adequate memory prior to deployment (i.e., clear memory during testing conducted prior to mobilization)
    b. The pressure transducer will be attached using the appropriate direct read communication cable (preferred) or Kevlar cord.
    c. The data acquisition will be set to linear logging under non-overwriting recording mode recording at a rate outlined in the field implementation plan (e.g., 1 to 5 seconds). Refer to field implementation plan or consult with project hydrogeologist if there are questions.
    d. The pressure transducer will be placed in the well at a distance below the anticipated water level accounting for expected drawdown or just above the bottom of the well (e.g., 6 inches) and/or just above the pump if the diameter of the well or the water column is limited. Using a direct read cable allows for real time monitoring with a laptop or similar interface.
    e. Take a water-level measurement prior deployment of the pressure transducer and before the pump install. However, proper static levels will need to be established if the pumping equipment is installed later causing temporary well water-level rise.
6. Pressure transducer cable or Kevlar cord will be attached to solid surface mount with wire ties or something similar.
7. Set up pumping system at the test well in accordance with the field implementation plan and consultation with the project hydrogeologist.
    a. Install extraction equipment (i.e., downhole test well pump) and verify that a check valve or a ball valve at the top of the well head is installed to inhibit drainage of the effluent line after pump shutdown. If a ball valve is used, the valve will need to be shut precisely after pump shut off.
    b. Ideally, the pump intake is placed above the top of the well screen if the water column and expected drawdown permits.
    c. Note that the flow meter and other sensitive equipment are recommended to be protected from the elements under a temporary shelter. The pump controller can be specifically sensitive to humidity and overheating with exposure to direct sunlight.
    d. Verify that the controller is well ventilated, in the shade, and the protective lid not closed.

   e. As with all pumping tests, it is critical that the flow rate be held steady. Set the desired flow rate as soon as possible after starting the pump. The flow rate for the low flow rate test is recommended to be determined by previous groundwater sampling or development data.

8. Start test: turn on pump and set a low flow rate as quickly as possible to be approximate to the design flow rate. As with all pumping tests, it is critical that the flow rate be held steady.
9. Record the manual depth-to-water measurements in the test well. The schedule below provides a general recommendation.
   a. every 5 seconds for the first minute,
   b. every 30 seconds for the next three minutes,
   c. every minute for the next 15 minutes (considering a steady state drawdown of greater than 0.2 feet is recorded),
   d. Repeat for recovery.
10. Flow meter readings are recommended to be recorded once every one to three minutes for the duration of the testing and during flow rate changes if appropriate.
11. If flow rate adjustments are necessary, record each change (including time and rate) on the field form. However, the flow rate is required to be maintained as close as possible to the start for the duration of the test. Consult with the project hydrogeologist if questions/issues arise relative to flow rate.
12. After the pumping test objectives have been achieved (i.e., steady state response has been verified), shut down the pump and monitor recovery to at least 95% or greater of the pre-test conditions. Manual depth-to-water measurements during aquifer recovery will follow the same schedule as during the start of the test or as outlined in the FIP.
13. Final depth-to-water measurements will be taken from the observation wells and test well prior to removing any equipment (e.g., pumps and transducers).
14. Once recovery has been verified (consult with project hydrogeologist), remove and download pressure transducers. Store/transfer/maintain the data on at least two separate devices (tablet, CPU and flash drive) and upload to project folder as soon as possible to prevent data loss. Following file naming convention outlined in the FIP; if not specified, use the following convention: Well ID_Date_Time.
15. Water-IDW. Follow the FIP and TGI for water-IDW management, treatment, and discharge. General guidelines for waste management are provided below.

9 Waste Management

Rinse water, PPE, and other waste materials generated during equipment decontamination will be placed in appropriate containers and labeled in accordance with the TGI on IDW and/or as outlined in the field implementation plan. Containerized waste will be disposed of, consistent with appropriate waste management procedures for investigation-derived waste.

Containerize all purged water as specified in the field implementation/work plan. Do not discharge on the ground in the area of testing as this recharge may affect shallow aquifer responses. Discharge water must be disposed of according to all applicable laws, regulations, and project guidelines. Contact the governing agencies to determine which restrictions apply. Arcadis will not "take possession" of purged water.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Field personnel will complete all applicable field forms for each test. Forms will include recommended data file naming protocol per the FIP. It is recommended that all data (copies of field forms/logs and digital data from the pressure transducers) be copied to a flash drive and transmitted along with field notes to the project team/project folder as soon as possible to prevent data loss. Field equipment calibration, decontamination activities, and waste management activities will be recorded in the field notebook or daily log.

11 Quality Assurance

Data collected during field testing will be reviewed in real time to determine reasonableness/quality given documented site-specific conditions. This can be completed using the direct read pressure transducer cables connected to a laptop or other device in real-time viewing mode as the test progresses. If the data are questionable, the field equipment must be checked to confirm proper working order and the test may be repeated, if possible. Consult with the project hydrogeologist to work through issues encountered in the field and to help determine test validity. Frequent and open communication with the technical staff/project hydrogeologist is essential for successful performance of any field activity. Document findings and resolution of any non-conformances.

Any issues that may affect the data must be recorded in the field notebook or daily log for consideration by the technical staff. Follow data file naming protocol as outlined in the FIP and other information needed on applicable field forms

12 References

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TGI – Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells

Rev: 2

Rev Date: April 5, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	October 12, 2018	All	Updated and re-written as TGI with new branding and content	Marc Killingstad
	1	May 8, 2020	Pages 5, 10-11	Added clarification/details for equipment requirements and procedure steps based on USEPA guidance	Marc Killingstad
	2	April 5, 2022	All	Updated to new branding template and minor edits	Marc Killingstad

Approval Signatures

Prepared by: 4/5/2022

Xuan Xu

Xuan Xu (Preparer) Date

Reviewed by: 4/5/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

Groundwater samples are collected from monitoring wells to evaluate groundwater quality. The protocol presented in this Technical Guidance Instruction (TGI) describes the procedures to purge monitoring wells and collect groundwater samples using the low flow purging/sampling methodology. This protocol has been developed in accordance with the United States Environmental Protection Agency (USEPA) Region I *Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells* (EQASOP-GW4; September 19, 2017).

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

Both filtered and unfiltered groundwater samples may be collected using this low-flow sampling method. Filtered samples will be obtained using a 0.45-micron disposable filter. Project teams will evaluate the last time the monitoring wells were developed and determine if additional development might be necessary. Water samples will not be taken immediately following well development. Sufficient time will be allowed for the groundwater flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week.

4 Personnel Qualifications

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations,such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as identified in the site-specific Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. The HASP will also identify any access control requirements.

Prior to mobilizing to the field, the groundwater sampling team will review and be thoroughly familiar withrelevant site-specific documents including but not limited to the task-specific work plan or field implementation plan (FIP)/field sampling plan, Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. Additionally, the groundwater sampling team will review and be thoroughly familiar with documentation provided by equipment manufacturers and become familiar with the operation of (i.e., hands-on experience) all equipment that will be used in the field prior to mobilization.

5 Equipment List

Specific to this activity, the following materials (or equivalent) will be used:

- Site-specific HASP and health and safety documents identified in the HASP
- Field Implementation Plan (FIP) that includes site map, well construction records, sampling plan (sample analyses, sample volume required, and sample holding time), and prior groundwater sampling records (if available)
- Field notebook and/or smart device (phone or tablet)
- Low-flow sampling field forms (**Attachment A**)
- Appropriate personal protective equipment (PPE) (e.g., latex or nitrile gloves, safety glasses, etc.)as specified in the HASP
- Well keys and other tools to remove manhole covers (manual torque wrench with 9/16” socket and flat head screwdriver typical)
- Photoionization detector (PID) or Flame ionization detector (FID) (as appropriate, depending onsite-specific constituents of concern)
- Electronic water-level indicator (e.g., Solinist Model 101) or oil/water interface probe with 0.01- foot accuracy (oil/water as appropriate, note that sampling will not be performed when sheen orlight non-aqueous phase liquid [LNAPL] is present)
- Down-hole multi-parameter water-quality sonde (temperature/pH/specific conductivity/oxidationreduction [ORP]/turbidity/dissolved oxygen) meter coupled with flow-through-cell for measurements, for example:

  - YSI 6-Series Multi-Parameter Instrument
  - Horiba U-22 Multi-Parameter Instrument.
  - Hydrolab Series 3 or Series 4a Multiprobe and Display.

  NOTE: *Transparent, small volume flow-through-cells (e.g., 250 milliliters or less) are preferred as they allow for easy detection of air bubbles and sediment buildup in the cell, which can interfere with the monitoring instrument probes. A small volume cell also allows for quick turnover of water in the cell between measurements of the indicator field parameters. It is recommended to use a flow-through-cell and monitoring probes from the same manufacturer and model to avoid incompatibility between the probes and flow-through-cell.*

- Plastic sheeting (e.g., Weatherall Visqueen) to protect all down-hole sampling equipment from contact with potential sources of contamination.
- Decontamination equipment
  - Non-phosphate laboratory soap (Alconox or equivalent), brushes, and clean buckets, and/or clean wash tubs—new buckets or tubs will be purchased if it cannot be determined if the present items are clean
  - Distilled or de-ionized water for equipment decontamination
- Indelible ink pen
- 150-foot measuring tape (or sufficient length for the maximum site depth requirement)
- Sampling pump, which may consist of one or more of the following:
  - Submersible pump (e.g., Grundfos Redi-Flo 2)
  - Peristaltic pump (e.g., ISCO Model 150)
  - Bladder pump (e.g., Marschalk System 1, QED Micropurge, Geotech)
- Appropriate controller and power source for pump:
  - Submersible and peristaltic pumps require electric power from either a generator or a deep cell battery
  - Submersible pumps such as Grundfos require a pump controller to run the pump
  - Bladder pumps require a pump controller and a gas source (e.g., air compressor or compressed N_2 or CO_2 gas cylinders)
- Teflon® tubing or Teflon®-lined polyethylene tubing of an appropriate size for the pump being used
  - For peristaltic pumps, dedicated Tygon® tubing (or other type as specified by the manufacturer) will be used through the pump apparatus
  - Teflon® will not be used when sampling for per- and polyfluoroalkyl substances (PFAS)
- Graduated cylinder and stopwatch or other device to measure time to determine pumping rate
- Appropriate water sample containers (supplied by the laboratory)
- Appropriate blanks (trip blank supplied by the laboratory)
- Sample labels and Chain-of-Custody forms (COC)
- 0.45-micron disposable filters (if field filtering is required)

- A supplemental turbidity meter (e.g., Horiba U-10, Hach 2100P, LaMotte 2020) may be required for specific projects and will be specified in the project FIP/ work plan and the kick-off notes.
    - If used, in-line 'T' and valve allows for collection of water for turbidity measurements before the pump discharge enters the flow-through cell

NOTE: *The maintenance requirements for the above equipment generally involve decontamination or periodic cleaning, battery charging, and proper storage, as specified by the manufacturer. For operational difficulties, the equipment will be serviced by a qualified technician.*

6 Cautions

Different USEPA regions and/or state regulatory agencies may stipulate deviations from this document. Itis the responsibility of the Project Team (Project Manager and Technical Lead) to be fully aware of the requirements from the applicable regulatory framework.

