ARCADIS U.S., Inc.
1100 Olive Way
Suite 800
Seattle
Washington 98101
Tel 206 325 5254
Fax 206 325 8218
www.arcadis-us.com

Environment

Ms. Maura O'Brien
Toxics Cleanup Program – NWRO
Washington State Department of Ecology
3190 – 160th Avenue SE
Bellevue, WA 98008-5452

Subject:
Work Plan for Additional Well Installation in Former Trench D Area and Offsite Area
Former Unocal Seattle Marketing Terminal
3001 Elliott Avenue
Seattle, Washington

Date:
May 14, 2015

Contact:
Rebecca K. Andresen

Phone:
206.726.4717

Email:
Rebecca.andresen@arcadis-us.com

Our ref:
B0045363.0006

Dear Ms. O'Brien:

On behalf of Chevron Environmental Management Company (Chevron), ARCADIS U.S., Inc. (ARCADIS) prepared this Work Plan for Additional Well Installation in Former Trench D Area and Offsite Area (work plan) for the former Unocal Seattle Marketing Terminal located at 3001 Elliott Avenue in Seattle, Washington (site). The site location and surrounding area are presented on Figure 1. This work plan presents the procedures that will be used to install and sample up to six monitoring wells.

Background

On behalf of Unocal, Chevron is conducting cleanup work at the site as required by Order on Consent DE88-N223 and Amendments 1 through 5 (Order; Unocal and Washington State Department of Ecology [Ecology] 1988). As described in Amendment No. 4 to the Order (Unocal and Ecology 1995), the site comprises four areas: Upper Yard, Elliott Avenue, Lower Yard, and Offsite Area.

The Upper Yard and Lower Yard were sold by Unocal to the Trust for Public Land for the Seattle Art Museum (SAM) in 1999. In 2004, SAM began construction for redevelopment of the property, including the Offsite Area (which is owned by the City of Seattle Parks and Recreation), as the Olympic Sculpture Park (OSP). SAM entered a Prospective Purchaser Agreement with Ecology. As part of the agreement, SAM submitted remediation design reports to Ecology for the OSP. In a letter dated January 17, 2008, Ecology indicated that the terms of the Prospective Purchaser

Agreement were satisfied. A Stipulation and Order of Dismissal (No. 99-2-50226-4SEA) was issued on October 31, 2008.

In July 2012, Chevron proposed an amendment to the Order, which included a recommendation to decommission the Trench D recovery wells, located along the Burlington Northern Santa Fe (BNSF) right of way (ROW), and to install up to five monitoring wells in the Trench D area. Prior to decommissioning, light nonaqueous phase liquid (LNAPL) was detected in five of the recovery wells and piezometers associated with Trench D. The Trench D recovery wells were decommissioned from February through June 2014 with Ecology approval (email correspondence, July 29, 2013). Locations for five monitoring wells were proposed to evaluate the presence of LNAPL and to assess concentrations of dissolved-phase constituents of concern (COCs) in the former Trench D area and downgradient of the former Trench D area.

Monitoring Well Installations

ARCADIS proposes to install six monitoring wells. Proposed locations are based on the presence of LNAPL as measured in February, May, and June 2014 during Trench D decommissioning activities and were refined based on input and requests from Ecology and interested stakeholders. The monitoring wells are positioned to further evaluate the presence of LNAPL in the former Trench D area, facilitate collection of current dissolved-phase COC data in the Trench D area, and evaluate potential dissolved-phase COC concentrations downgradient of Trench D in the Offsite Area. Proposed well locations were also selected based on the presence of known utilities in both the former Trench D and Offsite Areas. The new monitoring wells (MW-208 through MW-212 and MW-70R) are proposed adjacent to the former Trench D piezometers and recovery wells PZ-4.5, RW-7, and PZ-8.5, and downgradient of former Trench D piezometers PZ-10.5, PZ-11.5, and PZ-13 as shown on Figure 1.

Four wells (MW-208 through MW-211) will be installed in the BNSF ROW, and two additional monitoring wells (MW-212 and MW-70R) will be installed in the Offsite Area (Figure 1). Placement of the monitoring wells in the Offsite Area was based on proximity to well locations in the BNSF ROW known to have contained LNAPL, and the presence of utilities, based on as-built drawings provided by SAM. Proposed monitoring well MW-70R has been moved further west, close to the former location of MW-70, due to the presence of multiple underground utility conduits. The proposed location near former well MW-70 was also selected based on input from ARCADIS' subcontracted driller during a site visit based on equipment logistical constraints. Known utilities in the Offsite Area relative to MW-212 and MW-70R are shown on Figure 2. The wells will be installed to an approximate depth of 15 feet below ground surface (bgs). Monitoring well locations may be adjusted in the field depending on actual site conditions; monitoring wells will not be installed within 5 feet laterally of marked utilities.

Monitoring well locations will be cleared to a minimum depth of approximately 8 feet bgs to assure clearance of any potential underground utilities prior to drilling. The proposed monitoring wells will then be installed using a small-footprint hollow-stem auger drill rig. Collection of soil samples during well installation is described in the following section.

Upon reaching the proposed depth of each monitoring well location, the wells will be constructed with 10 feet of 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) with 0.020-inch slotted well screen and completed with 2-inch-diameter Schedule 40 blank PVC riser. Each well will have a sand pack of 10/20 silica sand from the total depth of the well to at least 1 foot above the screened interval. Above each sand pack will be at least a 6-inch seal of hydrated bentonite, and each well will be completed to the surface with concrete, a flush-mount traffic-rated well monument, and locking well cap.

After installation, each monitoring well will be developed via surge and purge methods using bailers. A disposable bailer will be surged along the entire length of the well screen, and a minimum of 10 pore volumes of water will be removed from each well. Purge water will be temporarily stored in 55-gallon drums pending characterization and disposal. The monitoring wells will be surveyed by a surveyor, licensed in Washington, for horizontal location and vertical elevation of the well casing. The proposed replacement monitoring wells will be incorporated into a quarterly groundwater monitoring program.

Soil Core Sample Collection – Former Trench D Area

During monitoring well installation activities, ARCADIS proposes to collect undisturbed soil cores to provide site-specific petrophysical data to evaluate the potential mobility of LNAPL remaining in the former Trench D Area. The undisturbed soil cores will be collected from wells MW-208 through MW-211.

The soil core samples will be collected in a manner that preserves the pore geometry and maintains the in-situ pore fluid content within the sample to the greatest possible degree. Procedures for collection, handling, and shipping of LNAPL mobility sample cores are summarized below and presented in detail in the ARCADIS Standard Operating Procedure (SOP) for Light Nonaqueous Phase Liquid Soil Core Collection, which is included as Appendix A. The geology in the area of the proposed soil core collection points was reviewed in conjunction with this SOP to select the most appropriate soil core collection method.

The soil borings will be cleared using a combination of a hand auger and an air knife to an approximate depth of 8 feet bgs to assure clearance from underground utilities. During hand clearing, a hand auger will be advanced ahead of the air knife to collect soil samples at approximately 1-foot intervals, to a depth of 8-feet bgs. Based on field screening with a PID and estimated depth to the water table, samples within the smear zone will be submitted to Eurofins Lancaster Laboratories (Lancaster), located in Lancaster, Pennsylvania for analysis. The samples will be analyzed to determine concentrations of volatile petroleum hydrocarbons (VPH) by Method Northwest volatile petroleum hydrocarbon (NWVPH) and extractable petroleum hydrocarbons (EPH) by Method Northwest extractable petroleum hydrocarbon (NWEPH).

Below a depth of 8 feet, Shelby tube samplers will be used to collect an undisturbed soil core across the LNAPL/groundwater interface. Four thin-walled soil core samplers will be advanced per well location over an 8-foot sample interval. The water table is expected to be encountered at the monitoring well locations at depths of 7 to 8 feet bgs. Tidal influence in this area of the site is minimal. Depending on the depth to water, sample collection using the Shelby tube samplers may start at or near the water table. Collection of the VPH and EPH samples above the water table will allow for comparison of potential LNAPL smear above a depth of 8 feet bgs. The undisturbed soil core samples will remain in the vertical orientation while flash-freezing with dry ice. Soil core samples will be placed on fresh dry ice and shipped to PTS Laboratory in Santa Fe, California via overnight shipping.

