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Remedial Action Plan

Former ARCO Facility No. 0977

VCP No. NW2447

155 Northwest 85th Street
Seattle, WA 98117

November 28, 2011

ARCADIS

Arti Patel
Environmental Engineer II

Scott Zorn
Project Manager

Peter Campbell PE
Project Engineer

PETER J CAMPBELL
STATE OF WASHINGTON
45051
REGISTERED
PROFESSIONAL ENGINEER
Exp 2/14/2012

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155 Northwest 85th Street
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Prepared by:
ARCADIS
2300 Eastlake Avenue East
Suite 200
Seattle, Washington 98102
Tel 206-325-5254
Fax 206-325-8218

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Acronyms and Abbreviations

ARCADIS	ARCADIS U.S., Inc.
AS	air sparge
bgs	below ground surface
BP	BP West Coast Products, LLC.
btoc	below top of casing
BTEX	benzene, toluene, ethylbenzene, and xylenes
CL	Cleanup Level
COC	constituents of concern
Delta	Delta Environmental Consultants, Inc.
DO	dissolved oxygen
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
g/L	grams per liter
gpm	gallons per minute
GRO	gasoline range organics
GSCI	Greenwood Shopping Center Inc.
HDPE	high density polyethylene
In. wc.	Inches of water column
LNAPL	light nonaqueous phase liquid
msl	mean sea level
µg/L	micrograms per liter
lb/day	pounds per day
L/L	liter per liter
mg/kg	milligrams per kilogram
MNA	monitored natural attenuation
MTBE	methyl tertiary-butyl ether
MTCA	Model Toxics Control Act
NFA	No Further Action
NWTPH	Northwest Total Petroleum Hydrocarbon
PAHs	polynuclear aromatic hydrocarbons
PID	photoionization detector
PLC	Programmable Logic Control
PPE	personal protective equipment
ppm(v)	parts per million (by volume)
psi	pound per square inch
PVC	polyvinyl chloride
lbs	pounds

RAP	Remedial Action Plan
ROI	radius of influence
scfm	standard cubic feet per minute
SOP	Standard Operating Procedure
SVE	soil vapor extraction
UST	Underground Storage Tank
VOC	volatile organic compound

1. Introduction

ARCADIS U.S., Inc. (ARCADIS) has prepared this Remedial Action Plan (RAP) for ARCO Facility number 0977 located at 155 Northwest 85th Street in Seattle, Washington (the Site). The Site and surrounding area is illustrated on **Figure 1**.

2. Objective

The objective of the RAP is to outline the actions which would allow for a No Further Action (NFA) designation for the Site on behalf of BP West Coast Products, LLC., (BP). This RAP summarizes pilot testing results and presents the proposed remedial strategy. Two remedial approaches are proposed for this Site. Low-flow air sparge and soil vapor extraction (AS/SVE) will be used onsite to recover, remove, or volatilize residual light nonaqueous phase liquid (LNAPL) from the subsurface and treat dissolved phase impacts. Enhanced anaerobic biodegradation through injection of magnesium sulfate (Epsom Salt) solution will be used to treat dissolved phase impacts in offsite wells.

3. Background

The Site is located at the intersection of 3rd Avenue Northwest and Northwest 85th Street in Seattle, Washington. The property is a former retail gasoline facility and convenience store and is now an automotive glass repair shop. Operations at the Site included the storage and distribution of unleaded gasoline and diesel fuel. The former service station building and canopy remain onsite although the two fuel dispensers and underground storage tanks (USTs) have been removed (Delta 2004).

The Site is located in a mixed commercial and residential area. A retail property is immediately adjacent to the Site to the east; residential properties are located to the south, 3rd Avenue Northwest and a restaurant are located to the west, and North 85th Street and a grocery store parking lot are located to the north. Site features are illustrated on **Figure 2**.

4. Site Cleanup Levels

The Washington State Department of Ecology (Ecology) issued cleanup levels under Model Toxics Control Act (MTCA) Method A and Method B Cleanup Levels (CLs). The Method A and Method B CLs have been established for groundwater where drinking water is a beneficial use, soil for unrestricted land use and industrial properties.

Residual and dissolved phase constituents of concern (COCs) detected at the Site greater than MTCA Method A CLs are as follows:

- Gasoline Range Organics (GRO) (soil and groundwater)
- Benzene (soil and groundwater)
- Toluene (groundwater)
- Ethylbenzene (soil and groundwater)
- Total xylenes (soil and groundwater)

Additional guidance used to compare concentrations of residual and dissolved phase COCs with cleanup criteria is from the Washington State Department of Ecology Model Toxics Control Act Cleanup Regulation Method A Cleanup Levels (MTCA Chapter 173-340) and from the Cleanup Levels and Risk Calculation (CLARC) Summary for Method B soil CLs for benzene, toluene, ethylbenzene and total xylenes determined by the Standard Formula Value (carcinogen and non-carcinogen) based on direct contact (ingestion only) for unrestricted land use.

Groundwater

Constituent	Cleanup Criteria (µg/L)[1]
GRO	800 / 1,000 [2]
Benzene	5
Toluene	1,000
Ethylbenzene	700
Total Xylenes	1,000

Soils

Constituent	Cleanup Criteria (mg/kg)[1]
GRO	30 / 100 [2]
Benzene	18 [3]
Toluene	6,400 [4]
Ethylbenzene	8,000 [4]
Total Xylenes	16,000 [4]

[1] Clean-up Criteria based on Washington State MTCA Method A Cleanup Levels for Soils and Groundwater (MTCA Cleanup Regulation 173-340).
[2] Method A Cleanup Levels for GRO are determined based on the presence of benzene.
[3] Method B Cleanup Levels for benzene determined by the Standard Formula Value (Carcinogen) based on direct contact (ingestion only) for unrestricted land use.
[4] Method B Cleanup Levels for toluene, ethylbenzene and total xylenes determined by the Standard Formula Value (Non-carcinogen) based on direct contact (ingestion only) for unrestricted land use.
µg/L =micrograms per liter.
mg/kg = milligrams per kilogram.