Weather

- If heavy precipitation occurs, and no cover over the sampling area and monitoring well can be erected, sampling may be discontinued until adequate cover is provided. Rainwater could compromise groundwater samples.
- Avoid extreme weather situations. Be aware that thermal currents and vertical mixing of cold and warm water inside the well casing could create a convection cell within the well and compromise data collection (e.g., biological mechanisms).
    - Direct sunlight and hot ambient temperatures may cause the groundwater in the tubing orflow-through-cell to heat up and de-gas. This may result in the loss of volatile organic compounds (VOCs) and dissolved gases. Shade the equipment from direct sunlight, keep the tubing as short as possible and avoid the hottest times of the day.
    - Sampling during freezing conditions may adversely impact the data quality objectives. USEPA recommends low-flow sampling be conducted at air temperatures above 32°F (0°C) or taking special precautions to prevent groundwater from freezing in the equipment.

Cross-Contamination

- To mitigate potential cross-contamination, groundwater samples are to be collected in a pre- determined order from least impacted to impacted based on previous analytical data. If no analytical data are available, collect samples in order of up-gradient, then furthest down-gradient tosource area locations.
- Note that permanent markers could introduce volatile constituents into the samples*; therefore, indelible ink is recommended* to be used for labels on sample containers or sample coolers.
- When using a gasoline generator, this power source will be set-up at least 30 feet downwind from the well to avoid exhaust fumes to contaminate samples.

Pumps

- Preferred methods of extracting groundwater are adjustable rate, submersible pumps - such as centrifugal pumps or bladder pumps – constructed of stainless steel or polytetrafluoroethylene (PTFE, i.e., Teflon®). However, *PTFE will not be used when sampling for per- and polyfluoroalkyl substances (PFAS). PTFE could contain PFAS*.

- When using a bladder pump for collecting VOCs and dissolved gases, “best practice” is to set-up the pump to deliver sufficient water to fill a 40 mL VOC vial.
- The use of peristaltic pumps will be based on the type of data to be collected. *Because the use a peristaltic pump can result in de-gassing of VOC and / or dissolved gases from groundwater, a different type of pump will be considered if these compounds are of concern.*
- *Manual or motor driven inertial pumping devices are not recommended because they cause greater disturbance during purging and pumping than regular pumps and are less easily controlled. This could cause a higher degree of data variability.*

Tubing

- When sampling for VOCs, SVOCs, pesticides, PCBs and inorganics, use of PTFE (Teflon®) or PTFE-lined tubing is preferred. However, PTFE tubing will not be used when sampling for PFAS.
- PVC, polypropylene or polyethelene tubing may be used when sampling for metals or other inorganics.
- Tubing with inside diameters of 1/4 or 3/8 inch is recommended because this will help ensure tubing remains water filled when operating at very low pumping rates.

General Precautions

- Store and/or stage empty and full sample containers and coolers out of direct sunlight.
- It may be necessary to field filter the groundwater for some parameters (e.g., metals) during collection, depending on preservation, analytical method, and project quality objectives. The task-kick-off notes and the FIP/work plan will list the samples that require field filtering.
- Be careful not to overtighten lids with Teflon® liners or septa (e.g., 40 mL vials). Over-tightening can cause the glass to shatter or impair the integrity of the Teflon® seal.

7 Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel.

Appropriate personal protective equipment (PPE) will be always worn in line with the task and the site-specific HASP.

Review all site-specific and procedural hazards as they are provided in the HASP, and review Job Safety Analysis (JSA) documents in the field each day prior to beginning work.

Access to wells may expose field personnel to hazardous materials such as contaminated groundwater or non-aqueous phase liquid (NAPL) (e.g., oil). Other potential hazards include pressurized wells, stinging insects that may inhabit well heads, other biologic hazards (e.g. ticks in long grass/weeds around well head), and potentially the use of sharp cutting tools (scissors, knife)—open well caps slowly and keep face and body away to allow to vent any built-up pressure; only use non-toxic peppermint oil spray for stinging insect nests; review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives, and use appropriate hand protection.

Generators and cord and plug equipment will employ an overcurrent protection device such as an integrated ground fault circuit interrupter (GFCI) cord. Grundfos pump controllers will not run properly with a GFCI, so the power source will be equipped with other overcurrent protection means.

Overtightening of lids with Teflon® liners can cause the glass to shatter and create a risk for hand injuries.

8 Procedure

Field personnel will set up and perform low-flow sampling in accordance with the following procedures.

1. Review FIP and groundwater sampling records from previous sampling events (if available) prior to mobilization to estimate the optimum pumping rate and anticipated drawdown for each well to perform sampling as efficiently as possible (i.e., reach a stabilized pumping condition).
2. Calibrate field instruments according to manufacturer procedures for calibration and record calibration procedure and results in field log.
3. All equipment will either be new or decontaminated in accordance with appropriate guidance document *(TGI – Groundwater and Soil Sampling Equipment Decontamination)* prior to use.
4. Visually inspect the well to ensure that it is undamaged, properly labeled and secured
   a. Damage or other conditions that may affect the integrity of the well will be recorded in the Field Activity Daily Log and brought to the attention of the designated Field Manager and/or Project Manager
   b. Record well construction and conditions on the Low-Flow Sampling Field Form **(Attachment A)**.
5. Place clean plastic sheeting on the ground near the well to keep monitoring and sampling equipment off the surface unless the equipment is elevated above the ground (e.g., on a table).
6. Open the well cover while standing upwind of the well. Remove the well cap and place it on the plastic sheeting. If appropriate or required for site-specific conditions, insert the photoionization detector (PID) probe approximately 4 to 6 inches into the casing or the well headspace and cover it with a gloved hand. Record the PID reading in the field log. Perform air monitoring in the breathing zone according to the HASP and/or JSA.
7. Measure and record the initial depth to groundwater prior to placing the pumps.
8. Prepare and install the pump in the well.

   NOTE: *Groundwater will be purged from the wells using an appropriate pump. If the depth to water is below the sampling range of a peristaltic pump (approximately 25 feet below ground surface), a submersible or bladder pump will be used, provided that the well is constructed with a casing diameter of at least two (2) inches (the minimum well diameter capable of accommodating such pumps). For smaller diameter wells, where the depth to water is below the sampling range of a peristaltic pump, alternative sampling methods (i.e., bailing or small diameter bladder pumps) will be used to purge and sample the groundwater. Bladder pumps are preferred over peristaltic and submersible pumps to prevent volatilization if sampling of VOCs and/or dissolved gasses is required. Purge water will be collected and containerized according to the direction of the project team.*

   a. For submersible and non-dedicated bladder pumps, decontaminate the pump according to site decontamination procedures. Non-dedicated bladder pumps will require a new bladder and attachment of an air-line, sample discharge line, and safety cable prior to placement in the well. Attach the air-line tubing to the air-port on the top of the bladder pump. Attach the sample discharge tubing to the water port on the top of the bladder pump. Take care not to reverse the air and discharge tubing lines during bladder pump setup, as this could result in bladder failure or rupture. Attach and secure a safety cable to the eyebolt on the top of pump (if present, depending on pump model used). Slowly lower the pump, safety cable, tubing, and electrical lines into the well to a depth corresponding to the approximate center of the saturated screen section of the well. Avoid twisting and tangling of safety cable, tubing, and electrical lines while lowering the pump into the well; twisted and tangled lines could result in the pump becoming stuck in the well casing. Also, make sure to keep tubing and lines from touching the ground or other surfaces while introducing them into the well, as this could lead to unintended contamination.

   b. If using a bladder pump, connect the air-line to the pump controller output port. The pump controller will be connected to a supply line from an air compressor or compressed gas cylinder using an appropriate regulator and air hose. Tighten the regulator connector onto the gas cylinder (if used) to prevent leaks. Teflon® tape may be used on the threads of the cylinder to provide a tighter seal. Once the air compressor or gas cylinder is connected to the pump controller, turn on the compressor or open the valve on the cylinder to begin the gas flow. Turn on the pump controller power (if an on/off switch is present) and verify that all batteries are charged and fully functioning before starting the pump.
   c. If a peristaltic pump is being used, slowly lower the sampling tubing into the well to a depth corresponding to the approximate center of the saturated screen section of the well. The pump intake or sampling tube must be kept at least two (2) feet above the bottom of the well to prevent mobilization of any sediment present in the bottom of the well.
   d. If using an in-line ‘T’ and valve, install between pump discharge water line and the bottom inlet port of the flow-through cell. Attach a short piece of tubing to the outlet. This set-up will be used to collect samples for turbidity readings.

9. Connect the pump discharge water line to the bottom inlet port on the flow-through cell connected to the multi-parameter water-quality sonde and make sure to record equipment/instrument identification (manufacturer and model number).
10. Before starting the pump, ensure that the water level inside the well has stabilized (i.e., measure the water level multiple times after deploying the pump in the well).
11. Start pumping the well at 200 to 500 milliliters (mL) per minute (or at lower site-specific rate if specified) and adjust the pumping rate to cause little or no water level drawdown in the well (less than 0.3 feet below the initial static depth to water measurement): the water level should stabilize, however, this is not always possible.
12. If the well diameter is of sufficient size, measure the water level every 3 to 5 minutes (or as appropriate, lower flow rates may require longer time between readings) during pumping.
13. Maintain a steady flow rate to the extent practicable and do not break pump suction or cause entrainment of air in the sample.
14. Record pumping rate adjustments and depths to water.