Offsite Area

Analytical soil sample collection is not proposed for the two monitoring wells proposed in the Offsite Area. Historical dissolved-phase concentrations in this area do not suggest the presence of LNAPL. These wells will monitor for potential migration of COCs from the former Trench D Area.

Groundwater Monitoring

Groundwater samples will be collected from the newly installed wells following development. Existing monitoring wells (MW-30, MW-61A-R, and MW-200 through MW-207) will be sampled during the regularly scheduled semiannual monitoring event in June 2015. It is expected that installation and sampling of the new wells will occur in early third quarter 2015.

Prior to sampling, ARCADIS will conduct a comprehensive groundwater gauging event at the site. During this event, all site wells (including the newly installed and previously existing wells) will be gauged to determine depth to water and LNAPL, if present.

Following gauging, the newly installed monitoring wells will be purged and sampled with a peristaltic pump in general accordance with the procedures outlined in the SOP for Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells (Appendix B). New, disposable Teflon®-lined polyethylene tubing will be used for sampling. At the request of site stakeholders and with Ecology's concurrence (email correspondence, August 11, 2011), tubing placement will deviate from the specifications in the SOP; tubing will be placed within 6 inches of the groundwater surface in each monitoring well. Water quality parameters including temperature, pH, electrical conductivity, dissolved oxygen, and oxidation-reduction potential will be measured approximately every 3 minutes using an In-Situ® Troll 9500 low-flow groundwater sampling system.

Samples will be collected in clean, laboratory-supplied containers with appropriate preservatives and stored in coolers with ice. Samples will be delivered via overnight delivery, under chain of custody procedures, to Lancaster. Groundwater samples will be analyzed for the following:

- Total petroleum hydrocarbons (TPH) as gasoline by NWTPH-Gx, extended range

- TPH as diesel and TPH as heavy oil by NWTPH-Dx, extended range with silica gel cleanup

- Benzene, toluene, ethylbenzene, and xylenes by United States Environmental Protection Agency (USEPA) Method 8021B

- Benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene, collectively referred to as carcinogenic polycyclic aromatic hydrocarbons, by USEPA Method 8270C SIM

Management of Investigative-Derived Waste

Drill cuttings, purge water, and decontamination water generated during drilling and sampling activities will be temporarily stored along the retaining wall on the BNSF ROW in labeled 55-gallon steel drums pending characterization. The drums will be transported for disposal by Waste Management, Inc.

Reporting and Schedule

BNSF requires review of this work plan before initiating the field activities. This work plan will be forwarded to BNSF for review and acceptance concurrently with submittal to Ecology. Field activities will begin following acceptance of this work plan by Ecology and BNSF. ARCADIS will coordinate with the SAM to schedule the field activities for a time that will minimize disruption to planned OSP activities and will procure a permit from Seattle Department of Parks and Recreation for use of park pathways to access the site.

A tentative start date of June 15 is planned, pending work plan approval, subcontractor coordination, and permit approval.

A report will be prepared after completing the proposed activities and upon receipt of the final analytical data. The report will summarize the field activities, measurements collected during the activities, and laboratory analytical data.

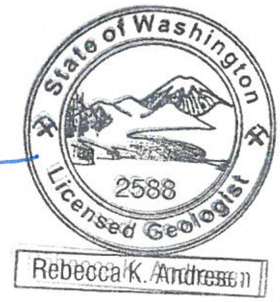
If you have any questions or require additional information, please contact Rebecca Andresen with ARCADIS at 206.726.4717.

Sincerely,

ARCADIS U.S., Inc.

Samuel Miles
Staff Environmental Scientist

Rebecca K. Andresen, L.G.
Associate Vice President



References

Ecology. 2008. Letter dated January 17, 2008. Satisfaction of Prospective Purchaser Decree No. 99-2-50226-4 SEA, The Former Unocal Seattle Marketing Terminal Property, Seattle, Washington.

Unocal and Ecology. 1988. Order on Consent. In the Matter of: Union Oil Company of California, d/b/a Unocal, No. Order on Consent. December 3, 1988.

Unocal and Ecology. 1995. Amendment No. 4 to the Order. In the Matter of: Union Oil Company of California, d/b/a Unocal, No. DE 88-N223, Amendment No. 4 to Order on Consent. May 10, 1995.

Enclosures:

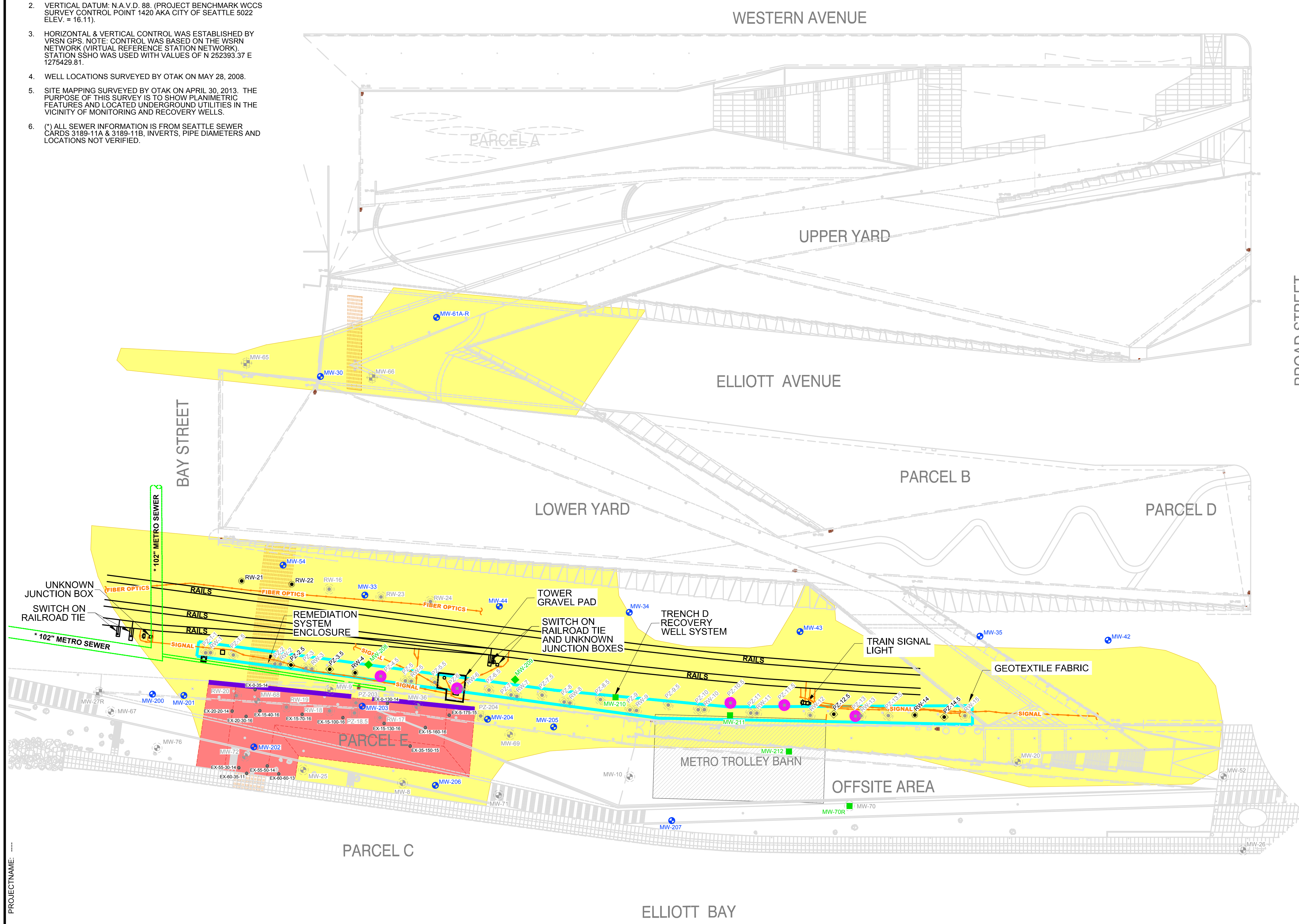
Figure 1	Proposed Monitoring Well Location Map
Figure 2	Utility Location Map
Appendix A	ARCADIS Standard Operating Procedure for Light Nonaqueous Phase Liquid Soil Core Collection
Appendix B	ARCADIS Standard Operating Procedure for Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells

Copies:
Kim Jolitz – Chevron
Mark Mazzola – City of Seattle
Tad Shimazu – City of Seattle
Richard Beckerman – SAM
Janet Knox – Pacific Groundwater Group
BNSF

CITY: SAN RAFAEL, CA (PETALUMA) DIV/GROUP: ENVCAD DB: J. HARRIS
C:\Users\jharris\Desktop\ENVCAD\B0045363\0007\00003\DWG\45363V01.dwg LAYOUT: 1 SAVED: 5/6/2015 9:31 PM ACADVER: 19.1S (LMS TECH) PAGESETUP: SETUP4 PLOTSTYLETABLE: ARCADIS.CTB PLOTTED: 5/13/2015 3:23 PM BY: HARRIS, JESSICA
XREFS: 45363X01 IMAGES: PROJECTNAME: ----

NOTES:

1. HORIZONTAL DATUM: WASHINGTON COORDINATE SYSTEM NORTH ZONE (NAD 83/98).
2. VERTICAL DATUM: N.A.V.D. 88. (PROJECT BENCHMARK WCCS SURVEY CONTROL POINT 1420 AKA CITY OF SEATTLE 5022 ELEV. = 16.11).
3. HORIZONTAL & VERTICAL CONTROL WAS ESTABLISHED BY VRSN GPS. NOTE: CONTROL WAS BASED ON THE WSRN NETWORK (VIRTUAL REFERENCE STATION NETWORK). STATION SSHO WAS USED WITH VALUES OF N 252393.37 E 1275429.81.
4. WELL LOCATIONS SURVEYED BY OTAK ON MAY 28, 2008.
5. SITE MAPPING SURVEYED BY OTAK ON APRIL 30, 2013. THE PURPOSE OF THIS SURVEY IS TO SHOW PLANIMETRIC FEATURES AND LOCATED UNDERGROUND UTILITIES IN THE VICINITY OF MONITORING AND RECOVERY WELLS.
6. (*) ALL SEWER INFORMATION IS FROM SEATTLE SEWER CARDS 3189-11A & 3189-11B, INVERTS, PIPE DIAMETERS AND LOCATIONS NOT VERIFIED.



LEGEND

- MONITORING WELL (MW-35)
- RECOVERY WELL (RW-14)
- PIEZOMETER (PZ-14.5)
- CONFIRMATION SOIL SAMPLE LOCATION (EX-20-20-14)
- PROPOSED WELL LOCATION (MW-208)
- WELL DECOMMISSIONED
- SHORING WALL
- EXISTING PIPING CORRIDOR
- 2005 HOT SPOT EXCAVATION AREA
- RAILROAD SIGNAL LINE (SIGNAL)
- FIBER OPTIC LINE (FIBER OPTICS)
- UTILITY CONTINUES BUT WAS NOT SURVEYED
- STORM DRAIN LINE
- TRENCH D AREA
- APPROXIMATE AREA OF PETROLEUM CONTAMINATED SOIL (GEOENGINEERS 1997)
- MEASURABLE LIGHT NON-AQUEOUS PHASE LIQUID (LNAPL) DETECTED IN 2014

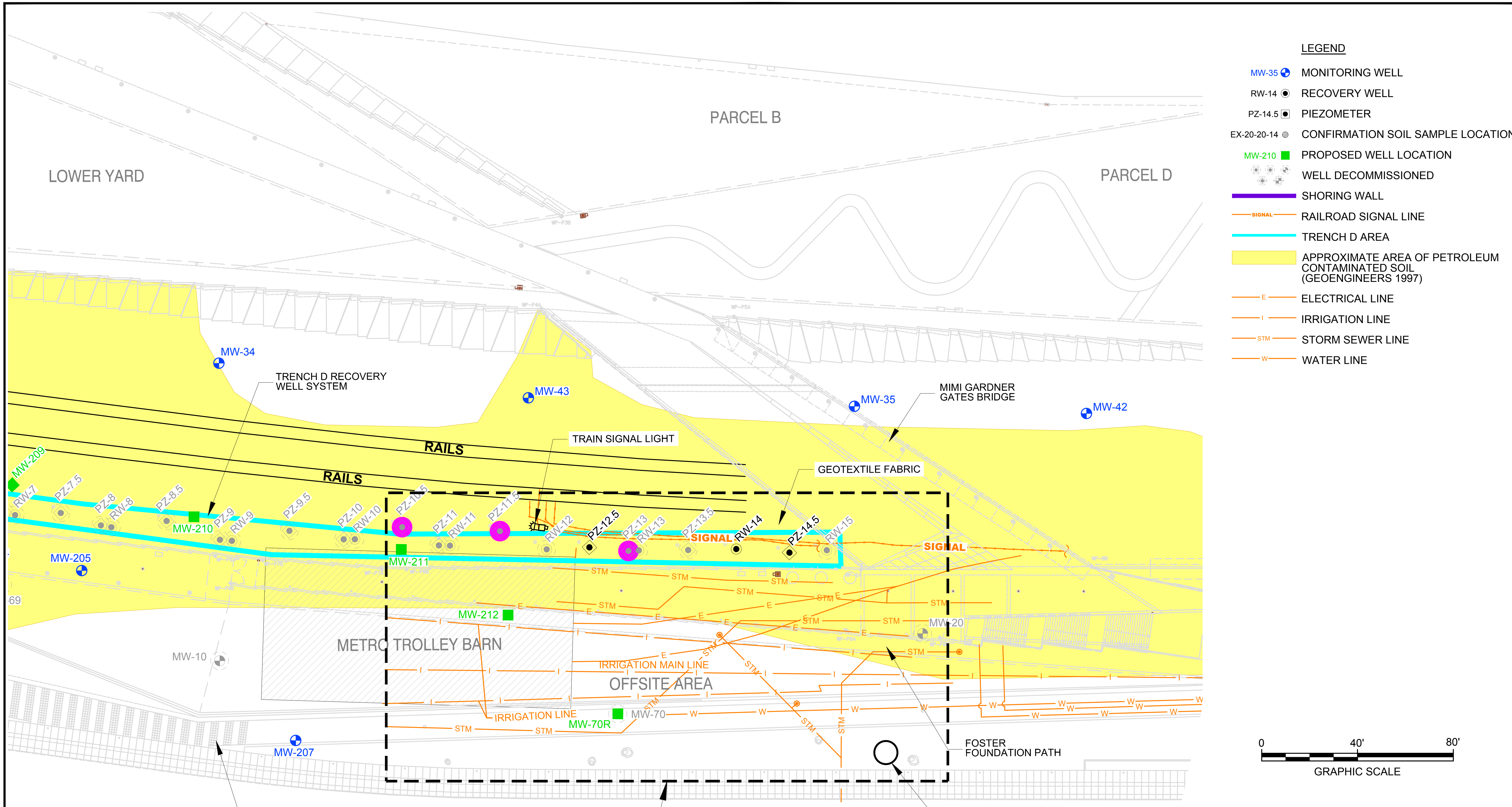
0 80' 160'
GRAPHIC SCALE

FORMER UNOCAL SEATTLE MARKETING TERMINAL
SEATTLE, WASHINGTON

PROPOSED MONITORING WELL LOCATION MAP

ARCADIS

FIGURE
1



NOTE:

UTILITY LOCATIONS ARE APPROXIMATE AND ARE BASED ON IMAGES PROVIDED BY SEATTLE ART MUSEUM.