5. Site History

The Site was owned and operated as a gasoline service station by ARCO from 1954 to 1984, at which point the property was purchased by David and Mary Ehlers. In 1984 the retail gasoline station was closed and the USTs were removed in 1989. The property was then sold to Henry and Lydia Cheng (The Cheng Family Trust) in 1990, and again in September 2001, to Medhi Saghafi, the current property owner.

In 2001, total petroleum hydrocarbons as gasoline range organics (GRO) was discovered in soils at the southwest corner of the grocery store property to the north of the Site. In 2004, under direction of Ecology, dissolved phase GRO impacts were discovered in onsite groundwater and residual phase petroleum hydrocarbon related impacts were found in soil and remediation activities were initiated. A settlement agreement was reached in 2005 between Greenwood Shopping Center Inc. (GSCI) and ARCO, of which BP America Inc. is successor in interest. ARCO was deemed responsible for the remediation of all petroleum hydrocarbon related impacts in accordance with MTCA.

Site characterization activities were initiated on March 22, 2004, to determine the extent of residual hydrocarbons in soil and dissolved phase hydrocarbons in groundwater. Four soil borings were advanced to a maximum depth of 28 feet below ground surface (bgs) and the borings were completed as monitoring wells MW-1, MW-2, MW-3, and MW-4. Groundwater was encountered at approximately 20 feet bgs and groundwater flow was determined to be to the north. Soil samples were collected at approximately five foot intervals and analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX), methyl tertiary-butyl ether (MTBE), GRO and lead. Laboratory analysis did not detect GRO, benzene, ethylbenzene or MTBE at concentrations greater than laboratory detection limits. Toluene and total xylenes were detected at concentrations greater than the laboratory detection limits but less than Method A CLs, from the soil sample collected at MW-2 at 16 feet bgs (Delta, 2004). Well locations are illustrated on **Figure 2**.

Supplemental soil and groundwater assessment activities were conducted by Delta Environmental Consultants Inc. (Delta), in October, 2004. During these activities, six soil borings were advanced in offsite locations to depths ranging from 28 to 30.5 feet bgs. These borings were completed as monitoring wells MW-5 through MW-10. Petroleum hydrocarbon related concentrations in soil samples collected during installation were less than the laboratory reporting limits, except for BTEX constituents detected in the soil samples collected from borings MW-5 and MW-6 at 15 feet bgs. All detected petroleum hydrocarbon constituents were less than their applicable Method A CLs, with the exception of the benzene concentration of 0.143 mg/kg in the soil sample collected from soil boring MW-5 at 15 feet bgs (Delta, 2005).

On September 23, 2010, one monitoring well (MW-2) was decommissioned in place using bentonite chips. One monitoring well (MW-16) was installed at the Site as a replacement for monitoring well MW-2. Two soil samples and one duplicate soil sample were collected during the installation of the monitoring well at depths of 18.0 and 22.5 feet bgs, and were submitted for petroleum hydrocarbon laboratory analysis. The sample collected at 18 feet bgs was also analyzed for polynuclear aromatic hydrocarbons (PAHs). **Figure 3** shows boring locations and soil analytical data**.**

A quarterly groundwater monitoring program was initiated at the Site in the first quarter of 2004, and is currently ongoing. During quarterly sampling, groundwater samples are collected from seven monitoring wells; MW-1, MW-5, MW-6, MW-11, MW-12, MW-16 and MW-GW-1. LNAPL has been measured in monitoring well MW-2 since June, 2004. The maximum LNAPL thickness in MW-2 was measured at 2.06 feet in November, 2004. To determine if LNAPL was trapped in the sand-pack of MW-2, this well was decommissioned on September 24, 2010, and replacement well MW-16 was installed in close proximity of MW-2. Prior to being decommissioned, MW-2 was gauged and the LNAPL thickness was 0.25 feet. MW-16 has not contained measurable amounts of LNAPL. Analytical data and the estimated groundwater flow direction from the most recent monitoring event are illustrated on **Figure 4**.

6. Regional and Site-specific Settings

6.1 Regional Geology and Hydrogeology

The Site is located in the Puget Lowland, bound by the North Cascade Mountains to the east, South Cascade Mountains to the south, Puget Sound and Olympic Mountains to the west. (Lasmanis, 1991). The Puget Lowland is underlain by unconsolidated deposits originating from continental glacial drift from the Pleistocene age (WA DNR, 2005). Such deposits are typically sand and gravel, which are as much as 3,000 feet deep, and often form discontinuous lenses. The local topography slopes to the south and the approximate elevation of the Site is 320 feet above mean sea level (msl).

Previous assessments indicate that the Site is underlain by poorly graded sand and silty sand to the maximum depth explored (28 feet bgs). Small zones of well-graded sands exist intermittently at shallower depths (ARCADIS, 2010; Delta, 2004).

The Site is located within the Puget-Willamette Trough Regional Aquifer System, which is a linear elongated basin stretching from the Canadian border in Washington to central Oregon. Specifically, the Site is located in an unconsolidated-deposit aquifer, which is the principle aquifer type in the Puget Lowlands. Sand and gravel lenses underlain in the area can retain localized productive groundwater (USGS, 1994).

6.1.1 Historical Site Specific Semi-annual Gauging Data

Historically, depth to groundwater measured at onsite and offsite wells has ranged from 14.08 to 19.65 feet below top of casing (btoc) and groundwater flow direction has ranged from southwest to north. During the second half 2011 monitoring event, groundwater conditions at the Site remained generally consistent with previous years. The depth to groundwater during this sampling event ranged between 14.08 feet btoc in well MW-7 to 16.67 feet btoc in well MW-3. Groundwater elevations during this sampling event ranged from 249.77 feet above msl in well MW-1 to 250.82 feet above msl in well MW-3. Based on the data collected, the inferred direction of groundwater flow could not be determined because of the extensively flat gradient, but in general groundwater flow is southwest to west across the Site. Groundwater gauging data are presented in **Table 1** and on **Figure 4**.

7. Site Petroleum Hydrocarbon Impacts

7.1 Soil Impacts

Supplemental soil assessment activities were conducted by Delta in October, 2004. During these activities, six soil borings were advanced in offsite locations to depths ranging from 28 to 30.5 feet bgs. All detected COCs were less than their applicable Method A or Method B CLs (Delta, 2005).