    If necessary, reduce pumping rates to the minimum capabilities of the pump to avoid pumping the well dry and/or to stabilize indicator parameters; if the recharge rate of the well is very low, use alternative purging techniques, which will vary based on the well construction and screen position.

    For wells screened across the water table, the well may be pumped dry, and sampling can commence as soon as the volume in the well has recovered sufficiently to permit collection of samples.

    For wells screened entirely below the water table, the well can be pumped until a stabilized level (which may be greater than the maximum displacement goal of 0.3 feet) is maintained and monitoring for stabilization of field indicator parameters can commence; if a lower stabilization level cannot be maintained, the well may be pumped until the drawdown is at a level slightly higher than top of the well screen.

15. After water levels have stabilized and a sufficient volume has been purged (see note below), continue pumping and begin monitoring field indicator parameters using a multi-parameter water-quality sonde coupled with a flow-through-cell.

    NOTE: *The final purge volume must be greater than the stabilized drawdown volume plus the pump's tubing volume. If the drawdown has exceeded 0.3 feet and stabilizes, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are collected.*

16. Use the flow to measure all indicator field parameters, except for turbidity, every 3 to 5 minutes (or after each volume of the flow-through cell has been purged or other appropriate interval); turbidity samples will be collected before the flow-through-cell using the T-valve and a clean container such as a glass beaker.
17. Record field indicator parameters on the groundwater sampling log.
18. The well is considered stabilized and ready for sample collection when three consecutive readings are within the following limits:
    - **Turbidity** within ± 10% for values greater than 5 nephelometric turbidity units [NTUs] or if three turbidity values are less than 5 NTUs, consider the values stabilized
    - **Dissolved Oxygen (DO)** within ± 10% for values greater than 0.5 mg/L or if three DO values are less than 0.5 mg/L, consider the values stabilized
    - **Specific Conductance** within ± 3%
    - **Temperature** within ± 3%
    - **pH** within ± 0.1 unit
    - **Oxidation/Reduction Potential (ORP)** within ±10 millivolts (mV)

    NOTE: *Alternate stabilization goals may exist in different geographic regions, consult the site- specific FIP/work plan for stabilization criteria).*

    NOTE: *While achieving turbidity levels less than 5 NTU and a stable drawdown of less than 0.3 feet is desirable, sample collection may still take place provided the indicator field parameter criteria in this procedure are met.*

19. If the parameters have stabilized but turbidity remains relatively high (e.g., greater than 50 NTUs), the pump flow rate may be decreased to a minimum rate of 100 mL/min to reduce turbidity levels as low as possible. If groundwater turbidity has been minimized (i.e., consecutive readings within ± 10%) and the values for all other parameters have stabilized, the well may be sampled; however, consult specifications in the FIP/work plan and/or the project technical lead prior to sampling.
20. If after one (1) hour of purging indicator field parameters have not stabilized, consult specifications in the FIP/work plan and/or the project technical lead prior to sampling.

    In general, three potential options are available if stabilization criteria are not met:

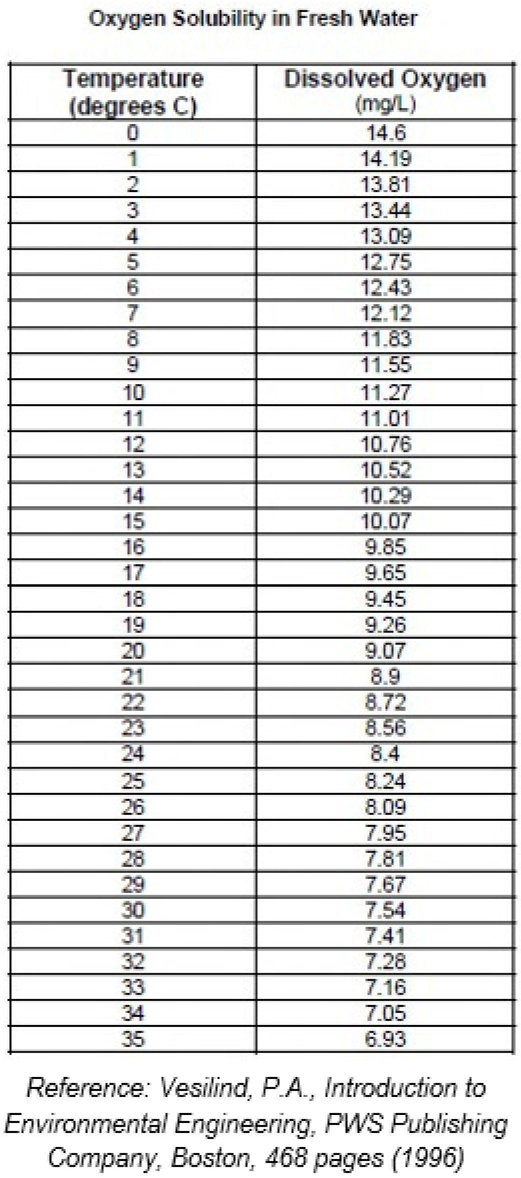
    a. Continue purging until stabilization is achieved.
    b. Discontinue purging, do not collect any samples, and record in field logbook/on the sampling form that stabilization could not be achieved (documentation must describe attempts to achieve stabilization).

c. Discontinue purging, collect samples, and provide full explanation of attempts to achieve stabilization. There is a risk that the analytical data obtained under these conditions, particularly metals and hydrophobic organic analytes, may reflect a sampling bias and, as a result, the data may not meet the data quality objectives of the sampling event.

NOTE: *DO is extremely susceptible to various external influences (including temperature or the presence of bubbles on the DO meter); therefore, great care will be taken to minimize the agitation or other disturbance of water within the flow-through cell while collecting these measurements. If air bubbles are present on the DO probe or in the discharge tubing, remove them before taking a measurement. If DO values are not within acceptable range for the temperature of groundwater, again check for and remove air bubbles on the probe before re-measuring. The table below may be used as a general guide for DO values under various temperatures; however, understand that the table corresponds to freshwater solubility and groundwater contaminants may affect oxygen solubility. If DO value is 0.00 or less, then the meter will be serviced and re-calibrated. If DO values are above possible results, then the meter will be serviced and re-calibrated.*

NOTE: *During extreme weather conditions, stabilization of field indicator parameters may be difficult to attain. Modifications to the sampling procedures to alleviate these conditions (e.g., measuring the water temperature in the well adjacent to the pump intake) will be documented in the field logbook/on the sampling form.*

NOTE: *If other field conditions are suspected of preventing stabilization of certain parameters, detailed observations will be documented in the field logbook/on the sampling form.*



Oxygen Solubility in Fresh Water

Temperature (degrees C)	Dissolved Oxygen (mg/L)
0	14.6
1	14.19
2	13.81
3	13.44
4	13.09
5	12.75
6	12.43
7	12.12
8	11.83
9	11.55
10	11.27
11	11.01
12	10.76
13	10.52
14	10.29
15	10.07
16	9.85
17	9.65
18	9.45
19	9.26
20	9.07
21	8.9
22	8.72
23	8.56
24	8.4
25	8.24
26	8.09
27	7.95
28	7.81
29	7.67
30	7.54
31	7.41
32	7.28
33	7.16
34	7.05
35	6.93

Reference: Vesilind, P.A., Introduction to Environmental Engineering, PWS Publishing Company, Boston, 468 pages (1996)

21. Complete the sample label(s) and cover the label(s) with clear packing tape to secure the label onto the container.

22. After the indicator parameters have stabilized, collect groundwater samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container.
    a. If a flow-through analytical cell is being used to measure field parameters, the flow-through cell will be disconnected after stabilization of the field indicator parameters and prior to groundwater sample collection.
    b. Under no circumstances will analytical samples be collected from the discharge of the flow- through cell.
    c. If an in-line ‘T’ and valve are used, the valve needs to be removed as well.

   d. Samples will be collected in the following order: VOCs, total organic carbon (TOC), semi- volatile organic compounds (SVOCs), metals and cyanide, and others (or other order as defined in the site-specific FIP/work plan).
   e. When the container is full, tightly screw on the cap.

23. If sampling for total and filtered metals and/or polychlorinated biphenyls (PCBs), a filtered and unfiltered sample will be collected.
   a. Install an in-line, disposable 0.45-micron particle filter on the discharge tubing after the appropriate unfiltered groundwater sample has been collected.
   b. Continue to run the pump until an initial volume of “flush” water has been run through the filter in accordance with the manufacturer’s directions (generally 100 to 300 mL).
   c. Collect the filtered groundwater sample by diverting flow out of the filter into the appropriately labeled sample container.
   d. When the container is full, tightly screw on the cap.
24. Secure with packing material and store the samples on ice in an insulated transport container provided by the laboratory and include a temperature blank in each container to be shipped.
25. Record on the Low-Flow Sampling Field Form (and bound field logbook) the time at which sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance and the presence or lack of odors or sheens), and the values of the stabilized field indicator parameters as measured during the final reading during purging **(see Attachment A)**.
26. Turn off the pump and air compressor or close the gas cylinder valve if using a bladder pump setup.
27. Slowly remove the pump, tubing, lines, and safety cable from the well.
   a. If using dedicated tubing, do not allow the tubing or lines to touch the ground or any other surfaces which could contaminate them.
   b. If using dedicated tubing, it will be folded - without pinching it - to a length that will allow the well to be capped and also facilitate retrieval of the tubing during later sampling events.
   c. Use a length of rope or string to tie the tubing to the well cap.
   d. Alternatively, if tubing and safety line are to be saved and reused for sampling the well at a later date, coil the tubing neatly and placed in a clean plastic bag that is clearly labeled with the well ID ensuring the bag is tightly sealed before placing it in storage.
28. Secure the well and properly dispose of personal protective equipment (PPE) and disposable equipment.
29. Complete the procedures for packaging, shipping, and handling with the associated Chain-of- Custody.
30. Complete decontamination for flow-through analytical cell and submersible or bladder pump, as appropriate *(TGI – Groundwater and Soil Sampling Equipment Decontamination).*
31. At the end of each day of the sampling event, perform calibration check of field instruments and record procedure and results in field log.

9 Waste Management

Materials generated during groundwater sampling activities, including disposable equipment and excess purge water, will be stored on site in appropriately labeled containers and disposed of properly. Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage*, the procedures identified in the

FIP or QAPP as well as state-, federal- or client-specific requirements. Be certain that waste containers are properly labeled and documented in the field logbook.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Management of the original documents from the field will be completed in accordance with the site- specific QAPP.