FORMER UNOCAL SEATTLE MARKETING TERMINAL
SEATTLE, WASHINGTON

UTILITY LOCATION MAP

ARCADIS

FIGURE 2

CITY: SAN RAFAEL, CA (PETALUMA) DIV/GROUP: ENVCAD DB: J. HARRIS LAYOUT: 2 SAVED: 5/6/2015 9:31 PM ACADVER: 19.1S (LMS TECH) PAGESETUP: SETUP4 PLOTSTYLETABLE: ARCADIS.CTB PLOTTED: 5/13/2015 3:23 PM BY: HARRIS, JESSICA

ARCADIS

Appendix A

Standard Operating Procedure for Light Nonaqueous Phase Liquid Soil Core Collection

ARCADIS
Infrastructure, environment, buildings

Imagine the result

Standard Operating Procedure for Light Nonaqueous Phase Liquid Soil Core Collection

Rev. #: 1

Rev Date: March 25, 2009

Approval Signatures

Prepared by: ______________________ Date: 3/25/09
Toni Schoen

Reviewed by: ______________________ Date: 3/25/09
Brad Koons (Technical Expert)

I. Scope and Application

The collection of undisturbed soil cores is often required to support Light Nonaqueous Phase Liquid (LNAPL) mobility assessments at petroleum-impacted sites. The undisturbed soil cores are submitted to an analytical laboratory for specialized air/water drainage capillarity and fluid saturation testing. These data are used to support site-specific LNAPL mobility calculations.

The objective of the core collection procedure is to collect samples that are representative of the in-situ conditions that control LNAPL migration. Therefore, the following procedure outlines soil core collection methods that are optimal for:

- Maintaining soil pore structure
- Retaining aquifer fluids (LNAPL and groundwater) within the core

The soil cores are flash frozen in the field prior to shipment to maintain core integrity until it can be analyzed by the receiving laboratory.

This SOP does not address details of soil description or laboratory analysis. Refer to other ARCADIS SOPs and the project work plan, as appropriate.

II. Personnel Qualifications

ARCADIS personnel overseeing, directing, or supervising soil core collection using drilling equipment shall have a previous related experience (minimum of 2 years) under the supervision of an experienced drilling oversight person and a degree in hydrogeology or geology.

III. Equipment List

Below is a list of the equipment and materials that are required for the collection of LNAPL soil cores. Required equipment and materials include:

- personal protective equipment (PPE) including gloves rated for flash freezing, and other items specified by the site Health and Safety Plan (HASP),
- drill rig and other associated equipment based on soil core collection methodology,
- measuring tape,
- indelible ink pens,
- plastic baggies,
- graduated cylinder;
- duct tape,

- saran wrap,
- cleaning equipment/supplies,
- transport container with dry ice,
- foam, bubble wrap, or styrofoam peanuts,
- shippable cooler with inside length greater than soil core sampler,
- 6-inch wide polyvinyl chloride pipe with end cap (length based on length of soil core sampler), and
- logbook.

IV. Cautions

Drilling and drilling-related hazards including subsurface utilities are discussed in other SOPs and site specific HASPs and are not discussed herein.

The drilling Contractor is responsible for underground and aboveground utilities clearance by local “Dig Safe,” the owner of easements, and the property owner per the HASP.

V. Health and Safety Considerations

Field activities associated with collection of nonaqueous phase liquid soil cores 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 nonaqueous phase liquids and understand their hazards.

Prior to mobilization, select an appropriate monitoring device (flame ionization detector, photo-ionization detector, or other detector) based on a review of the sensitivity of the device to the potential constituents of concern.

Dry ice is extremely cold, sublimates into carbon dioxide, and is an asphyxiant (precludes access to oxygen). The site HASP shall contain a copy of the Material Safety Data Sheet (MSDS) for dry ice. Below is a list of health and safety conditions when handling dry ice:

- Store the dry ice in a dry, well ventilated area like a truck bed,
- Wear protective gloves rated for extreme cold/flash freezing,
- Avoid contact with water or other liquid, and
- Dispose of dry ice in a secure ventilated area. Dry ice will create an appearance of “smoke”, which may cause undue attention by site workers or pedestrians.

Communication with the drilling crew is essential to the successful collection of the LNAPL soil cores. The goal of the collection process (“push” sample, smooth steady retrieval by avoiding jarring or jerking during retrieval of the tube from the subsurface, and handling the core in a vertical position until frozen) should be discussed in detail to ensure the drilling crew and geologist are working as a team.

VI. Procedure

The primary objective for the collection of a LNAPL soil core is to collect an undisturbed soil sample with the water and LNAPL entrained in the pore spaces representative of subsurface conditions. This is accomplished by mechanically pushing the core collection device into the subsurface. Avoid using rotation, hammer or vibration when collecting the core. The use of air or drilling water during borehole advancement should be avoided if possible to prevent inadvertently affecting the in-situ fluid saturation profile at or near the coring interval.

The undisturbed soil cores are submitted to a petrophysical laboratory for analysis of soil characteristics such as porosity, capillarity, and LNAPL and water fluid saturations. The lab processes subsamples from the cores that are as small as 1 inch by 1 inch. The scale of the lab analyses and the sensitivity of the parameters being analyzed are two specific reasons why such importance is placed on obtaining cores that are as undisturbed as possible and as representative of in-situ conditions as possible.

The sampler diameter shall not be less than 3-inches in diameter (minimum of 2.5-inch diameter for split barrel sampler). Any sampler will disturb the perimeter of a soil core to some degree. The minimum diameter of 3 inches is based on the need for at least 2 inches in diameter of undisturbed core for the laboratory analysis procedures mentioned above.

Site geology and hydrogeology must be considered to select the most appropriate core collection method. The geology should be evaluated to determine the type of material that will be drilled through to obtain the samples. For example, loose sands or interbedded silt and clay require different sampling methods. Since samples are collected near the groundwater table, an understanding of the depth to water and probability of heaving sands will also influence the selection of a sampling method. Use of rotation, hammer, or vibration will only be utilized if mechanical pushing results in refusal, and the use of these alternative advancement methods should be prioritized as follows: push, rotate, then hammer. Several potential sampling methods are discussed below.

- Split spoon or split barrel samplers are used to collect soil samples across a wide variety of unconsolidated soils (ASTM D-1586). The split spoon consists of a 2-foot to 5-foot long tubular barrel that is split longitudinally into two equal halves. A 3-inch diameter split spoon sampler should be used with a 2.5-inch diameter liner. A retainer at the bottom will limit soils and fluids from falling out the bottom during sample retrieval from the subsurface. The split spoon sampler is attached to the drill rod and advanced into the undisturbed soil approximately the length of the split spoon sampler.

- Standard stationary piston sampler (ASTM D-6519) is a liner attached to a head assembly with a piston at the bottom to prevent soil from entering as the assembly is lowered into the hole. A rod is connected to the piston, and the liner is pressed past the piston into the soil. With a well fitted piston, a vacuum is created that holds the soil and fluids in the liner during core withdrawal.
- Osterberg hydraulic piston sampler is similar to the standard stationary piston sampler but has an actuating piston and a fixed piston. An opening at the head assembly allows for fluid pressure to be applied to the actuating piston which will cause the liner to be pushed past the fixed piston into the soil. This helps eliminate the possibility of over pushing.
- Denison core barrel consists of a rotating outer barrel, a bit with an inner fixed barrel, a liner, and a retainer at the end. During drilling, pressure is applied to the inner barrel while the outer barrel cuts the soil. For this purpose of collecting LNAPL soil cores, a 3.5" diameter by 24" sampler is preferred.
- Shelby tubes consist of a single thin-walled steel tube (ASTM D-1587-08)). The Shelby tube is attached to the lead auger and should be mechanically pushed into the undisturbed soil.

The length of soil core samples can be determined based on the expected height of capillary rise in the soil of interest. By matching core length to the height of capillary rise, drainage of fluids from the samples as they are collected will be minimized. API's technical document 4711 presents the relationship shown in Figure 1, based on an empirical approach developed by McWhorter in 1996. The values shown in the table below are approximations taken from Figure 1 and can be used as a guide to determine core length as a function of site-specific hydraulic conductivity.