On September 23, 2010, monitoring well MW-16 was installed at the Site as a replacement for monitoring well MW-2. Two soil samples and one duplicate soil sample were collected during the installation of the monitoring well at depths of 18.0 and 22.5 feet bgs, and were submitted for COC analysis. The sample collected at 18 feet bgs was also analyzed for PAHs. The concentration of GRO in the soil sample collected at 18 feet bgs exceeded Method A CLs, with a concentration of 3,230 mg/kg. The concentration of benzene in the soil sample collected at 18 feet bgs exceeded Method B CLs, with a concentration of 33.7 mg/kg. No other soil samples contained concentrations of COCs exceeding their applicable Method A or Method B CLs (ARCADIS, 2010). A map showing boring locations and soil analytical data is presented on **Figure 3.** Soil sample analytical results for petroleum hydrocarbons and lead are summarized in **Table 2**, and soil analytical results for PAHs are summarized in **Table 3**.

7.2 Groundwater Impacts

A quarterly groundwater monitoring program was initiated at the Site in the first quarter of 2004, and is currently ongoing. The most recent sampling event was performed in July, 2011. Groundwater samples collected from well MW-6, the duplicate sample from MW-6 and the sample collected from well MW-16 contained concentrations of GRO greater than the Method A CL of 800 micrograms per liter (µg/L), with concentrations of 7,870 µg/L, 7,830 µg/L and 167,000 µg/L, respectively. Groundwater samples collected from well MW-16 contained concentrations of benzene, toluene, ethylbenzene, and total xylenes greater than their respective Method A CLs with concentrations of 15,200 µg/L, 29,000 µg/L, 2,680 µg/L, and 18,400 µg/L, respectively.

As mentioned above, LNAPL had been observed in monitoring well MW-2 since June 2004. To determine if LNAPL was trapped in the sand-pack of MW-2, this well was decommissioned in 2010 and a replacement well (MW-16) was installed in close proximity to MW-2. No LNAPL has been observed in MW-16 since installation; however, the concentration of GRO in groundwater collected from MW-16 was 167,000 µg/L and benzene concentration was 15,200 µg/L in July, 2011.

Analytical groundwater data is presented in **Table 1**. The groundwater analytical data from July, 2011, is presented on **Figure 4**.

8. Biogeochemical Data

In October, 2010, groundwater samples were collected from monitoring wells MW-1, MW-4, MW-5, MW-6, MW-11, MW-12, and MW-16 and analyzed for GRO, BTEX, and the following biogeochemical parameters:

- Total Alkalinity
- Sulfate
- Nitrate and Nitrite as Nitrogen
- Methane
- Total and Dissolved Manganese
- Total and Dissolved Iron
- Total Organic Carbon
- Sulfide

Results for GRO and BTEX from October, 2010 are presented in **Table 1,** and biogeochemical data are presented on **Table 4**. Method A CL exceedances of GRO, benzene, toluene, ethylbenzene and total xylenes were observed in samples collected from monitoring wells MW-1, MW-5, MW-12, and MW-16.

Biogeochemical data were analyzed to determine the extent of naturally occurring attenuation within the Site plume. Reducing conditions in which hydrocarbons degrade are characterized by increased methane concentrations, higher concentrations of iron and manganese from disassociation of aquifer minerals due to lower pH levels, and lower concentrations of nitrates due to nitrogen reduction. Methane, a byproduct of reducing conditions, was detected in samples collected from all wells with Method A CLs exceedances except MW-1. Methane concentrations ranged from 43 µg/L in MW-16 to 9,110 µg/L in MW-5. Methane was not detected in samples collected from upgradient or downgradient wells, MW-4 and MW-11. For most wells with Method A CLs exceedances, concentrations of nitrate and sulfate (electron acceptors) were at least one order of magnitude lower than concentrations detected from samples at MW-4 and MW-11. Electron acceptors may be depleted in these wells due to bio-attenuation. Minimal sulfide production was observed in groundwater sampled from MW-6 and may be indicative of sulfide reducing conditions.

Laboratory analytical data reports for the October, 2010, sampling event are presented in **Appendix A**.

9. Historical Site Remediation

To date, a remedial action plan has not been implemented at the Site. In 2004, under direction of Ecology, GRO impacts were discovered on the Site and site monitoring activities were implemented. A settlement agreement was reached in 2005 between GSCI and ARCO. To assess the effectiveness of a SVE system at the Site, ARCADIS conducted an SVE pilot study in February, 2011.

9.1 SVE Well Installation and SVE Pilot Test

This section summarizes the installation of one vapor extraction well and SVE pilot testing activities. The original work plan for well installation and pilot study were submitted to Ecology under separate cover.

9.1.1 Extraction Well Installation

Extraction well VE-1 was installed approximately 13 feet to the south of well MW-16 (Figure 2). The initial 6.5-feet of the borehole were cleared using a vacuum truck. The boring was then advanced to a depth of 18 feet bgs using a truck mounted hollow stem auger drilling rig.

During drilling, soil samples were collected for lithologic description and volatile organic compound (VOC) analysis using a handheld photoionization detector (PID) at five-foot intervals from 2.5 feet bgs to the bottom of the boring (18 feet bgs). PID readings, soil types, and other pertinent geologic data was recorded on a boring log by an ARCADIS geologist. The boring log for well VE-1 is included in **Appendix B**.

Upon reaching the total depth of the borehole, SVE well VE-1 was installed within the annulus of the hollow-stem auger. The SVE well was constructed of 4-inch diameter, Schedule 40 polyvinyl chloride (PVC) casing with a screened interval of 8 to 18 feet bgs, with 0.02-inch wide horizontally slotted casing. Number 2/12 sand was used as the filter pack from the total depth of the wells to two feet above the screened interval. A 1.5-foot hydrated bentonite seal was placed above the filter pack. The remaining well annulus was backfilled with hydrated bentonite chips to 3 feet bgs. The top three feet of the well annulus was sealed using neat cement. The well was capped with a locking water tight well plug and a traffic-rated well box installed at grade.

9.1.2 SVE Pilot Test

An SVE pilot test was completed at VE-1 on February 22 and 23, 2011. The pilot test consisted of one step test and two constant rate tests. Monitoring wells MW-1, MW-4, MW-5, and MW-16 were used as observation wells during the pilot test (**Figure 2**).