In general, forms (e.g., Low-Flow Sampling Field Forms), logs/notes (including daily field and calibration logs), digital records, and Chain-of-Custody records will be maintained by the field team lead.

Field logs and Chain-of-Custody records will be transmitted to the Arcadis Project Manager and/or Task Manager, as appropriate, at the end of each day unless otherwise directed. Electronic data files will be sent to the project team and uploaded to the electronic project folder daily.

Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

11 Quality Assurance

Quality assurance procedures shall be conducted in accordance with the Arcadis Quality Management System or the site-specific QAPP.

Unless described otherwise in the project-specific FIP/work plan, QAPP, or Sampling and Analysis Plan, quality assurance/quality control samples will be collected as follows:

- One duplicate for every 10 samples
- One laboratory matrix/matrix spike sample for every 20 samples
- In addition to the quality control samples to be collected in accordance with this TGI, the following quality control procedures will be observed in the field:
- Collect samples from monitoring wells, in order of increasing concentration, to the extent known based on review of historical site information if available
- Equipment blanks will include the pump and tubing (if using disposable tubing) or the pump only (if using tubing dedicated to each well)
- Collect equipment blanks after wells with higher concentrations (if known) have been sampled

- Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures—calibrate instruments at the beginning of each day, verify the calibration at the end of each day, and record all calibration activities in the field notebook
- Clean all groundwater sampling equipment prior to use in the first well and after each subsequent well following the procedure for equipment decontamination

12 References

USEPA. 1986. *RCRA Groundwater Monitoring Technical Enforcement Guidance Document* (September 1986).

USEPA. 1991. *Handbook Groundwater, Volume II Methodology*, Office of Research and Development, Washington, DC. USEPN62S, /6-90/016b (July 1991).

USEPA Region I. 2017. *Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells* (EQASOP-GW4; September 19, 2017).

U.S. Geological Survey (USGS). 1977. *National Handbook of Recommended Methods for Water-Data Acquisition: USGS Office of Water Data Coordination*. Reston, Virginia.

13 Attachments

Attachment A – Low Flow Sampling Field Form

Attachment A

Low-Flow Sampling Field Form

GROUNDWATER SAMPLING FORM

ARCADIS

Page ____ of ____

Project No. ____________ Well ID ____________ Date ____________

Project Name/Location ____________ Weather ____________

Measuring Pt. Description ____________
Screen Setting (ft-bmp) ____________
Casing Diameter (in.) ____________
Well Material ____ PVC ____ SS

Static Water Level (ft-bmp) ____________
Total Depth (ft-bmp) ____________
Water Column (ft) ____________
Gallons in Well ____________

MP Elevation ____________
Pump Intake (ft-bmp) ____________
Purge Method: ____________
Centrifugal ____________
Submersible ____________
Other ____________
Sample Method ____________

Pump On/Off ____________

Sample Time: ____________
Volume Purged ____________
Purge Start ____________
Gallons Purged ____________
Sample ID ____________
Sampled by ____________
Purge End ____________
Replicate/Code No. ____________

Time	Minutes Elapsed	Rate (gpm)/(mL/min) 200mL/min +	Depth to Water (ft) -0.3	Gallons Purged	pH ± 0.1	Cond. (µMhos)/(mS/cm) ± 3%	Turbidity (NTU) ± 10%	DO (mg/L) ± 10%	Temp. (^{o}C)/(^{o}F) ± 3%	Redox (mV) ± 10mV	Appearance	
											Color	Odor
Stabilization Calculations (±)												
Stabilization Criteria					**± 0.1 s.u.**	**±3%**	**± 10% or within 1 NTU [(1)]**	**± 10%**	**±3%**	**±10 mV**		

(1) **Turbidity** < 50 NTU and ±10% or within 1 NTU of a previous reading when <10 NTU

Constituents Sampled	**Container**	**Number**	**Preservative**

Comments ____________

____

Well Casing Volumes

Gallons/Foot	*1" = 0.04*	*1.5" = 0.09*	*2.5" = 0.26*	*3.5" = 0.50*	*6" = 1.47*
	1.25" = 0.06	*2" = 0.16*	*3" = 0.37*	*4" = 0.65*	

Well Information

Well Location: ____________ Well Locked at Arrival: Yes / No

Condition of Well: ____________ Well Locked at Departure: Yes / No

Well Completion: Flush Mount / Stick Up Key Number To Well:

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TGI – Groundwater and Soil Sampling Equipment Decontamination

Rev: 2

Rev Date: June 14, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	February 23, 2017	All	Conversion from SOP to TGI	Cassandra McCloud / Pete Frederick
	1	May 8, 2020	4, 5	Added note regarding use of Liquinox and 1,4-Dioxane	Marc Killingstad
	2	June 14, 2022	All	Conversion to new TGI format and minor edits.	Kevin Engle / Marc Killingstad

Approval Signatures

Prepared by: 6/14/2022

Name (Preparer) Date

Reviewed by: 6/14/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This document is intended to provide guidance to staff performing decontamination procedures at project sites. The content in this document describes the intended use, scope and application, personnel qualifications, equipment, cautions, health and safety considerations, procedures, waste management, data recording and management, and quality assurance of decontamination procedures.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM’s responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project’s scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

Decontamination is performed on sampling equipment prior to sample collection to ensure that the sampling equipment that contacts a sample, or monitoring equipment that is brought into contact with environmental media to be sampled, is free from analytes of interest and/or constituents that could interfere with laboratory analysis for analytes of interest. Sampling equipment must be appropriately cleaned prior to use for sampling or coming into contact with environmental media to be sampled and following completion of the sampling event prior to shipment or storage. The effectiveness of the decontamination procedure should be verified by collecting and analyzing equipment blank samples.

The sampling equipment cleaning procedures described herein includes pre-field, in the field, and post- field cleaning of sampling equipment which may be conducted at an established equipment decontamination area (EDA) on site, as appropriate and necessary. Sampling equipment that may require decontamination at a given site include soil sampling tools; groundwater, sediment, and surface-water sampling devices; water testing instruments; down-hole instruments; and other activity-specific sampling equipment. Non-disposable equipment will be cleaned before collecting each sample, between each sample collected, and prior to placing sampling equipment in protective cases, or containers for transport. Cleaning procedures for sampling equipment should be monitored by collecting equipment blank samples as required in project work plans, field sampling plans, quality assurance project plans (QAPP), or other pertinent project documents. Dedicated and/or single-use (i.e., not to be re-used) sampling equipment will not require decontamination.

4 Personnel Qualifications

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations, such as 40-hour hazardous waste operations and emergency response (HAZWOPER) training and/or Occupational Safety and Health Administration (OSHA) HAZWOPER site supervisor training. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and Technical Guidance Instructions (TGIs) and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The project HASP and other documents will identify other training requirements or access control requirements.

5 Equipment List

The equipment required for equipment decontamination is presented below. Note that certain contaminants may require specific materials be used that are not captured in this list. Always review project and contaminant specific TGIs or work plans to ensure proper equipment is utilized. Note for per- and polyfluoroalkyl substances (PFAS) see *TGI – Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*.

- Health and safety equipment, including appropriate personal protective equipment (PPE), as required in the site HASP
- Deionized water that meets the analytical criteria for deionized water with no detectable constituents above the reporting limits for the methods to be used and analytes being analyzed for. Deionized water is used for inorganics, and organic-free water for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, etc.
- Non-phosphate detergent such as Alconox® or, if sampling for phosphorus or phosphorus- containing compounds, Liquinox (or equivalent). NOTE: Liquinox has shown to provide false positives for 1,4-Dioxane and should not be used at sites where that may be a constituent of concern (COC).
- Tap water
- Rinsate collection plastic containers

- Department of Transportation (DOT)-approved waste shipping container(s), as specified in the work plan, field sampling plan, or regulatory requirements if decontamination waste is to be shipped for disposal
- Brushes
- Large heavy-duty garbage bags
- Spray bottles
- (Optional) – Isopropyl alcohol (free of ketones) or methanol. These can be wipes or diluted with water (usually 1part isopropyl/methanol to 10 parts water) if a spray is needed.
- Airtight, sealable plastic baggies, such as Ziploc®-type
- Plastic sheeting

6 Cautions

Rinse equipment thoroughly and allow the equipment to dry before re-use or storage to prevent introducing solvent into sample medium. If manual drying of equipment is required, use clean lint-free material to wipe the equipment dry. Ensure all rinse materials do not adversely affect sample collection efficiency or analytical results.

Store decontaminated equipment in a clean, dry environment. Do not store near combustion engine exhausts. Properly containerize equipment to ensure cross-contamination doesn't happen from other uncontaminated surfaces or equipment.

If equipment is damaged to the extent that decontamination is uncertain due to cracks, gouges, crevices, or dents, the equipment should not be used and should be discarded or submitted for repair prior to use for sample collection.

A proper shipping determination regarding hazardous materials will be performed by a DOT-trained individual for cleaning materials shipped by Arcadis.

Caution should be exercised to avoid contact with the pump casing and water in the container while the pump is running (do not use metal drums or garbage cans) to avoid electric shock.

7 Health and Safety Considerations

Review the safety data sheets (SDS) for the cleaning agents and materials used in decontamination. If solvent is used during decontamination, use appropriate PPE and work in a well-ventilated area and stand upwind while applying solvent to equipment. Apply solvent in a manner that minimizes potential for exposure to workers and bystanders. Follow health and safety procedures outlined in the HASP.

8 Procedure

A designated area will be established to clean sampling equipment in the field prior to and following sample collection. Equipment cleaning areas will be set up within or adjacent to the specific work area, but not at a location that expose equipment to contamination (i.e., exposed to combustion engine exhaust). Detergent solutions will be prepared in clean containers for use in equipment decontamination. Decontaminated equipment will be handled by workers wearing clean gloves, properly changed to prevent cross-contamination. The procedures detailed in this section provide an overview of common decontamination techniques. Additional steps may be required based on the type of contaminant present or client/site requirements.