Hydraulic Conductivity	0-2.5 ft/day (0-7.5x10^{-4} cm/s)	2.5-10 ft/day (7.5x10^{-4}-3.5x10^{-3} cm/s)	>10 ft/day (>3.5x10^{-3} cm/s)
Core Length	2 ft (70 cm)	1ft (30 cm)	0.5 ft (15 cm)

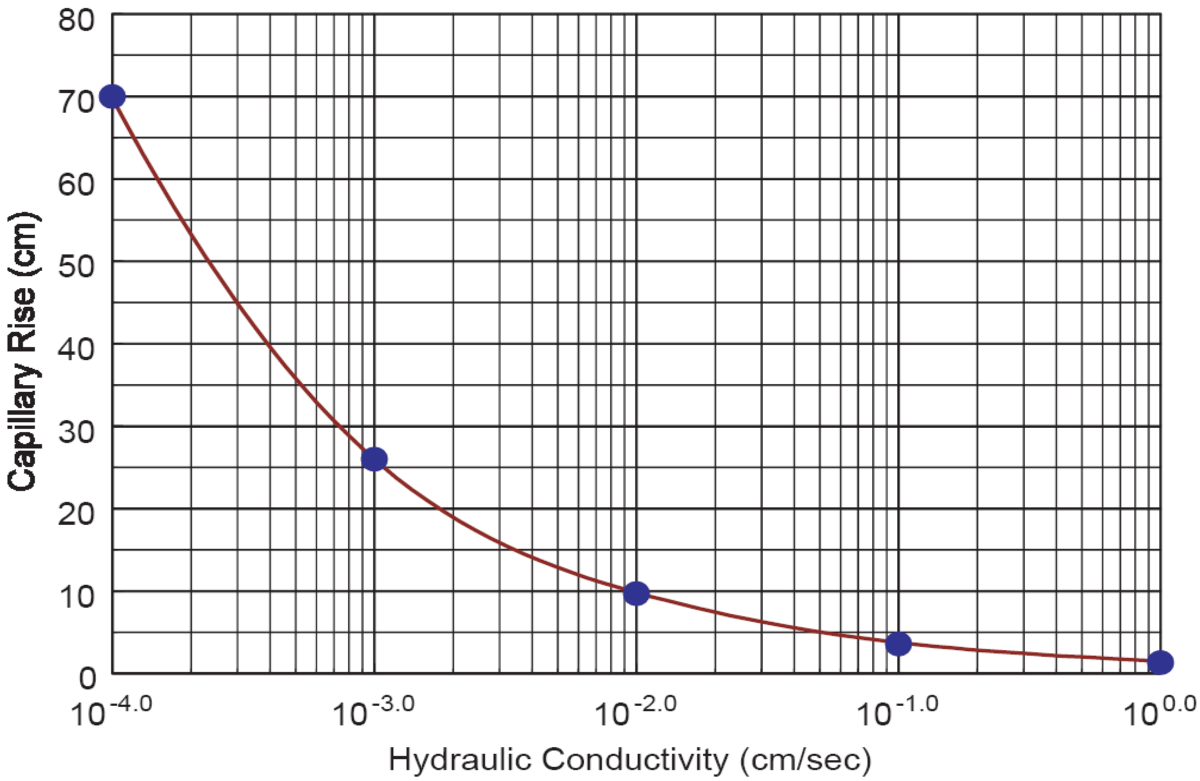


Figure 1 — Capillary rise as function of hydraulic conductivity (API 4711)

Below is the procedure for collection of a LNAPL soil core.

- Gauge a well near the proposed soil boring location for LNAPL soil core collection for depth to LNAPL and depth to water using an interface probe. The proposed soil boring location shall be near the well gauged for LNAPL (approximately 3 to 5 feet).
- Collect soil samples continuously from ground surface to the project-specified distance above the air-LNAPL/water interface using the selected drilling method (typically 1 foot above the groundwater table). Do not use air or water during sampling or drilling advancement.
- Advance the sampler to collect soil from the project-specified vertical extent (typically 1-foot of soil from the vadose zone (unsaturated soil) and approximately 3 feet of LNAPL/water-saturated soil). The sampler shall be mechanically pushed (no rotation, hammer, or vibration shall be applied to the split-barrel). If refusal is encountered using mechanical pushing before advancing the length of the sampler, then hammer or rotation may be applied to advance the sampler.

- Retrieve the sampler at a smooth, steady pace (avoid jarring or jerking of sampler) from the subsurface to minimize loss of fluid from the sampler.
- Maintain the sampler in an **upright position** for the following steps:
  - o Place the bottom of the sampler in a plastic bag for collection of fluids while the driller removes any mechanism holding drilling tube holding the sample. Once the soil core sample is released, cap both ends of the liner or tube with water-tight end caps. Capping the top of the liner/tube first will create a vacuum to minimize fluid loss from the soil.
  - o Pour liquid from the plastic bag to a graduated cylinder. Measure and record the volume of water and LNAPL loss.
  - o If there are any voids in the sample liner/tube, fill with plastic (Saran) wrap to minimize core movement.
  - o Wipe the outside of the sample liner/tube and duct tape the end caps (overlap tape a minimum of 2 layers).
  - o Label the liner/tube with the boring ID, interval sampled (fractions of a foot should be recorded in tenths), and an arrow pointing toward the top of liner/tube with a permanent marker (do not label duct tape). Each subsequent liner/tube shall be labeled sequentially with A, B, C… etc starting with A on the top (shallowest) sleeve. Also, each liner/tube shall have an arrow pointing toward the top of the tube. (See Figure 2.)

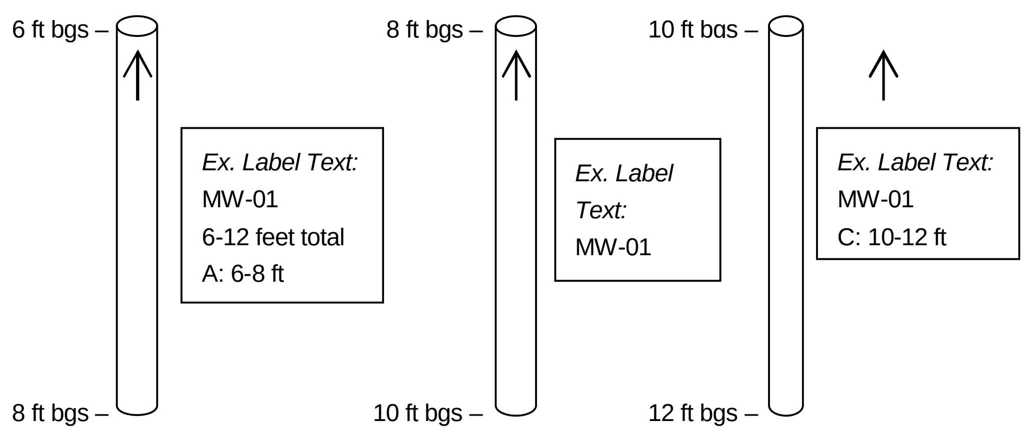


Figure 2 – Schematic showing example of how to label multiple cores per well.

- o Evaluate the integrity of the soil sample, noticing if the soil sample appears undisturbed and how much recovery was achieved. A disturbed soil sample or sample with poor recovery should be discarded. If the first soil core is acceptable, proceed to the core freezing procedure below. If the first soil core is disturbed or had poor recovery, discard it and select a different nearby drilling location for a second attempt. Communicate the change in sampling plan to the project manager.
- o Set the capped, taped, and labeled liner/tube in a vertically-aligned 6-inch Schedule 80 PVC tube or steel pipe surrounded by dry ice for a minimum of 30 minutes. The soil sample should remain in the same vertical direction as it was in the subsurface during freezing. Stabilize the PVC tube or steel pipe to avoid tipping over during the freezing process.
- o Once frozen, wrap core in several layers of plastic bags or 1-2 layers of bubble wrap before placing it into a cooler. A thin, insulative layer is needed between the core and the dry ice.