For each test, vacuum pressure was measured at extraction and monitoring well heads using vacuum gauges. Pretreatment effluent concentrations of VOCs were measured periodically with a PID at the extraction well manifold. Air velocity was measured using a hotwire anemometer inserted in a sampling port at the manifold and then used to calculate the extraction flow rate.

The step test was conducted for three hours. The flow rate ranged from approximately 20 to 80 standard cubic feet per minute (scfm). At the start of the pilot study concentrations of VOCs spiked to 10,000 parts per million by volume (ppmv), and after the first hour concentrations ranged from approximately 340 ppmv to 1,540 ppmv as the extraction flow rate was increased from approximately 19 to 86 scfm. Flow rates and PID readings were used to calculate mass removal rates and the total mass removed. Mass removal rates ranged from 8.2 to 46.2 pounds per day (lb/day). It is estimated that approximately 2.4 lb of petroleum hydrocarbons were removed during the step test.

The first constant rate test was conducted for two hours. The average flow rate and vacuum was 56 scfm and 26 in. wc., respectively. The concentrations of VOCs ranged from 330 to 821 ppmv. The calculated mass removal rate ranged from 7.4 to 12.4 lb/day, and the estimated mass removed was 0.9 lb. Vacuum readings collected from the extraction and monitoring wells were used to determine the extraction vacuum radius of influence (ROI). The calculated ROI was 77 feet.

The second constant rate test was conducted for over five and a half hours. The average flow rate and vacuum was 60 scfm and 26.4 in. wc., respectively. The concentrations of VOCs ranged from 200 to 4,882 ppmv. The calculated mass removal rate ranged from ranged from 4.0 to 103 lb/day, and the estimated mass removed was 2.3 lb. Vacuum readings collected from the extraction and monitoring wells were used to determine the extraction vacuum ROI. The calculated ROI was 68 feet.

Details of the SVE pilot study are presented in **Appendix C.**

10. Evaluation of Remedial Alternatives

The following provides a feasibility discussion for potential remedial alternatives for the Site. For the purpose of this RAP, three remedial alternatives were identified and evaluated for their effectiveness at remediating affected soil and groundwater:

- Monitored natural attenuation (MNA)
- Enhanced anaerobic bio-attenuation using electron acceptor solution injected / gravity feed into the dissolved phase petroleum hydrocarbon plume
- Active remediation utilizing an AS/SVE system to address identified soil and groundwater impacts in the vicinity of the dispenser island

10.1 Alternative 1 - MNA

This alternative does not involve the implementation of engineered remedial technologies to remove, treat or contain COCs at the Site. Under this alternative, natural attenuation processes will reduce chemical concentrations through time and routine (quarterly) groundwater monitoring will be performed to document changes.

MNA has been defined as the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site specific remediation objectives within a time frame that is reasonable compared to that offered by other, more active methods. The “natural attenuation processes” at work in such a remediation approach include a variety of physical, chemical or biological processes that, under favorable conditions, act to reduce the mass, toxicity, mobility, volume or concentration of COCs in soil and groundwater. These in-situ processes include dilution, sorption, biodegradation, volatilization and chemical biological stabilization, transformation or destruction of COCs.

Natural attenuation processes are typically occurring at all sites, but to varying degrees of effectiveness, depending on the types and concentrations of contaminants present, and physical, chemical, and biological characteristics of the soil and groundwater. Natural attenuation processes may reduce the potential risk posed by site contamination in three ways:

1. The contaminant may be converted into a less toxic form through destructive processes such as bioremediation or abiotic transformations.

2. Potential exposure levels may be reduced by lowering concentrations levels through physical processes or by dilution.

3. Contaminant mobility and bioavailability may be reduced by sorption to the soil or aquifer matrix.

Long term trends indicate that COC concentrations are decreasing within the onsite plume. However, MNA is not the preferred remedial alternative at the Site due to elevated COC concentrations and a prohibitive timeframe required to achieve dissolved concentrations less than MTCA Method A CLs.

10.2 Alternative 2 – Enhanced Anaerobic Biodegradation

Organic carbon in the form of aromatics and ketones (i.e., GRO and BTEX constituents) can stimulate indigenous microorganisms to utilize available electron acceptors to facilitate microbial growth. As the indigenous ecology evolves, available electron acceptors are depleted in order of thermodynamic favorability in the following order: oxygen, nitrate, manganese, iron, sulfate, and eventually carbon dioxide under methanogenic conditions. The electron acceptors are reduced through electron transport as the hydrocarbon constituents are oxidized to benign end products (hydrogen, acetic acid, and carbon dioxide) as microbes generate energy.

Typical undisturbed hydrocarbon related impacts can generate strong sulfate reducing conditions, and establish strongly reductive environments. If sulfate exists (or is supplied) in sufficient quantity to meet the stoichiometric demand of the available hydrocarbon related impacts, the constituents will be destroyed naturally. This alternative involves adding electron acceptors in the form of magnesium sulfate to enhance ongoing petroleum hydrocarbon related oxidation mechanisms induced by metabolic activity of native microorganisms.

Previous groundwater data collected at the Site indicates anaerobic bio-oxidation is occurring within the Site plume. Sulfate and nitrate concentrations are depleted or reduced within the plume as compared to upgradient and downgradient concentrations. Implementation of this approach would involve the injection or gravity flow of a potable water, and magnesium sulfate solution within the impacted saturated zone to enhance anaerobic bio-oxidation of the dissolved and sorbed-phase petroleum related hydrocarbons.

Components of this alternative potentially include:

- Installing an electron acceptor delivery system through a network of injection wells at and/or hydraulically upgradient from the source area.

- Performing a baseline sampling event in all Site wells to collect COC data and biogeochemical data prior to injection of the electron acceptor solution. Biogeochemical parameters may include: alkalinity, nitrate, sulfate, total and dissolved iron, downhole field parameters (pH, conductivity, temperature), and sulfide (collected in the field with a field spectrometer kit).

- Performing an initial pilot study injection of electron acceptor solution and monitoring downgradient wells to confirm distribution characteristics.