Cleaning Sampling Equipment

1. Wash the equipment/pump with potable water.
2. Wash with detergent solution (Alconox®, Liquinox® or equivalent) to remove all visible particulate matter and any residual oils or grease. NOTE: Liquinox® has shown to provide false positives for 1,4-Dioxane and will not be used at sites where that may be a COC.
3. If equipment is very dirty, precleaning gross debris with a brush and tap water may be necessary.
4. If non-aqueous phase liquids are present, the use of isopropyl alcohol (free of ketones) or methanol is recommended. Cloth wipes or diluted solution can be used to remove the non-aqueous phase liquids that are hard to remove with detergent solution in step 2. Consult with project manager if non-aqueous phase liquids are present onsite and design an appropriate decontamination procedure that includes step 4.
5. Rinse with deionized water.

Decontaminating Submersible Pumps

Submersible pumps may be used during well development, groundwater sampling, or other investigative activities. The pumps must be cleaned and flushed before and between uses. This cleaning process will consist of an external detergent solution wash and tap water rinse, a flush of detergent solution through the pump, followed by a flush of potable water through the pump. Flushing will be accomplished by using an appropriate container filled with detergent solution and another container filled with potable water. The pump will be be flushed with deionized water as the last step prior to use. The pump will run long enough to effectively flush the pump housing and hose (unless new, disposable hose is used). Disconnect the pump from the power source before handling. The pump and hose will be placed on or in clean polyethylene sheeting to avoid contact with the ground surface.

9 Waste Management

Equipment decontamination rinsate will be managed in conjunction with all other waste produced during the field sampling effort. Waste management procedures are outlined in the work plan or Waste Management Plan (WMP).

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Equipment cleaning and decontamination will be noted during project documentation. Information will include the type of equipment cleaned, the decontamination location, specific procedures utilized, solvents and/or cleaning agents used, source of water, and deviations or omissions from this TGI.

Unusual field conditions should be noted if there is potential to impact the efficacy of the decontamination or subsequent sample collection.

An inventory of the solvents brought on site and used and removed from the site will be maintained in the project documentation. Records will be maintained for solvents used in decontamination, including lot number and expiration date.

Containers with decontamination fluids will be labeled.

11 Quality Assurance

Equipment blanks should be collected to verify that the decontamination procedures are effective in minimizing potential for cross contamination. The equipment blank is prepared by pouring deionized water (or organic-free water, for organic analyses) over the clean and dry tools and collecting the water into appropriate sample containers. Equipment blanks should be analyzed for the same set of parameters that are performed on the field samples collected with the equipment that was cleaned as specified in the sampling and analysis plan. Equipment blanks are collected per equipment set, which represents all the tools needed to collect a specific sample.

12 References

USEPA Region 9 - Field Sampling Guidance #1230, Sampling Equipment Decontamination.

USEPA Region 1 - Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells.

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TGI – Solid Slug Testing

Rev: 5

Rev Date: April 28, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	1				
	2				
	3				
	4	March 5, 2015	All	New TGI template	Everett Fortner Marc Killingstad
	5	April 28, 2022	All	New TGI template; Updates to pneumatic slug testing guidance; Addition of forms	Everett Fortner Marc Killingstad

Approval Signatures

Prepared by:		4/28/2022
	Everett H. Fortner III, PG (Preparer)	Date
Reviewed by:		4/28/2022
	Marc Killingstad, PE (Subject Matter Expert)	Date

1 Introduction

Slug testing is a common field method used for estimating hydraulic conductivity. This Technical Guidance Instruction (TGI) document outlines field procedures for conducting such testing using a solid slug.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

The use of a solid slug allows for both falling- and rising-head slug tests to be completed. Solid slug(s) of a known volume are inserted and removed from the water column in a well in a near-instantaneous manner. The water level response is observed using a data-logging pressure transducer with manual measurement backup or using just a manual water level meter for slow recovering wells with fully submerged screens.

4 Personnel Qualifications

Field personnel performing the testing are required to have the following qualifications:

- Sufficient “hands-on” experience necessary to successfully complete the slug test field work. Training requirements for conducting slug tests including the review of this guidance and other applicable documents related to instrumentation.
- Demonstrate familiarity with the electronic data logging equipment (*see TGI – Water-Level Monitoring Using Data Logging Instruments*).
- Completed current health and safety training in accordance with the project health and safety plan (e.g., 40-hour Hazardous Waste Operations training and site-specific training, as appropriate)

5 Equipment List

The following materials will be available, as required, during slug testing using a solid slug:

- Job safety analysis and site Health and Safety Plan
- Related project-specific requirements and plans
- Personal protective equipment, as required by the site Health and Safety Plan
- Solid slug(s) of known volume
- Pressure transducer and barometric pressure logger (if necessary)
- Pressure transducer software
- Laptop computer, smart device (phone or tablet), and/or data transfer device
- Rope or cables (for deep wells) (chemical resistant, low stretch [stainless steel or Kevlar] is optimal)
- Water level meter
- Measuring tape
- Spring-loaded clamps and zip ties
- Decontamination equipment
- Slug test field form (paper or digital)
- Field tablet and/or daily logs
- Waterproof marker

6 Cautions

- Pressure Transducers/Data Loggers (see TGI – Water-Level Monitoring Using Data Logging Instruments)
    - Ensure that all rental instruments and tapes have been calibrated and checked prior to use.
    - Small-diameter pressure transducers (typically 0.5 to 0.75 in) are available that cover a range of pressures. Install the pressure transducer at a reasonable distance below (approximately 3 to 5 feet) the targeted drawdown estimated for the well to prevent noise. Do not install the pressure transducer closer than 6 inches from the base of the well to eliminate the possibility of fouling the transducer with material accumulated at the bottom of the well. To prevent pressure transducer malfunction or damage, do not submerge pressure transducers in excess of the operating range, and do not insert objects in the sensor opening.

  - For vented pressure transducers/data loggers, test functionality with a field test of readings using a bucket or barrel filled with water. Submerge the pressure transducer, accurately measure the water head above the pressure transducer sensor, and compare the measurement to the reading. If the measurements don't generally agree, there may be an issue with the instrument.
  - Non-vented transducers, which record a combined pressure of barometric and the water column above the pressure transducer, can be tested in the same fashion as the vented pressure transducer (outlined above). The water column above the pressure transducer can be checked by subtracting out current atmospheric pressure.
  - In general, when testing the pressure transducers, check the pressure transducer general response to changing heads by raising the pressure transducer a certain distance, observing the change in head, and then measuring the distance manually. Additionally, water level meters will be in good working condition and calibrated to true depth and ensuring that there are no breaks or splices in the cable.
  - Pressure transducers will be set in the well at least 15 minutes prior to testing to allow to the instrument to thermally equilibrate with groundwater, collect static water-level measurements, and ensure that the pressure transducer cable will not stretch during testing.
  - Logarithmic or head-change settings will not be used to log data, only linear.
  - Prior to testing, secure pressure transducer cables at the wellhead to prevent movement that may affect measurements. Mark a reference point, such as masking tape, on the down-hole transducer cable or securing line and check regularly to detect slippage.
- Data Management
  - Data management is critical to prevent any loss. Use caution not to overwrite any previously recorded files and remember, data backup is always necessary. Multiple tests at the same well do not require for the pressure transducer to be reset and the same log can run throughout the duration of all tests. Always back up data on a laptop computer to a flash drive and keep at different spots (e.g., back pack and glove compartment) or upload data collected via smart device by email or cloud server to reduce the risk of data loss (e.g., computer failure).
- Slug Volume
  - Solid slugs will be calibrated to determine their accurate volume(s) for theoretical displacement. In most cases, rental slugs offer economic and data quality benefits over field-built slugs.
  - When completing baildown or inflow testing, purge or injected volume will need to be measured accurately using a graduated cylinder.
- Initial Displacement and Recovery
  - When performing slug tests, the general rule of thumb for initial displacement is between 1 and 3 feet and/or generally less than 25% of the effective screen length. For high conductivity formations, initial displacements will be small (0.3 – 0.7 ft) to avoid remobilizing fines and to limit turbulence.
  - Water levels will need to be recorded to within 80% to 95% recovery. In addition, duplicate tests will be completed only after the first test has recovered by at least 95%.

- Equipment Care
    - Keep sensitive electronic equipment away from devices that generate significant magnetic fields. For example, do not place pressure transducers near electric power generators or electric pump motors. Likewise, radio signals may cause pressure transducers or computers to malfunction.
- Decontamination
    - Make sure all equipment that enters the test well (slug, water-level meter, pressure transducer) is decontaminated before use. If testing multiple wells, start with the least contaminated and progress to the most contaminated.
- Non-Aqueous Phase Liquids (NAPL)
    - Slug tests are not recommended in wells where Non-Aqueous Phase Liquids are present. Consult TKI Aquifer Testing and Characterization Focus Group lead for guidance.

7 Health and Safety Considerations

The site-specific HASP will be used to ensure that the tests are conducted in a safe manner and will include a Job Safety Analysis (JSA). The following specific health and safety issues will be considered when conducting slug tests:

- Appropriate PPE with minimum of Level D will be worn to avoid contact with site chemicals of concern during slug test.
- Well covers will be carefully removed to avoid potential contact with insects or animals. Well caps will be vented or tethered to avoid potential eye injury in case of gas buildup in the well.