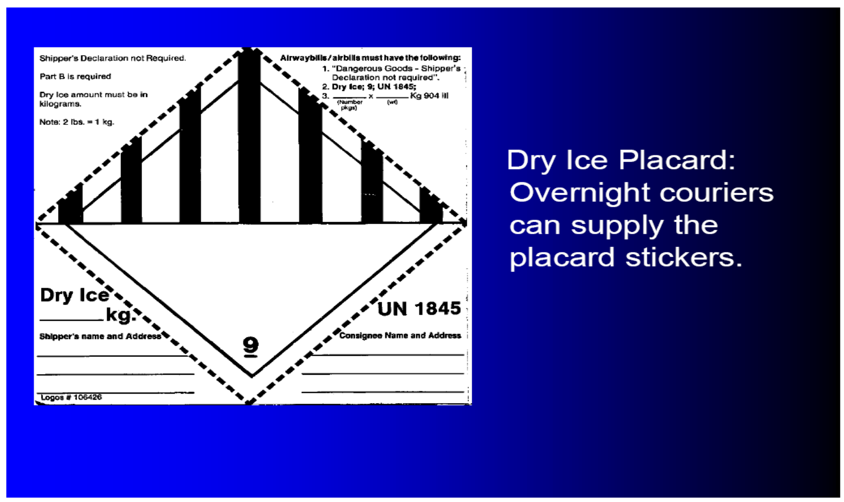
VII. Cooler Preparation and Shipping

Below is a generalized procedure for packing and shipping of frozen LNAPL soil cores. A Shipping Determination must be performed, by DOT-trained personnel, for all environmental and geotechnical samples that are to be shipped, as well as some types of environmental equipment/supplies that are to be shipped.

From the bottom of the cooler up, pack the cooler as follows:

- Place a layer of foam, bubble wrap, or styrofoam peanuts in the bottom of the cooler to absorb shock during transport.
- Place a layer of dry ice over the foam, bubble wrap, or styrofoam peanuts. Do not pack the dry ice in sealable containers.
- Place the core(s) horizontally over the layer of dry ice.
- Place a layer of dry ice over the core. The cooler should contain approximately 30 to 50 pounds of dry ice for shipping. FedEx has a weight limit of 150 pounds for coolers. Up to 22.5 feet of cores can fit into the large marine ice chests with 50-75 feet of ice.
- Fill remainder of cooler with foam, bubble wrap, or styrofoam peanuts.
- Seal the completed chain of custody into a plastic bag and affix to the inside of the lid of the cooler.
- Tape the cooler closed by wrapping two bands of tape around the cooler (overlap tape a minimum of 2 layers). Do not seal the cooler with tape. As the dry ice sublimates to carbon dioxide, the gas needs to escape the cooler.

- Core samples shall not be held overnight onsite. Collect samples early enough to allow time for same-day vertical core freezing, cooler packaging, and FedEx shipping.
- Complete the FedEx airway bill and dry ice placard (see attached examples). Samples shall be shipped for overnight delivery. Arrange shipment so that coolers do not sit in a warehouse or truck for days.
- Use the buddy system for lifting these coolers. The size of the coolers used and volume of dry ice used to maintain a frozen state for the soil cores will result in heavy coolers.
- Notify the laboratory of shipment arrival time and FedEx tracking number(s).



VIII. Data Recording and Management

The supervising geologist will be responsible for documenting drilling events using a logbook to record all relevant information in a clear and concise format. The drilling event record shall include:

- Name and location of project,
- Project number, client, and site location,
- Names of Contractor, Contractor personnel, inspectors, and other people onsite,
- Weather conditions,
- Depth to water and depth to LNAPL from nearby well and distance from sample location,
- Type of drilling method,
- Soil core collection method and sampler dimensions,
- Procedure (noting use or no use of rotation, hammer, or vibration for sample collection),
- Start and finish dates and times of drilling,
- Sample interval, length of unsaturated and saturated soil, and total recovery length,
- Volume of water and LNAPL loss as measured in a graduated cylinder,
- Condition of sampler pre- and post-retrieval from subsurface, and
- Photo document the soil cores, freezing technique, and cooler packaging.

IX. Quality Assurance

Equipment will be cleaned prior to use onsite, between each drilling location, and prior to leaving the site. All drilling equipment and associated tools, including augers, drill rods, sampling equipment, wrenches, and other equipment or tools, that may have come in contact with soils will be cleaned with high-pressure steam cleaning equipment using a clean potable water source. The drilling equipment will be cleaned in an area designated by the supervising geologist that is located outside of the work zone.

X. Waste Management

All dry ice not utilized for freezing the soil cores will be stored in an open container in a well ventilated, secured area and permitted to volatilize. Personal protective equipment (such as gloves, disposable clothing, and other disposable equipment) resulting from 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 disposed of in a designated debris box for disposal. All decontamination water and soil will be placed in separate sealed 55-gallon steel drums and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

XI. References

API 4711. Methods for Determining Inputs to Environmental Petroleum Hydrocarbon Mobility and Recovery Models. American Petroleum Institute Publication Number 4711. July 2001.

ASTM. D-1587-08 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes.

ASTM. D-6282 Standard Guide for Direct Push Soil Sampling for Environmental Site Characterization.

ASTM Method D-1586 Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D-3550 Practice for Thick-Walled, Ring-Lined. Split Barrel, Drive Sampling of Soils.

ASTM D-6519 Standard Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler.

Appendix B

Standard Operating Procedure for Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells

ARCADIS
Infrastructure, environment, facilities

Imagine the result

Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells

Rev. #: 3

Rev Date: March 9, 2009

Approval Signatures

Prepared by: ______________________ Date: 3/9/2009

Reviewed by: ______________________ Date: 3/9/2009
(Technical Expert)

I. Scope and Application

Groundwater samples will be collected from monitoring wells to evaluate groundwater quality. The protocol presented in this standard operating procedure (SOP) describes the procedures to be used to purge monitoring wells and collect groundwater samples. 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 (USEPA SOP No. GW0001; July 30, 1996). 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. No wells will be sampled until well development has been performed in accordance with the procedures presented in the SOP titled Monitoring Well Development, unless that well has been sampled or developed within the prior 1-year time period. Groundwater samples will not be collected within 1 week following well development.

II. Personnel Qualifications

ARCADIS personnel directing, supervising, or leading groundwater sample collection activities should have a minimum of 2 years of previous groundwater sampling experience. ARCADIS personnel providing assistance to groundwater sample collection and associated activities should have a minimum of 6 months of related experience or an advanced degree in environmental sciences, engineering, hydrogeology, or geology.

The supervisor of the groundwater sampling team will have at least 1 year of previous supervised groundwater sampling experience.

Prior to mobilizing to the field, the groundwater sampling team should review and be thoroughly familiar with relevant site-specific documents including but not limited to the site work plan, field sampling plan, QAPP, HASP, and historical information. Additionally, the groundwater sampling team should review and be thoroughly familiar with documentation provided by equipment manufacturers for all equipment that will be used in the field prior to mobilization.

III. Equipment List

Specific to this activity, the following materials (or equivalent) will be available:

- Health and safety equipment (as required in the site Health and Safety Plan [HASP]).

- Site Plan, well construction records, prior groundwater sampling records (if available).
- 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); and/or
  - bladder pump (e.g., Marschalk System 1, QED Well Wizard, etc.).
- 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 also be used through the pump apparatus.
- Water-level probe (e.g., Solinist Model 101).
- Water-quality (temperature/pH/specific conductivity/ORP/turbidity/dissolved oxygen) meter and flow-through measurement cell. Several brands may be used, including:
  - YSI 6-Series Multi-Parameter Instrument;
  - Hydrolab Series 3 or Series 4a Multiprobe and Display; and/or
  - Horiba U-10 or U-22 Water Quality Monitoring System.
- Supplemental turbidity meter (e.g., Horiba U-10, Hach 2100P, LaMotte 2020). Turbidity measurements collected with multi-parameter meters have been shown to sometimes be unreliable due to fouling of the optic lens of the

turbidity meter within the flow-through cell. A supplemental turbidity meter will be used to verify turbidity data during purging if such fouling is suspected. Note that industry improvements may eliminate the need for these supplemental measurements in the future.