- One month following injection, performing one sampling event to evaluate the extent of biodegradation processes (i.e. occurring within site groundwater). This includes collecting biogeochemical indicator parameters including total and dissolved iron, sulfate, and downhole field parameters. Based on this sampling event additional sampling may occur three months and six months following injections.

- Performing additional electron acceptor solution injections with volumes and target concentrations adjusted based on pilot test results.

- Initiating a quarterly monitoring program for one year following injection.

As mentioned above in section 7.3, previous biogeochemical sampling shows elevated concentrations of methane and depleted concentrations of sulfate and nitrate in the presence of dissolved-phase petroleum hydrocarbons, thus, suggesting bioactivity within the plume. Therefore, it was determined that enhanced anaerobic biodegradation can be used for treating dissolved phase impacts observed at offsite wells MW-5, MW-6, and MW-12.

10.3 Alternative 3 – Air Sparge and Soil Vapor Extraction (AS/SVE)

An AS/SVE system involves injecting air under pressure into the saturated zone to increase dissolved phase oxygen concentrations thus degrading dissolved phase COC concentrations through aerobic degradation. Air sparging also increases volatilization of dissolved phase petroleum hydrocarbon related impacts through phase transfer from dissolved phase to vapor phase. SVE removes residual LNAPL and sorbed phase hydrocarbons from vadose zone soils, as well as, captures the vapor phase from sparging activities. An AS/SVE system would consist of a series of AS and SVE wells connected to a blower and compressor via manifold piping. Effluent vapors would be treated above ground through activated carbon filtration or catalytic oxidation. Components of this alternative potentially include:

- Installing a skid-mounted AS/SVE treatment system at the Site

- Installing new trenching and subsurface piping

- Performing system startup and operation and maintenance (O&M) activities

- Conduct air monitoring activities to evaluate the reduction of total VOC concentrations in the influent air to the treatment system

- Continued groundwater and air monitoring activities to evaluate the reduction of VOC concentrations in soil and groundwater

SVE removes residual LNAPL and sorbed-phase hydrocarbons from vadose zone soils, as well as, increases the oxygen concentration in vadose zone soils enhancing aerobic oxidation of COCs. ARCADIS performed an SVE pilot test in February, 2011, to determine the feasibility of remediating vadose zone soils and reducing residual LNAPL within the smear zone. As part of the pilot study ARCADIS installed one vapor extraction well (VE-1) and performed a vapor extraction step and constant rate test.The results of the pilot study are summarized above in *Section 9.2.1 SVE Pilot Test* and are presented in further detail in **Appendix C**.

Based on pilot test results it was determined that AS/SVE is the preferred remedial alternative at the Site to treat residual and sorbed-phase LNAPL impacts in the area of wells MW-2 (abandoned) and MW-16 and dissolved phase impacts observed at MW-1.

It is proposed that AS/SVE will be used onsite to recover, remove, or volatilize residual LNAPL from the subsurface and treat dissolved phase impacts. Initially, low-flow AS will be used to prevent migration of any potential LNAPL, and sparging flow rates may increase to treat dissolved phase impacts if LNAPL is no longer observed at the Site. AS/SVE treatment may be followed by enhanced anaerobic biodedgradation to treat remaining dissolved phase impacts.

11. Remedial Design

11.1 Objectives

To address onsite GRO and BTEX impacts stemming from historical Site activities, ARCADIS proposes to install an AS/SVE system to treat impacts observed at onsite wells MW-1, MW-2 (abandoned) and MW-16. Enhanced anaerobic biodegradation (magnesium sulfate injection) will be used to treat dissolved-phase impacts observed at offsite monitoring wells MW-5, MW-6, and MW-12.

11.2 AS/SVE Remedial Approach

The AS/SVE system will be used to remediate smear zone soils, volatilize residual LNAPL, and treat dissolved phase impacts detected during previous soil boring investigations and quarterly groundwater monitoring events at onsite wells MW-1, MW-2 (abandoned), and MW-16. The existing extraction well VE-1 may provide adequate extraction coverage; however, to ensure effective treatment, two additional extraction wells, VE-2 and VE-3, will be installed. The location of these wells is shown on **Figure 5**. Initially, low-flow AS will be used to prevent migration of LNAPL, sparging flow rates may increase to treat dissolved phase impacts if LNAPL is no longer observed at the Site. Remediation equipment will be procured through a system vendor to meet ARCADIS design specifications. AS/SVE treatment may be followed with sulfate injection as a polishing step.

11.2.1 Well Design and Completion Details

SVE wells will be installed within the estimated source area based on previous site assessments. The results from a SVE pilot study conducted in February, 2011, (Appendix C) concluded that a 72.5 foot ROI could be achieved by SVE wells. This result is the average ROI from the two constant rate tests conducted during the pilot study. For design purposes, an ROI of 90 percent of this value, or 65 feet, will be assumed. These design criteria are within typical SVE system design criteria as described in the Army Corps of Engineers Engineering Manual- EM1110-1-4001 (US Army Corps of Engineers, 2002).

AS/SVE treatment may be followed with sulfate injection as a polishing step. Based on this remedial approach, the location of VE-2 and VE-3 will be based on implementation of enhanced anaerobic biodegradation. As described in Section 9.3, *Enhanced Anaerobic Biodegradation Remedial Approach*, the assumed ROI for injection is 15 feet based on soil types and target injection volumes. Historically, flow direction has ranged from southwest to west across the Site, therefore, it is assumed that the new wells, VE-2 and VE-3, will be located 15 feet to the northeast of MW-1 and MW-16, respectively.

Groundwater seasonally fluctuates between 16.28 and 19.65 feet btoc based on historical groundwater data from MW-1, MW-2 (abandoned), and MW-16. The average depth to groundwater is approximately 17.88 feet btoc. Therefore, the dual purpose injection and soil vapor extraction wells will be set approximately 28 feet bgs, with 20 feet of well screen, with approximately 10 feet of screen within vadose zone soils. The AS wells will have two feet of screen, set approximately 30 feet bgs, 10 feet below the deepest depth-to-water recorded (19.65 feet btoc).