8 Procedure

1. Decontaminate all down-well equipment: pressure transducer and cable, slug(s), rope or cable, water level meter in accordance with project specific requirements. In general, wells will be tested from least contaminated to more contaminated, if possible or applicable.
2. Select a solid slug according to a target initial displacement using the table below. A general guideline is that initial displacements are between 1 and 3 feet, but will depend on the anticipated response (i.e., smaller initial displacements will be chosen for formations with high hydraulic conductivity). When utilizing the FieldNow® – Slug Test Field Log, the bailer size and length and the well diameter can be entered, and a theoretical displacement will be automatically calculated.
3. Measure depth to water and well total depth. Determine the water column length.
    a. Multiple depth to waters will be measured and any trends will be noted.
    b. The "static” depth to water will be representative of the water level after the well equalizes with atmosphere.
4. Review the well construction log to determine screened interval and confirm depth to bottom. If discrepancies exist, consult with project hydrogeologist.
5. Program the pressure transducer to record water levels at the following suggested frequencies. Note that the lithologic descriptions and datalogger memory will be used to select the highest measurement frequency possible.

   a. In hydrogeologic settings where high hydraulic conductivity is expected, water levels will be measured at 0.5-second intervals or the highest frequency available. This measurement frequency will be selected for gravels and sands.
   b. In hydrogeologic settings where low hydraulic conductivity is expected, water levels may be measured at 1second intervals. This measurement frequency will be selected for silts and clays.
6. If applicable, program the barometric pressure logger to record barometric pressure. The logger will be placed in the headspace of an adjacent well, or on grade, adjacent to the well being tested and kept protected from the elements (e.g., rain or sun)
7. Install the pressure transducer deep enough within the water column to not interfere with the testing equipment. Ideally the transducer will be 3 to 5 feet lower than the maximum depth of the slug testing equipment not closer than 6 inches above the well bottom. Remember to use measurements and not the well bottom as silt can clog the pressure transducer sensor. Secure the pressure transducer cable to the well casing or other static object.
8. View the measured water level in real time. Wait for the water levels to stabilize. Note that the temperature of the pressure transducer will require to equilibrate to groundwater temperatures to ensure accurate water-level measurements (at least 15 minutes).
9. After static measurements and equilibration (15 minutes), re-measure the depth to water.
10. Measure the slug and rope assembly length and mark the rope at a length as follows:

    Rope Mark #1 = Depth to Potentiometric Surface from TOC

    Rope Mark #2 = Depth to Potentiometric Surface from TOC + Length of Slug + Safety Factor (Safety Factor = 10% of the Length of Slug)

    When deployed, Rope Mark #2 will be at the well top of casing, and the slug will be totally submerged. If insufficient water column is available to cover the slug assembly top, note the theoretical length of the slug to be inserted into the water column. Upon removal, measure the wet slug length.
11. Slowly insert the slug assembly into the well and stop just above the potentiometric surface Rope Mark #1.
12. With slack in the rope and the slug being suspended above the water column, place the Rope Mark #2 at the top of casing. Clamp the non-slug end of the rope to a static object.
13. Quickly drop the slug into the water column.
14. Observe the water level response on the laptop computer and/or measure depth to water, being careful not to interfere with the pressure transducer cable. Several manual depth to water measurements will be made throughout the test (typically 2 to 3 in the first 30 seconds to 1 minute, one reading a minute for the next 5 to 10 minutes, and every 2 to 5 minutes thereafter). If the water level meter is used as the primary measurement technique, the measurement frequency will need to be increased as practicable.
15. Allow sufficient time for water level to recover to static level. If completing one test (just a falling head test or just a rising head test), then 80% recovery is sufficient. Duplicate tests are highly recommended, and the next test will be completed after the first test has recovered to greater than 95%. A third test at a displacement of twice the initial is recommended.

    Percent Recovery=((current displacement)/(maximum displacement))*100

    This calculation can be used to determine the depth to water that will be needed before conducting a duplicate test. For example, if your theoretical maximum displacement is 1.92 ft and 95% recovery is needed then 1.82 feet of recovery is necessary to conduct a duplicate test which means the depth to water or be less than or equal to 0.10 feet below the static water level.

16. Quickly remove the slug assembly from the water column. The slug assembly will be left in the well above the static water level in order to limit pressure cable disturbance until the testing is complete and the water levels have equilibrated to the target level.
17. Repeat both the falling- and rising-head slug tests for data reproducibility by repeating steps 12 and 13, if applicable. If possible, complete a third test with a slug or combination of slugs that equates to twice or half the volume as the original.
18. Save all data files to the laptop, backup on flash drive or by emailing, and finalize any field notes.
19. Review the data collected to determine the reasonableness of the preliminary results and compare the pressure transducer results to the water level meter results. The observation of apparently anomalous results will be discussed with senior project staff prior to additional testing or leaving the field site. The water level record for each test will show static conditions, the insertion or removal of the slug(s), and the water level response. Make notes on the field form and notebook concerning any irregularities.
20. Decontaminate all down-well equipment in accordance with project plans.

9 Waste Management

Rinse water, PPE, and other waste materials generated during equipment decontamination will be placed in appropriate containers and labeled. Containerized waste will be disposed of, consistent with appropriate waste management procedures for investigation-derived waste.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Field personnel will complete a Slug Test Field Log form for each test. The digital field form is available through the FieldNow® Application titled *FieldNow – Slug Test Field Log*. A hardcopy example is included in the attachments. As previously noted, it is generally recommended to conduct three tests per well (the original displacement, a duplicate, and double original displacement); therefore, one field log will be completed for each test. Multiple tests can be entered into the FieldNow® digital application for each well tested. It is strongly recommended that data be copied to a flash drive or electronically transmitted to the project team as soon as possible to ensure no data loss. Field equipment calibration, decontamination activities, and waste management activities will be recorded in the daily field log.

11 Quality Assurance

Review data collected during field testing to determine reasonableness/quality given site-specific conditions. Again, this can also be completed using the transducer in real-time viewing mode as the test progresses and resulting charts to confirm with project hydrogeologist. Compare the theoretical head displacement calculated from the slug volume or pressure to the observed displacement. If the data are questionable, the field equipment will need to be checked to confirm proper working order and the test may be repeated, if possible. Consult with the project hydrogeologist to work through issues encountered in the field and to help determine test validity. Any issues that may affect the data will be recorded in the daily field log for consideration by the project hydrogeologist.

12 References

Butler, J.J., Jr., 2019. The Design, Performance, and Analysis of Slug Tests (2nd Ed), CRC Press, Boca Raton, 280p.

Butler, J.J. Jr., 2020. Slug Test Strategies for Challenging Conditions. Presentation – Midwest Geosciences Webinar. December.

Kruseman, G.P. and N.A. de Ridder, 1994. Analysis and Evaluation of Pumping Test Data (2nd ed.), Publication 47, Intern. Inst. for Land Reclamation and Improvement, Wageningen, The Netherlands, 370p.

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ARCADIS Design & Consultancy for natural and built assets

TGI - INVESTIGATION-DERIVED WASTE HANDLING AND STORAGE

Rev #: 1

Rev Date: May 15, 2020

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	February 23, 2017	ALL	Conversion from SOP to TGI	Ryan Mattson / Peter Frederick
1	May 15, 2020	ALL	Updated to reflect regulatory changes	

APPROVAL SIGNATURES

Prepared by:	Derrick Maurer	02/23/2017
	Derrick Maurer	Date:
Technical Expert Reviewed by:		05/15/2020
	Ryan Mattson (Technical Expert)	Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

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2 SCOPE AND APPLICATION

The objective of this Technical Guidance Instruction (TGI) is to describe the procedures to manage investigation-derived wastes (IDW), both hazardous and nonhazardous, generated during site activities, which may include, but are not limited to: drilling, trenching/excavation, construction, demolition, monitoring well sampling, soil sampling, decontamination and remediation. For the purposes of this TGI, IDW is considered to be discarded materials which are defined as solid waste by United States Environmental Protection Agency (EPA) standard 40 CFR § 261.2 (which may include liquids, solids, or sludges). IDW may include soil, groundwater, drilling fluids, decontamination liquids, as well as contaminated personal protective equipment (PPE), sorbent materials, construction and demolition debris, and disposable sampling materials. Hazardous or uncharacterized IDW will be collected and staged at the point of generation. Quantities small enough to be containerized in 55-gallon drums will be taken to a designated temporary onsite storage area (discussed in further detail under Drum Storage) pending characterization and disposal. IDW materials will be characterized using process knowledge and appropriate laboratory analyses to determine the waste classification and evaluate proper safe handling and disposal methods.

This TGI describes the necessary equipment, field procedures, materials, regulatory references, and documentation procedures necessary for proper handling and storage of IDW up to the time it is properly transported from the project site and disposed. The procedures included in this TGI for handling and temporary storage of IDW are based on the EPA's guidance document *Guide to Management of Investigation Derived Wastes* (USEPA, 1992). IDW is assumed to be contaminated with the site constituents of concern (COCs) until analytical evidence indicates otherwise. IDW will be managed to ensure the protection of human health and the environment and will comply with all applicable or relevant and appropriate requirements (ARAR). Although not comprehensive, the following laws and regulations on Hazardous Waste Management should be considered as potential ARAR. It is the Arcadis Certified Project Manager (CPM) and/or designated Technical Expert to determine which laws and regulations, at all levels of government, are applicable to each project site and activity falling under this TGI.

Federal Laws and Regulations

- Resource Conservation and Recovery Act (RCRA) 42 USC § 6901-6987.
- Federal Hazardous Waste Regulations 40 CFR § 260-265

Department of Transportation (DOT) Hazardous Materials Transportation 49 CFR

Occupational Safety and Health Administration (OSHA) Regulations 29 CFR

State Laws and Regulations

- To be determined based on location of site and location of treatment, storage, and/or disposal facility (TSDF) to be utilized.

Regional, County, Municipal, and Local Regulations

- To be determined based on location of site and location of treatment, storage, and/or disposal facility (TSDF) to be utilized.

Initial Storage

Pending characterization, IDW will be temporarily stored appropriately within each area of contamination (AOC). Under RCRA, "storage" is defined as the "holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere" (40 CFR § 260.10). The onsite waste staging area will be in a secure and controlled area. Uncharacterized wastes are considered potentially hazardous wastes and must be stored in DOT approved packaging. Liquid wastes must be stored in DOT approved closed head drums or other approved containers (e.g., portable tank containers) that are compatible with the type of material stored therein. Solid materials must be stored in DOT approved open head drums where practicable. Larger quantities of solid IDW can be containerized in bulk containers (such as in a roll-off box). Soil from large excavation projects may be managed in stockpiles with within the AOC and does not need to be containerized until exiting the AOC.

Characterization

Waste characterization can either be based on generator knowledge, such as using historical process knowledge and safety data sheets (SDS), or can be based upon characterization sampling analytical results. IDW typically is not characterized using SDS as it is a mixture of aged chemicals and environmental media. Historical process knowledge should be used to determine if the IDW is a listed hazardous waste (40 CFR § 261.31-33). If the IDW is not a listed hazardous waste, waste characterization can be completed by laboratory analysis of representative samples of the IDW. The laboratory used for waste characterization analysis must have the appropriate state and federal accreditations and may be required to be pre-approved by the Client. IDW will be classified as RCRA hazardous or non-regulated under RCRA based on the waste characterization determination.

If IDW is characterized as RCRA hazardous waste, RCRA and DOT requirements must be followed for packaging, labeling, transporting, storing, and record keeping as described in 40 CFR § 262 and 49 CFR § 171-178. Waste material classified as RCRA nonhazardous may be handled and disposed of as nonhazardous waste in accordance with applicable federal, state, and local regulations.