- Appropriate water sample containers (supplied by the laboratory).
- Appropriate blanks (trip blank supplied by the laboratory).
- 0.45-micron disposable filters (if field filtering is required).
- Large glass mixing container (if sampling with a bailer).
- Teflon® stirring rod (if sampling with a bailer).
- Cleaning equipment.
- Groundwater sampling log (attached) or bound field logbook.

Note that in the future, the client may acquire different makes/models of some of this equipment if the listed makes/models are no longer available, or as a result of general upgrades or additional equipment acquisitions. In the event that the client uses a different make/model of the equipment listed, the client will use an equivalent type of equipment (e.g., pumps, flow-through analytical cells) and note the specific make/model of the equipment used during a sampling event on the groundwater sampling log. In addition, should the client desire to change to a markedly different sampling methodology (e.g., discrete interval samplers, passive diffusion bags, or a yet to be developed technique), the client will submit a proposed SOP for the new methodology for USEPA approval prior to implementing such a change.

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.

IV. Cautions

If heavy precipitation occurs and no cover over the sampling area and monitoring well can be erected, sampling must be discontinued until adequate cover is provided. Rain water could contaminate groundwater samples.

Do not use permanent marker or felt-tip pens for labels on sample container or sample coolers – use indelible ink. The permanent markers could introduce volatile constituents into the samples.

It may be necessary to field filter some parameters (e.g., metals) prior to collection, depending on preservation, analytical method, and project quality objectives.

Store and/or stage empty and full sample containers and coolers out of direct sunlight.

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, samples are collected in order of upgradient, then furthest downgradient to source area locations.

Be careful not to over-tighten 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.

V. Health and Safety Considerations

Use caution and appropriate cut resistant gloves when tightening lids to 40 mL vials. These vials can break while tightening and can lacerate hand. Amber vials (thinner glass) are more prone to breakage.

If thunder or lighting is present, discontinue sampling and take cover until 30 minutes have passed after the last occurrence of thunder or lighting.

Use caution when removing well caps as well may be under pressure, cap can dislodge forcefully and cause injury.

Use caution when opening protective casing on stickup wells as wasps frequently nest inside the tops of the covers. Also watch for fire ant mounds near well pads when sampling in the south or western U.S.

VI. Procedure

Groundwater will be purged from the wells using an appropriate pump. Peristaltic pumps will initially be used to purge and sample all wells when applicable. If the depth to water is below the sampling range of a peristaltic pump (approximately 25 feet), submersible pumps or bladder pumps will be used provided the well is constructed with a casing diameter greater than or equal to 2 inches (the minimum well diameter capable of accommodating such pumps). Bladder pumps are preferred over peristaltic and submersible pumps if sampling of VOCs is required to prevent volatilization. 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. Purge water will be collected and containerized.

1. Calibrate field instruments according to manufacturer procedures for calibration.

2. Measure initial depth to groundwater prior to placement of pumps.

3. Prepare and install pump in well: For submersible and non-dedicated bladder pumps, decontaminate pump according to site decontamination procedures. Non-dedicated bladder pumps will require a new Teflon® 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. Care should be taken not to reverse the air and discharge tubing lines during bladder pump set-up as this could result in bladder failure or rupture. Attach and secure a safety cable to the eyebolt on the top of bladder pump (if present, depending on pump model used). Slowly lower 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. Take care to avoid twisting and tangling of safety cable, tubing, and electrical lines while lowering pump into 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 well contamination. 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 2 feet above the bottom of the well to prevent mobilization of any sediment present in the bottom of the well.

4. Connect the pump to other equipment. If using a bladder pump, the discharge water line should be connected to the bottom inlet port on the flow-through cell connected to the water quality meter. Connect the air line to the pump controller output port. The pump controller should then be connected to a supply line from an air compressor or compressed gas cylinder using an appropriate regulator and air hose. Take care to 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 if an on/off switch

is present and verify that all batteries are charged and fully operating before beginning to pump.

5. Measure the water level again with the pump in the well before starting the pump. Start pumping the well at 200 to 500 milliliters (mL) per minute (or at lower site-specific rate if specified). The pump rate should be adjusted to cause little or no water level drawdown in the well (less than 0.3 feet below the initial static depth to water measurement) and the water level should stabilize. The water level should be monitored every 3 to 5 minutes (or as appropriate, lower flow rates may require longer time between readings) during pumping if the well diameter is of sufficient size to allow such monitoring. Care should be taken not to break pump suction or cause entrainment of air in the sample. Record pumping rate adjustments and depths to water. If necessary, pumping rates should be reduced to the minimum capabilities of the pump to avoid pumping the well dry and/or to stabilize indicator parameters. A steady flow rate should be maintained to the extent practicable. Groundwater sampling records from previous sampling events (if available) should be reviewed prior to mobilization to estimate the optimum pumping rate and anticipated drawdown for the well in order to more efficiently reach a stabilized pumping condition.

   If the recharge rate of the well is very low, alternative purging techniques should be used, which will vary based on the well construction and screen position. For wells screened across the water table, the well should be pumped dry and sampling should 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 should be pumped until a stabilized level (which may be below the maximum displacement goal of 0.3 feet) can be maintained and monitoring for stabilization of field indicator parameters can commence. If a lower stabilization level cannot be maintained, the well should be pumped until the drawdown is at a level slightly higher than the bentonite seal above the well screen. Sampling should commence after one well volume has been removed and the well has recovered sufficiently to permit collection of samples.

   During purging, monitor the field indicator parameters (e.g., turbidity, temperature, specific conductance, pH, etc.) every 3 to 5 minutes (or as appropriate). Field indicator parameters will be measured using a flow-through analytical cell or a clean container such as a glass beaker. Record field indicator parameters on the groundwater sampling log. The well is considered stabilized and ready for sample collection when turbidity values remain within 10% (or within 1 NTU if the turbidity reading is less than 10 NTU), the specific conductance and temperature values remain within 3%, and pH remains within 0.1 units for three consecutive readings collected at 3- to 5-minute intervals (or other appropriate interval, alternate stabilization goals may exist in different geographic regions, consult the site-specific Work Plan for stabilization criteria). If the field indicator parameters do not stabilize within 1 hour of the start of purging, but the groundwater turbidity is below the goal of 50 NTU and the values for all other parameters are within 10%, the well can be sampled. If the parameters have stabilized but the turbidity is not in the range of the 50 NTU goal, the pump flow rate should be decreased to a minimum rate of 100 mL/min to reduce turbidity levels as low as possible. If dissolved oxygen values are not within acceptable range for the temperature of groundwater (Attachment 1), then check for and remove air bubbles on probe or in tubing. If the dissolved oxygen value is 0.00 or less, then the meter should be serviced and re-calibrated.

During extreme weather conditions, stabilization of field indicator parameters may be difficult to obtain. 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 notes. If other field conditions exist that preclude stabilization of certain parameters, an explanation of why the parameters did not stabilize will also be documented in the field logbook.

6. Complete the sample label and cover the label with clear packing tape to secure the label onto the container.

7. After the indicator parameters have stabilized, collect groundwater samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container. If a flow-through analytical cell is being used to measure field parameters, the flow-through cell should be disconnected after stabilization of the field indicator parameters and prior to groundwater sample collection. Under no circumstances should analytical samples be collected from the discharge of the flow-through cell. When the container is full, tightly screw on the cap. Samples should be collected in the following order: VOCs, TOC, SVOCs, metals and cyanide, and others (or other order as defined in the site-specific Work Plan).

8. If sampling for total and filtered metals and/or PCBs, a filtered and unfiltered sample will be collected. Install an in-line, disposable 0.45-micron particle filter on the discharge tubing after the appropriate unfiltered groundwater sample has been collected. 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). Collect filtered groundwater sample by diverting flow out of the filter into the appropriately labeled sample container. When the container is full, tightly screw on the cap.

9. Secure with packing material and store at 4°C in an insulated transport container provided by the laboratory.

10. Record on the groundwater sampling log or bound field logbook the time 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 (Attachment 2 – Example Sampling Log).

11. Turn off the pump and air compressor or close the gas cylinder valve if using a bladder pump set-up. Slowly remove the pump, tubing, lines, and safety cable from the well. Do not allow the tubing or lines to touch the ground or any other surfaces which could contaminate them. .