Proposed AS wells will be 2-inch diameter schedule 80 PVC, approximately 30 feet bgs with 2 feet of 0.020" slot stainless steel wire wrapped or stainless steel slotted screen at the bottom of the well. #2/12 silica sand will be placed to a depth of 1-foot above the top of screen. Several feet of coated pelletized bentonite seal will be place above the sand through the saturated zone. Neat cement will be placed above the coated pelletized bentonite seal to a depth just below the well box (approximately 3.5 to 4 feet bgs) for temporary completion.

The dual purpose injection and soil vapor extraction wells will be constructed of 4-inch diameter, Schedule 40 PVC with a 20 foot screened interval of stainless steel wire wrapped screen. #2/12 silica sand will be placed to a depth of 1-foot above the top of screen, a one foot layer of very fine (sugar) will be placed on top of the silica sand, and neat cement will be used to complete the well to ground surface. A traffic-rated well box and locking well cap will be installed at ground surface.

The SVE system is designed to remove one pore volume per day in the treatment area. SVE will be conducted at approximately 55 scfm per well. The design ROI will be verified during startup and testing procedures to ensure adequate vacuum influence and air flow is occurring over the treatment area. Startup procedures are described in Section 9.2.14 *System Start-up and Optimization*.

System design calculations are based on expected pore volume exchange and soil and groundwater pressures during average conditions observed over time, as well as, historical high and low groundwater elevations. System design parameters and calculations are included in **Appendix D**.

The ROI for AS wells is assumed to be 15 feet based on soil type and empirical data from the Air Sparging Design Paradigm (Leeson et al 2002). Considering well spacing and the targeted treatment area, four new AS wells will be installed (AS-1 to AS-4) as shown on **Figure 5**.

11.2.2 System Components

The AS/SVE system will be installed in a skid mounted temporary portable building to enable use of this system at different sites throughout Washington. The system includes a regenerative blower, knockout tank, vacuum piping manifold, ventilation fans, programmable logic control (PLC), pressure, temperature, vacuum and flow gauges and transmitters, and system heaters. The effluent vapor will be treated through an electric catalytic oxidizer mounted to the outside of the portable building.

11.2.2.1 AS System

Based on design calculations attached in **Appendix C**, the AS compressor will have to be capable of producing air at 21 pounds per square inche [gauge] (psig). Typical air flow rate to an AS well is 10 to 15 scfm, but due to the potential of LNAPL at the Site, air flow rates will initially have to be lower (2 to 3 scfm) to prevent further spreading of LNAPL impacts. To improve air distribution and lower capital and operational costs, the AS system will operate in pulse mode. It is assumed that in pulse mode, a maximum of two wells will be sparging at the same time, therefore, the maximum blower capacity will be approximately 30 scfm. At this flow rate, the maximum piping pressure drop is calculated to be less than 1 pound per square inch (psi). The compressor will be connected to four AS wells through a manifold consisting of individual well monitoring gauges and valves. Manifold gauges and valves include a rotameter, solenoid valve, gate valve, and pressure indicator. Immediately following the compressor, air will flow through a heat exchanger with condensate drain to reduce the air stream temperature and vapor content. The AS compressor will have an internal pressure relief switch to prevent high internal pressure buildup which may cause blower and piping damage. The compressor air inlet is composed of a filter to pull ambient air in from the exterior of the system compound. High pressure and temperature switches will be interlocked with the main PLC to automatically shut down the system if conditions become abnormal. Solenoid valves and a system timer will allow for pulsed sparging of two wells at a time. The pulsing schedule will be determined during the initial system optimization.

11.2.2.2 Soil Vapor Extraction System

The SVE blower will be selected to accommodate a wide range of applications and flow rates using a variable speed drive. For application at this Site, calculations for expected operating conditions are included in **Appendix D**. The blower will be connected to three SVE wells, VE-1, VE-2, and VE-3 through a manifold consisting of individual well monitoring gauges and valves. Based on this extraction flow rate and an estimated maximum piping vacuum drop of 0.15 psi, the vacuum blower will need a capacity of approximately 145 scfm. Manifold gauges and valves include a differential pressure gauge, gate valve, and vacuum indicator. Prior to the blower, piping will run through a condensate knock out drum. The blower will be equipped with a vacuum relief valve to prevent high vacuum in the system which may cause blower and piping damage. The blower air inlet bleed valve is composed of a filter and silencer to pull ambient air in from the exterior of the system and adjust vacuum. High vacuum and temperature switches are interlocked with the main PLC to automatically shut down the system if conditions become abnormal.

11.2.2.3 Remedial Compound

The remedial enclosure is composed of an equipment room housing the AS compressor and manifold, as well as SVE system components. The control panel will be mounted on the building exterior and contain a wireless cellular modem, a PLC with user interface, heater, ventilation fan, and the main system breakers and switches. Additional health and safety equipment, including an emergency eyewash station, first aid kit, and fire extinguisher, will be installed in the equipment room.

11.3 Air Sparge Conveyance Piping

AS conveyance piping will be below ground and lead from the system manifold to four newly installed AS wells. The AS conveyance piping will be 2-inch diameter high-density polyethylene (HDPE), or 2-inch Schedule 80 PVC piping to allow for the increased pressures required during sparging. At the location where AS piping daylights near the system, 1-inch galvanized steel piping will be used and 3-inch schedule 80 PVC sleeves may be placed around the AS piping to protect it from accidental damage during asphalt replacement. All transitional fittings will be made below grade. The AS conveyance piping will be connected to the AS manifold via union fittings and lead through the sidewall of the system building. Conveyance piping will be installed in trenches at a minimum depth of 30-inches and will be connected below grade to the AS well casing through PVC or HDPE 2-inch tee fittings.

11.4 SVE Conveyance Piping

SVE conveyance piping will be below ground and will lead from the system manifold to two newly installed dual purpose wells. The SVE conveyance piping will be 2-inch Schedule 40 PVC and connected to the wells will be made below grade through a 2-inch by 4-inch PVC tee fitting. At the location where SVE piping daylights near the system, 2-inch Schedule 80 PVC will be used. Aboveground SVE piping to the system compound will be protected by a 3-inch schedule 80 PVC sleeve. SVE piping will connect to the system manifold through the sidewall of the remediation building. Conveyance piping will be installed in trenches at a minimum depth of 30-inches and will be connected below grade to the SVE well casing through PVC or HDPE 2-inch tee fittings. System piping and connection details are shown on **Figure 6**.