Storage Time Limitations

Containerized hazardous wastes can be temporarily stored for a maximum of 90 calendar days from the accumulation start date for a large quantity generator or a maximum of 180 calendar days from the accumulation start date for a small quantity generator. Wastes classified as nonhazardous may be handled and disposed of as nonhazardous waste and are not subject to storage time limitations.

This is TGI may be modified by the CPM and/or Technical Expert for a specific project or client program, as required, dependent upon client requirements, site conditions, equipment limitations, or limitations imposed by the procedure. The resulting procedure employed to execute the work will be documented in the project work plans or reports. If changes to the sampling procedures are required due to unanticipated field conditions, the changes will be discussed with the CPM and/or Technical Expert as soon as practicable, and if approved to be performed, be documented.

3 PERSONNEL QUALIFICATIONS

Arcadis field sampling personnel will have current regulatory- and Arcadis-required health and safety training including 40-hour HAZWOPER training, site supervisor training, site-specific training, first aid, and cardiopulmonary resuscitation (CPR), as needed. Personnel handling and packaging hazardous waste and performing hazardous waste characterizations must have RCRA hazardous waste management training per 40 CFR § 264.16. Additional state-specific hazardous waste management training is required in certain states (i.e., California).

Although not common practice, in certain situations Arcadis personnel may sign waste profiles and/or waste manifests on a case by case basis for clients, provided the appropriate agreement is in place between Arcadis and the client documenting that Arcadis is not the generator, but is acting as an authorized representative of the generator. Arcadis personnel who sign waste profiles and/or waste manifests will have both current RCRA hazardous waste management training per 40 CFR § 264.16 and current DOT hazardous materials transportation training per 49 CFR § 172.704. Arcadis field personnel will also comply with client-specific training. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and Technical Guidance Instructions (TGIs) and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The project health and safety plan (HASP) and other documents will identify other training requirements or access control requirements.

4 EQUIPMENT LIST

The Following Materials, as required, will be available for IDW handling and Storage:

- Appropriate personal protective equipment as specified in the Site Health and Safety Plan (HASP)
- DOT approved containers
- Hammer
- Leather gloves
- Drum dolly
- Appropriate drum labels (outdoor waterproof self-adhesive)
- Portable tank container
- Appropriate labeling, packing, chain-of-custody forms, and shipping materials as determined by the CPM and/or Technical Expert.
- Indelible ink and/or permanent marking pens
- Plastic sheeting
- Appropriate sample containers, labels, and forms
- Stainless-steel bucket auger
- Stainless steel spatula or knife
- Stainless steel hand spade
- Stainless steel scoop
- Digital camera
- Field logbook

5 CAUTIONS

Filled drums can be very heavy, become unbalanced, or spill its contents. Therefore, use appropriate moving techniques and equipment for safe handling. Similar media (e.g. soils with other soils; or liquids with other liquids) will be stored in the same drums to aid in sample analysis and disposal. Drum lids must be secured to prevent rainwater from entering the drums and leakage during movement. Drums containing solid material may not contain any free liquids. Waste containers stored for extended periods of time may be subject to deterioration. Drum Over Packs may be used as secondary containment. All drums must be visually inspected for condition to ensure that they are in good condition without visible evidence of rusting, holes, breakage, etc., to prevent potential leakage and facilitate subsequent disposal. All drum lids must be verified as having a properly functioning secured lid prior to use.

6 HEALTH AND SAFETY CONSIDERATIONS

As determined by the site’s known and suspected hazards, appropriate PPE must be worn by all field personnel within the designated work area. Exposure air monitoring may be required during certain field activities as required in the Site Health and Safety Plan. If soil excavation in areas with potentially hazardous contaminants is possible, contingency plans will be developed to address the potential for encountering gross contamination or non-aqueous phase liquids. All excavation activities shall be in compliance with OSHA standard 29 CFR 1926.651 Excavations, and any other applicable regulations.

Arcadis field personnel and subcontractors will be trained in and perform their work in compliance with all applicable federal, state, and local health and safety regulations as well as Arcadis' HASP and applicable Client health and safety requirements.

7 PROCEDURE

Specific waste temporary storage and handling procedures to be used are dependent upon the type of generated waste, including type of media (e.g. soils or free liquids) and constituents of concern. For this reason, IDW can be stored in a secure location onsite in separate 55-gallon storage drums, where solids can be stockpiled onsite (if nonhazardous) and purge water may be stored in portable tank containers. Waste materials such as broken sample bottles or equipment containers and wrappings will be stored in 55-gallon drums unless they were not in contact with sample media.

Management of IDW

Minimization of IDW should be considered by the project team during all phases of the project. Site managers may want to consider techniques such as replacing solvent based cleaners with aqueous-based cleaners for decontamination of equipment, reuse of equipment (where it can be properly decontaminated), limitation of traffic between exclusion and support zones, and drilling methods and sampling techniques that minimize the generation of waste. Alternative drilling and subsurface sampling methods may include the use of small diameter boreholes, as well as borehole testing methods such as a core penetrometer or direct push technique instead of coring.

Drum Storage

Drums containing hazardous waste will be stored in accordance with the requirements of 40 CFR 265 Subpart I (for containers) and 265 Subpart DD (for containment buildings). All 55-gallon drums will be stored at a secure, centralized onsite location that is readily accessible for vehicular pick-up. Drums confirmed as, or assumed to contain hazardous waste will be stored over an impervious surface provided with secondary spill containment. The storage location will, for drums containing liquid, have a containment system that can contain at least the larger of 10% of the aggregate volume of staged materials or 100% of the volume of the largest container. Drums will be closed during storage and be in good condition in accordance with the Guide to Management of Investigation-Derived Wastes (USEPA, 1992).

Hazardous Waste Determination

Waste material must be characterized to determine if it meets any of the federal definitions of hazardous waste as required by 40 CFR § 262.11. If the waste does not meet any of the federal definitions, it must then be established if any state-specific or local-specific hazardous waste criteria exist/apply.

Generator Status

Once hazardous waste determination has been made, the generator status will be determined. Large quantity generators (LQG) are generators who generate more than 1,000 kilograms of hazardous waste in a calendar month. Small quantity generators (SQG) of hazardous waste are generators who generate greater than 100 kilograms but less than 1,000 kilograms of hazardous waste in a calendar month. Very small quantity generators (VSQG) are generators who generate less than 100 kilograms of hazardous waste per month. Please note that a generator status may change from month to month and that a notice of this change is usually required by the generator's state agency.

Accumulation Time for Hazardous Waste

A LQG may accumulate hazardous waste on site for 90 calendar days or less without a permit and without having interim status, provided that such accumulation is in compliance with requirements in 40 CFR § 262.17. A SQG may accumulate hazardous waste on site for 180 calendar days or less without a permit or without having interim status, subject to the requirements of 40 CFR § 262.16. VSQG requirements are found in 40 CFR § 262.14. NOTE: The federal VSQG and SQG provisions may not be recognized by some states (e.g., California and Rhode Island). State-specific and local-specific regulations must be reviewed and understood prior to the generation of hazardous waste.

Satellite Accumulation of Hazardous Waste Satellite accumulation (SAA) will mean the accumulation of as much as fifty-five (55) gallons of hazardous waste, or the accumulation of as much as one quart of acutely hazardous waste, in containers at or near any point of generation where the waste initially accumulates, which is under the control of the operator of the process generating the waste, without a permit or interim status and without complying with the requirements of 40 CFR § 262.15 and without any storage time limit, provided that the generator complies with 40 CFR § 262.15.

Once more than 55 gallons of hazardous waste accumulates in SAA, the generator has three days to move this waste into storage.

Storage recommendations for hazardous waste include:

- Ignitable or reactive hazardous wastes must be >50 feet from the property line per 40 CFR § 265.176 (LQG generators only).
- Hazardous waste should be stored on a concrete slab (asphalt is acceptable if there are no free liquids in the waste).
- Drainage must be directed away from the accumulation area.
- Area must be properly vented.
- Area must be secure.

Drum/Container Labeling

Drums will be labeled on both the side and lid of the drum using a permanent marking pen. Old drum labels must be removed to the extent possible, descriptions crossed out should any information remain, and new labels affixed on top of the old labels. Other containers used to store various types of waste (e.g., polyethylene tanks, roll-off boxes, end-dump trailers, etc.) will be labeled with an appropriate "Waste Container" or “Testing in Progress” label pending characterization. Drums and containers will be labeled as follows:

- Appropriate waste characterization label (Pending Analysis, Hazardous, or Nonhazardous)
- Waste generator's name (e.g., client name)
- Project Name
- Name and telephone number of Arcadis project manager
- Composition of contents (e.g., used oil, acetone 40%, toluene 60%)
- Media (e.g., solid, liquid)
- Accumulation start date

- Drum number of total drums as reconciled with the Drum Inventory maintained in the field log book.

IDW containers will remain closed except when adding or removing waste. Immediately upon beginning to place waste into the drum/container, a “Waste Container” or “Pending Analysis” label will be filled out to include the information specified above, and affixed to the container. Once the contents of the container are identified as either non-hazardous or hazardous, the following additional labels will be applied.

- Containers with waste determined to be non-hazardous will be labeled with a green and white "Nonhazardous Waste" label over the "Waste Container" label.
- Containers with waste determined to be hazardous will be stored in an onsite storage area and will be labeled with the "Hazardous Waste" label and affixed over the "Waste Container" label.

The ACCUMULATION DATE for the hazardous waste is the date the waste is first placed in the container and is the same date as the date on the "Waste Container" label. DOT hazardous class labels must be applied to all hazardous waste containers for shipment offsite to an approved disposal or recycling facility. In addition, a DOT proper shipping name will be included on the hazardous waste label. The transporter should be equipped with the appropriate DOT placards. However, placarding or offering placards to the initial transporter is the responsibility of the generator per 40 CFR § 262.33.

Inspections and Documentation

All IDW will be documented as generated on a Drum Inventory Log maintained in the field log book. The Drum Inventory will record the generation date, type, quantity, matrix and origin (e.g., Boring-1, Test Pit 3, etc.) of materials in every drum, as well as a unique identification number for each drum. The drum inventory will be used during drum pickup to assist with labeling of drums. The drum storage area and any other areas of temporarily staged waste, such as soil/debris piles, will be inspected weekly. The weekly inspections will be recorded in the field notebook or on a Weekly Inspection Log. Digital photographs will be taken upon the initial generation and drumming/staging of waste, and final labeling after characterization to document compliance with labeling and storage protocols, and condition of the container. Evidence of damage, tampering or other discrepancy should be documented photographically.