12. If tubing is to be dedicated to a well, it should be folded to a length that will allow the well to be capped and also facilitate retrieval of the tubing during later sampling events. A length of rope or string should be used to tie the tubing to the well cap. Alternatively, if tubing and safety line are to be saved and reused for sampling the well at a later date they may be coiled neatly and placed in a clean plastic bag that is clearly labeled with the well ID. Make sure the bag is tightly sealed before placing it in storage.

13. Secure the well and properly dispose of personal protective equipment (PPE) and disposable equipment.

14. Complete the procedures for packaging, shipping, and handling with associated chain-of-custody.

15. Complete decontamination procedures for flow-through analytical cell and submersible or bladder pump, as appropriate.

16. At the end of the day, perform calibration check of field instruments.

If it is not technically feasible to use the low-flow sampling method, purging and sampling of monitoring wells may be conducted using the bailer method as outlined below:

1. Don appropriate PPE (as required by the HASP).

2. Place plastic sheeting around the well.

3. Clean sampling equipment.

4. Open the well cover while standing upwind of the well. Remove well cap and place on the plastic sheeting. 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 log. 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 breathing zone reading is less than 5 PID units, proceed. If the PID reading in the breathing zone 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 appropriate respiratory protection in accordance with the requirements of the HASP. Record all PID readings. For wells that are part of the regular weekly monitoring program and prior PID measurements have not resulted in a breathing zone reading above 5 PID units, PID measurements will be taken monthly.

5. Measure the depth to water and determine depth of well by examining drilling log data or by direct measurement. Calculate the volume of water in the well (in gallons) by using the length of the water column (in feet), multiplying by 0.163 for a 2-inch well or by 0.653 for a 4-inch well. For other well diameters, use the formula:

   Volume (in gallons) = • TIMES well radius (in feet) squared TIMES length of water column (in feet) TIMES 7.481 (gallons per cubic foot)

6. Measure a length of rope or twine at least 10 feet greater than the total depth of the well. Secure one end of the rope to the well casing and secure the other end to the bailer. Test the knots and make sure the rope will not loosen. Check bailers so that all parts are intact and will not be lost in the well.

7. Lower bailer into well and remove one well volume of water. Contain all water in appropriate containers.

8. Monitor the field indicator parameters (e.g., turbidity, temperature, specific conductance, and pH). Measure field indicator parameters using a clean container such as a glass beaker or sampling cups provided with the instrument. Record field indicator parameters on the groundwater sampling log.

9. Repeat Steps 7 and 8 until three or four well volumes have been removed. Examine the field indicator parameter data to determine if the parameters have stabilized. The well is considered stabilized and ready for sample collection when turbidity values remain within 10% (or within 1 NTU if the turbidity reading is less than 10 NTU), the specific conductance and temperature values remain

within 3%, and pH remains within 0.1 units for three consecutive readings collected once per well volume removed.

10. If the field indicator parameters have not stabilized, remove a maximum of five well volumes prior to sample collection. Alternatively, five well volumes may be removed without measuring the field indicator parameters.

11. If the recharge rate of the well is very low, wells screened across the water table may be bailed dry and sampling should 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 should only be bailed down to a level slightly higher than the bentonite seal above the well screen. The well should not be bailed completely dry, to maintain the integrity of the seal. Sampling should commence as soon as the well volume has recovered sufficiently to permit sample collection.

12. Following purging, allow water level in well to recharge to a sufficient level to permit sample collection.

13. Complete the sample label and cover the label with clear packing tape to secure the label onto the container.

14. Slowly lower the bailer into the screened portion of the well and carefully retrieve a filled bailer from the well causing minimal disturbance to the water and any sediment in the well.

15. The sample collection order (as appropriate) will be as follows:

    a. VOCs;

    b TOC;

    c. SVOCs;

    d. metals and cyanide; and

    e. others.

16. When sampling for volatiles, collect water samples directly from the bailer into 40-mL vials with Teflon®-lined septa.

17. For other analytical samples, remove the cap from the large glass mixing container and slowly empty the bailer into the large glass mixing container. The sample for dissolved metals and/or filtered PCBs should either be placed directly from the bailer into a pressure filter apparatus or pumped directly from the bailer with a peristaltic pump, through an in-line filter, into the pre-preserved sample bottle.

18. Continue collecting samples until the mixing container contains a sufficient volume for all laboratory samples.

19. Mix the entire sample volume with the Teflon® stirring rod and transfer the appropriate volume into the laboratory jar(s). Secure the sample jar cap(s) tightly.

20. If sampling for total and filtered metals and/or PCBs, a filtered and unfiltered sample will be collected. Sample filtration for the filtered sample will be performed in the field using a peristaltic pump prior to preservation. Install new medical-grade silicone tubing in the pump head. Place new Teflon® tubing into the sample mixing container and attach to the intake side of pump tubing. Attach (clamp) a new 0.45-micron filter (note the filter flow direction). Turn the pump on and dispense the filtered liquid directly into the laboratory sample bottles.

21. Secure with packing material and store at 4°C in an insulated transport container provided by the laboratory.

22. After sample containers have been filled, remove one additional volume of groundwater. Measure the pH, temperature, turbidity, and conductivity. Record on the groundwater sampling log or bound field logbook the time 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 field indicator parameters.

23. Remove bailer from well, secure well, and properly dispose of PPE and disposable equipment.

24. If a bailer is to be dedicated to a well, it should be secured inside the well above the water table, if possible. Dedicated bailers should be tied to the well cap so that inadvertent loss of the bailer will not occur when the well is opened.

25. Complete the procedures for packaging, shipping, and handling with associated chain-of-custody.

VII. Waste Management

Materials generated during groundwater sampling activities, including disposable equipment, will be placed in appropriate containers. Containerized waste will be disposed of by the client consistent with the procedures identified in the HASP.

VIII. Data Recording and Management

Initial field logs and chain-of-custody records will be transmitted to the ARCADIS PM at the end of each day unless otherwise directed by the PM. The groundwater team leader retains copies of the groundwater sampling logs.

IX. Quality Assurance

In addition to the quality control samples to be collected in accordance with this SOP, the following quality control procedures should 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 should 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 and verify the calibration at the end of each day. 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 using procedures for equipment decontamination.

X. References

United States Environmental Protection Agency (USEPA). 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document (September 1986).

USEPA Region II. 1998. *Ground Water Sampling Procedure Low Stress (Low Flow) Purging and Sampling*.

USEPA. 1991. Handbook Groundwater, Volume II Methodology, Office of Research and Development, Washington, DC. USEPN62S, /6-90/016b (July, 1991).

U.S. Geological Survey (USGS). 1977. National Handbook of Recommended Methods for Water-Data Acquisition: USGS Office of Water Data Coordination. Reston, Virginia.

Attachment 1

Groundwater Sampling Log

ARCADIS
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Low-Flow Groundwater Sampling Log

Project ______________________________

Project Number ____________ Site Location ____________ Well ID ____________

Date ____________ Sampled By ____________

Sampling Time ____________ Recorded By ____________

Weather ____________ Coded Replicate No. ____________

Instrument Identification

Water Quality Meter(s) ____________ Serial # ____________

Casing Material ____________ Purge Method ____________

Casing Diameter ____________ Screen Interval (ft bmp) Top ____________ Bottom ____________

Sounded Depth (ft bmp) ____________ Pump Intake Depth (ft bmp) ____________ ____________

Depth to Water (ft bmp) ____________ Purge Time Start ____________ Finish ____________

Field Parameter Measurements During Purging

Time	Minutes Elasped	Flow Rate (mL/min)	Volume Purged	Temp (°C)	pH (s.u.)	Conductivity (umhos or mS/cm) 1)	ORP (mV)	DO (mg/L)	Turbidity (NTU)	Depth to Water (ft bmp)

Collected Sample Condition Color__________________ Odor__________________ Appearance__________________

Parameter	Container	No.	Preservative

PID Reading ____________

Comments ______________________________

____

____

____

1) Circle one unit type

Attachment 2

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).