11.5 Site Preparation

The construction perimeter will be fenced off in sections with secure temporary fencing during drilling, trenching, and system installation activities. A traffic control plan will be established with agreement by the business and property owners in order to reduce impacts to current Site operations. A pre-construction meeting will be scheduled prior to drilling, and a second pre-construction meeting will be scheduled prior to trenching involving an ARCADIS representative and contractor representatives.

11.5.1 Well Location and Utility Clearance

A public utility clearance using Washington 811 dig alert will be conducted prior to construction and drilling activities. A private utility locating service will also be scheduled for site clearance using ground penetrating radar (GPR) and magnetic locating equipment to identify utilities not included under the public locate. Representatives from the drilling contractor and the general contractor will be present to ensure that equipment maneuverability and site access is adequate around the placement of AS and SVE wells and trenching. An additional private utility locate, prior to trenching activities, will be scheduled to locate utility markings removed during well installation.

11.5.2 Well Installation and Construction

Two dual purpose soil vapor extraction and injection wells (VE-2 and VE-3) and four AS wells (AS-1 to AS-4) will be installed in the western portion of the Site (**Figure 5**). The initial 6.5 feet of the borehole will be cleared using an air-knife and vacuum truck to reduce the potential for damage to underground improvements. The boring will then be advanced using a hollow-stem auger rig. If a hollow-stem auger rig cannot be used due to site constraints, and if soil conditions allow, a direct push drill rig will be used. The drilling rig will be provided and operated by Cascade Drilling Incorporated (Cascade) of Woodinville, Washington.

During drilling, soil samples will be collected by split spoon at 2.5-foot to 5-foot intervals from five feet bgs to the total depth of boring (28 feet bgs and 30 feet bgs). Soil samples will be screened in the field for VOCs using a PID. PID readings, soil types, and other pertinent geologic data will be recorded on the boring log.

Groundwater seasonally fluctuates between 16.28 and 19.65 feet btoc based on historical groundwater data from MW-1, MW-2 (abandoned), and MW-16. The average depth to groundwater is approximately 17.88 feet btoc. Therefore, the dual purpose injection and soil vapor extraction wells will be set approximately 28 feet bgs, with 20 feet of well screen, with approximately 10 feet of screen within vadose zone soils. The AS wells will have two feet of screen, set at approximately 30 feet bgs, 10 feet below the deepest depth-to-water recorded (19.65 feet btoc).

Screen interval may vary based on encountered groundwater elevation during drilling. The sand pack of #2/12 silica sand will be placed around the well screen to one foot above the top of screen for all wells. For sparge wells, coated pelletized bentonite place above the sand through the saturated zone. Neat cement will be placed above the pelletized bentonite seal to a depth just below the well box (approximately 3.5 to 4 feet bgs) for temporary completion. ARCADIS standard operating procedure (SOP) for monitoring well installation has been included in **Appendix E**.

11.5.3 Well Development

Newly installed wells will be developed using a combination of surging and purging or jetting techniques based on well screen type. Wells with wire wrapped stainless steel screen will be developed through jetting which introduces high velocity water into the well screen through a small diameter tube equipped with nozzles. Injected water is purged simultaneously, effectively keeping the in-well water level equal to the static water level. The well will initially be gently surged to remove fines by moving the pump the length of the saturated screen. The submersible pump will be capable of purging between 0.5 to 4 gallons per minute (gpm). Wells with PVC slotted screen will be developed through standard surging and purging techniques. Storage of well development purge water is discussed below under the Management of Investigation Derived Waste Section. Details describing well jetting are attached in the Well Development-Water Jetting Standard Operating Procedure included as **Appendix E**.

11.5.4 Trenching

Trenching activities will be completed by an ARCADIS-approved subcontractor. Trenching will be excavated to a minimum of 30-inches. Two inches of self compacting sand bedding material will be placed in the trench prior to conveyance piping. An additional 2 inches of bedding material will be placed over and surrounding the piping. Geotextile fabric will be placed above the compacted sand bedding to ensure separation from native fill. Native fill and locating tape will be placed within the upper 1-foot of trench fill material. Trenching will be finished to match existing grade. Where trenching is installed through asphalt or concrete, the surface will initially be saw-cut.

Upon completion, trenching through asphalt will be sealed and concrete will be matched to the existing surface. Proposed trenching locations are shown on **Figure 5**.

11.5.5 Management of Investigation Derived Waste

Excavated soil will be stockpiled in bermed containment areas to allow for characterization sampling prior to disposal. Soils will be sampled in in accordance with Guidance for Site Checks and Site Assessments for Underground Storage Tanks from Ecology (Ecology 2003). Soil samples will be submitted to Pace Analytical for the following COCs analyses:

- GRO by NWTPH-Gx
- BTEX by EPA 8021B

And the following Resource Conservation Recovery Act (RCRA) 8 Metals:

- Arsenic, Barium, Cadmium, Chromium, Lead, Selenium, Silver by EPA 6010
- Mercury by EPA 7470
- Based on results from metals analysis, samples may be analyzed for Toxicity Characteristic Leaching Procedure (TCLP).

Pending sampling results, waste soil will be loaded onto haul trucks for transport to the appropriate disposal facility. Soil stockpiles will be covered with plastic sheeting at the end of each day.

11.5.6 System Delivery and Installation

Prior to system shipment, vendor factory inspection of system components will be reported to ARCADIS. Full power will be applied to the system for testing. The system blower and compressor will be tested under load to verify initial design specifications are met. System interlocks will be tested including float switches, lower explosive limit (LEL) meter, emergency stop buttons, and temperature and pressure switches. Results of the initial system inspection will be reported in a system installation report submitted to Ecology following system startup.

The system will be delivered to the Site with internal components connected and tested. The system will be placed by the general contractor onsite under the direction of ARCADIS personnel.

Electrical permits will be obtained by the electrical contractor, and connections will be tested prior to utility company and city inspection. Final electrical system inspection, including voltage loading from ground to phase and between phases, will be performed in the presence of ARCADIS personnel and relevant subcontractors.