Emergency Response and Notifications

Specific procedures for responding to site emergencies will be detailed in the HASP. If the generator is designated as a LQG, a Contingency Plan will need to be prepared to include emergency response and notification procedures per 40 CFR § 265 Subpart D. In the event of a fire, explosion, or other release which could threaten human health outside of the site or when Client or Arcadis has knowledge of a spill that has reached surface water, Client or Arcadis must immediately notify the National Response Center (800-424-8802) in accordance with 40 CFR § 262.265. Other notifications to state and/or other local regulatory agencies may also be necessary.

Drilling Soil Cuttings and Muds

Soil cuttings are solid to semi-solid soils generated during trenching activities, subsurface soil sampling, or installation of monitoring wells. Depending on the drilling method, drilling fluids known as "muds" may be used to remove soil cuttings. Drilling fluids flushed from the borehole must be directed into a settling section of a mud pit. This allows reuse of the decanted fluids after removal of the settled sediments. Soil cuttings will be labeled and stored in 55-gallon drums with bolt-sealed lids.

Excavated Solids

Excavated solids may include, but are not limited to: soil, fill, and construction and demolition debris. Prior to permitted treatment or offsite disposal, potentially hazardous excavated solids may be temporarily stockpiled onsite as long as the stockpile remains in the same AOC from where it was excavated. Potentially hazardous excavated solids removed from the AOC must be immediately containerized in labeled drums or closable top roll-offs lined with 9-mil polyvinyl chloride (PVC) sheeting and are subject to LQG storage time limits. Nonhazardous excavated solids can be stockpiled either inside or outside of the AOC, do not have to be containerized and are not subject to hazardous waste regulations. Potentially hazardous excavated solids must not be mixed with nonhazardous excavated solids. All classes of excavated solid stockpiles should be maintained in a secure area onsite. At a minimum, the floor of the stockpile area will be covered with a 20-mil high density polyethylene liner that is supported by a foundation or at least a 60-mil high density polyethylene liner that is not supported by a foundation. The excavated material will not contain free liquids. The owner/operator will provide controls for windblown dispersion, run-on control, and precipitation runoff. The run-on control system will prevent flow onto the active portion of the pile during peak discharge from at least a 25-year storm and the run-off management system will collect and control at least the water volume resulting from a 24-hour, 25-year storm (USEPA, 1992). Additionally, the stockpile area will be inspected on a weekly basis and after storm events. Individual states may require that the stockpile be inspected/certified by a licensed professional engineer. Stockpiled material will be covered with a 6-mil polyvinyl chloride (PVC) liner or sprayed dust control product. The stockpile cover will be secured in place with appropriate material (concrete blocks, weights, etc.) to prevent the movement of the cover.

Decontamination Solutions

Decontamination solutions are generated during the decontamination of personal protective equipment and sampling equipment. Decontamination solutions may range from detergents, organic solvents and acids used to decontaminate small field sampling equipment to steam cleaning rinsate used to wash heavy field equipment. These solutions are to be labeled and stored in closed head drums compatible with the decontamination solution. Decontamination procedures, including personnel and field sampling equipment, must comply with applicable Arcadis procedural documents.

Disposable Equipment

Disposable equipment includes personal protective equipment (e.g., tyvek coveralls, gloves, booties and APR cartridges) and disposable sampling equipment such as trowels or disposable bailers. If the media sampled exhibits hazardous characteristics per results of waste characterization sampling, contaminated disposable equipment will also be disposed of as a hazardous waste. If compatible with the original IDW waste stream (i.e., the IDW is a solid and the disposal equipment is a solid), the disposable equipment can be combined with the IDW. If these materials are not compatible (i.e., the IDW is a liquid and the disposal equipment is a solid), the disposable equipment will be stored onsite in separate labeled 55-gallon drums. Uncontaminated or decontaminated disposable equipment can be considered nonhazardous waste.

Purge Water

Purge water includes groundwater generated during well development, groundwater sampling, or aquifer testing. The volume of groundwater generated will dictate the appropriate storage procedure. Monitoring well development and groundwater sampling may generate three well volumes of groundwater or more. This volume will be stored in labeled 55-gallon drums. Aquifer tests may generate significantly greater volumes of groundwater depending on the well yield and the duration of the test. Therefore, large-volume portable polyethylene tanks will be considered for temporary storage pending groundwater-waste characterization.

Purged Water Storage Tank Decontamination and Removal

The following procedures will be used for inspection, cleaning, and offsite removal of storage tanks used for temporary storage of purge water. These procedures are intended to be used for rented portable tanks such as Baker Tanks or Rain for Rent containers. Storage tanks will be made of inert plastic materials. The major steps for preparing a rented tank for return to a vendor include characterizing the purge water, disposing of the purge water, decontaminating the tank, final tank inspection, and mobilization. Decontamination and inspection procedures are described in further detail below.

- Tank Cleaning: Most vendors require that tanks be free of any visible sediment and water before returning, a professional cleaning service may be required. Each specific vendor should be consulted concerning specific requirements for returning tanks.
- Tank Inspection: After emptying the tank, purged water storage tanks should be inspected for debris, chemical staining, and physical damage. The vendors require that tanks be returned in the original condition (i.e., free of sediment, staining and no physical damage).

8 WASTE MANAGEMENT

Soil/Solids Characterization

Waste characterization will be conducted in accordance with waste hauler, waste handling facility, and local/state/federal requirements. In general, RCRA hazardous wastes are those solid wastes determined by a Toxicity Characteristic Leaching Procedure (TCLP) test or to contain levels of certain toxic metals, pesticides, or other organic chemicals above specific applicable regulatory agency thresholds. If the one or more of 40 toxic compounds listed in Table I of 40 CFR § 261.24 are detected in the sample at levels above the maximum unregulated concentrations, the waste must be characterized as a toxic hazardous waste. Wastes can also be considered “listed” hazardous waste depending on site-specific processes.

Composite soil samples will be collected at a frequency of one sample per 250 cubic yard basis for stockpiled soil or one per 55-gallon drum per different waste stream for containerized. A four-point composite sample will be collected per 250 cubic yards of stockpiled material and for each drum waste stream. Sample and composite frequencies may be adjusted in accordance with the waste handling facility’s requirements and may be reduced for large volumes of waste with consistent properties. Waste characterization samples will be considered valid for consistent waste streams for a period of 1 year. Waste characterization samples may be analyzed for the TCLP volatile organic compounds (VOCs), TCLP semi-volatile organic compounds (SVOCs), TCLP RCRA metals, and polychlorinated biphenyls (PCBs), as well as reactivity and flammability (flashpoint). Additional samples may be collected and analyzed by the laboratory on a contingency basis. Site-specific constituents of concern including pesticides may require additional sampling. Please note that state- or local-specific regulations may require a different or additional sampling approaches.

Wastewater Characterization

Waste characterization will be conducted in accordance with the requirements of the waste hauler, waste handling facility, and local/state/federal governments. In general, purge water should be analyzed by methods appropriate for the known contaminants, if any, that have been historically detected in the monitoring wells. Samples will be collected and analyzed in accordance with the requirements of the waste disposal facility. Wastewater characterization samples may be analyzed for TCLP volatile organic compounds (VOCs), TCLP semi-volatile organic compounds (SVOCs), TCLP RCRA metals, and polychlorinated biphenyls, as well as corrosivity (pH), reactivity and flammability (flashpoint). Additional samples may be collected and analyzed by the laboratory on a contingency basis. Site-specific constituents of concern including pesticides may require additional sampling. Please note that state- and/or local-specific regulations may require different or additional sampling approaches.

Sample Handling and Shipping

All samples will be appropriately labeled, packed, and shipped, and the chain-of-custody will be filled out in accordance with current Arcadis sample chain of custody, handling, packing, and shipping procedures and guidance instructions.

It should be noted that additional training is required for packaging and shipping of hazardous and/or dangerous materials. Please refer to the current Arcadis training requirements related to handling and shipping of samples, shipping determinations, and hazardous materials.

Preparing Waste Shipment Documentation (Hazardous and Nonhazardous)

Waste profiles will be prepared by the Arcadis CPM and forwarded, along with laboratory analytical data to the Client for approval/signature. The Client will then return the profile to Arcadis who will then forward to the waste removal contractor for preparation of a manifest. The manifest will be reviewed by Arcadis prior to forwarding to the Client for approval. Upon approval of the manifest, the Client will return the original signed manifest directly to the waste contractor or to the Arcadis CPM for forwarding to the waste contractor. Arcadis personnel may sign waste profiles and/or waste manifests on a case by case basis for clients, provided the appropriate agreement is in place between Arcadis and the client documenting that Arcadis is not the generator, but is acting as an authorized representative of the generator.

Final drum labeling and pickup will be supervised by an Arcadis representative who is trained and experienced with applicable waste labeling procedures. The Arcadis representative will have a copy of the drum inventory maintained in the field book and will reconcile the drum inventory with the profile numbers on the labels and on the manifest. Different profile numbers will be generated for different matrices or materials in the drums. For example, the profile number for drill cuttings will be different than the profile number for purge water. When there are multiple profiles it is critical that the proper label, with the profile number appropriate to a specific material be affixed to the proper drums. A copy of the Arcadis drum inventory will be provided to the waste transporter during drum pickup and to the facility receiving the waste.

9 DATA RECORDING AND MANAGEMENT

Waste characterization sample handling, packing, and shipping procedures will be documented in accordance with relevant Arcadis procedures and guidance instructions as well as applicable client and/or project requirements, such as a Quality Assurance Project Plan or Sampling and Analysis Plan. Copies of the chain-of-custody forms will be maintained in the project file. Arcadis should photograph or maintain a copy of any hazardous waste manifest signed on behalf of Client in the corresponding office DOT record file.

10 QUALITY ASSURANCE

The CPM or APM will review all field documentation once per week for errors or omissions as compared to applicable project requirements including but not limited to: the proposal/scope of work, QAPP, SAP, HASP, etc. Deficiencies will be noted, tracked, and resolved. Upon correction, they will be noted for project documentation.

11 REFERENCES

United States Environmental Protection Agency (USEPA). 1992. Guide to Management of Investigation-Derived Wastes. Office of Remedial and Emergency Response. Hazardous Site Control Division. January 1992.

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