11.5.7 Site Surveying and As-Built Report

An ARCADIS-approved licensed surveyor will survey existing Site features including building corners, monitoring well top-of-casing, new remediation wells, and trenching locations relative to NAD83 ASP Zone 4 horizontal datum. The NAVD88 datum is the standard vertical geoid used by the North American Geological Survey. For reporting purposes, the NAVD88 referenced datum will be considered mean sea level. An as-built report with drawings, soil boring data, soil disposal data, and final trenching and well locations will be submitted to Ecology following completion of system installation.

11.5.8 System Start-up and Optimization

11.5.8.1 SVE System

During initial start-up activities, design criteria will be tested to ensure adequate SVE radius of influence are met. Initial testing will involve system operation in an unloaded condition with bleed valves open. Pressure, temperature, flow and effluent vapor concentration readings will be recorded as baseline conditions.

The SVE system will be optimized so that field operating conditions meet or exceed design criteria. SVE wells will be closed and vacuum gauges will be placed on the well heads of MW-1, MW-4, and MW-16. The main manifold bleed valve and flow control valve for well VE-1 will be fully opened. System flow and vacuum data will then be recorded from the manifold. Additional vacuum readings will be taken from the vacuum gauges placed on MW-1, MW-4, and MW-16. The vacuum gauges will read a minimum of 0-30 in. wc. The variable speed throttle will initially be set at the midpoint. The bleed valve will be throttled closed until a total system vacuum reaches a maximum set point (e.g. 40 inches of water). Vacuum readings on the monitoring well gauges, as well as total flow readings will be recorded every five minutes for 30 minutes. Results will be plotted logarithmically to verify the induced vacuum radius of influence. Additional bleed valve throttling will occur and measurements will be taken until adequate ROI and flow rate are met. The test will be repeated on dual purpose well VE-2 while vacuum measurements are observed at monitoring MW-1, MW-4, and MW-16.

When individual well parameter settings have been determined, all wells will be opened and valves will be throttled to meet test conditions. If testing indicates field operation does not meet design criteria, additional SVE wells or alternative remedial strategies may be required to adequately address vacuum influence.

11.5.8.2 AS System

To verify that the design AS radius of influence is achieved under field conditions, compliance wells will be monitored for dissolved oxygen (DO) and groundwater mounding effects during initial startup of each AS well. A downhole DO meter and a water level transducer will be installed in compliance wells during the operation of each AS well. Pressure and flow will be adjusted using bleed valves and the variable frequency drive on the compressor to obtain adequate radius of influence. These data will also be used to determine adequate time sequences for pulsed sparge operation. DO and mounding effects will be plotted vs. time to determine peak DO concentrations and groundwater elevation influence.

11.5.9 System Monitoring

Prior to system startup, groundwater will be sampled to obtain baseline conditions in Site wells. Baseline monitoring will be performed in conjunction with regularly scheduled groundwater sampling. Following system startup, groundwater monitoring will continue based on the regularly scheduled semi-annual sampling events. Groundwater samples will be collected using low-flow peristaltic pumps.

Groundwater samples will be submitted to Pace Analytical, a Washington state-certified laboratory, for analysis. Chain-of-custody procedures will be followed from the time the samples are collected until the time the samples are relinquished to the laboratory. The samples will be analyzed for the following:

- GRO by Northwest Method NWTPH-Gx
- BTEX by EPA Method 8260B
- Total lead by EPA Method 6010

System parameters will be collected daily during the first week of operation, weekly for the first month of operation and monthly thereafter. System readings will include manifold pressure, individual well pressure, individual well flow, overall system flow, and pre- and post-heat exchanger temperature and pressure readings. PID measurements will be taken from the SVE system effluent stack on a monthly basis.

Influent air filters will be inspected and cleaned or replaced monthly. Additional system maintenance procedures will include recordable hours of operation, and adjustments to vacuum pressure and flow rates. Compliance wells will be monitored for observable signs of sparging (i.e., bubbling) and a measureable increase in DO during the first two weeks of operation.

11.5.10 Shutdown Criteria

The AS/SVE system is expected to operate for 2 years based on typical AS/SVE remediation efforts at similar sites. Periodic shutdown of both AS and SVE components will be performed to evaluate concentration rebound in groundwater and soil vapor. A rebound test will be recommended after mass removal has become asymptotic and dissolved phase groundwater concentrations are within an order of magnitude of CLs and indicate overall decreasing trends. During rebound testing, the system will remain shut down for approximately one month, and compliance wells will be sampled for GRO and BTEX. The system will be restarted and allowed to run approximately 24-hours. Vapor samples will be collected and submitted for COC analysis. The system will again be shutdown pending analytical data. If dissolved concentrations rebound greater than the pre-rebound test groundwater data for GRO and BTEX the AS system may be restarted. If SVE vapor analytical samples show significant rebound the SVE will operate until asymptotic mass removal rates are again observed. If continued system operation is required, subsequent rebound evaluation should be conducted following the initial rebound test. If rebounded concentrations are not lower than those detected during the previous rebound evaluation, the AS system may no longer be effective and additional site remediation strategies may be considered. If system shutdown criteria are met, equipment will remain near the location and available for hookup for one year after shutdown to evaluate rebound prior to decommissioning.

11.5.11 Post -Remediation Success Criteria

After system shutdown, groundwater will be monitored semi-annually to determine if stable and decreasing dissolved-phase plume concentrations are present and support a move to one of the following strategies: enhanced anaerobic biodegradation, MNA, or potentially a “No Further Action” designation.

11.6 Enhanced Anaerobic Biodegradation

As mentioned in section 7.3, biogeochemical data was last collected in October, 2010, and suggests sulfate reducing conditions exist in the subsurface based on concentrations of methane, nitrate, and sulfate. Conditions indicate that increasing sulfate concentrations within the core of the hydrocarbon plume may stimulate naturally occurring bacteria, therefore, Epsom salt application is a feasible remedial strategy for this Site.

ARCADIS proposes to use enhanced anaerobic biodegradation to treat offsite impacts observed at MW-5, MW-6, and MW-12. This remedial approach proposes to inject under gravity feed an Epsom salt solution into these wells.

11.6.1 Technical Background

Aquifers impacted by petroleum hydrocarbons are typically anaerobic because DO is energetically favorable and is preferentially consumed by indigenous microbes during aerobic oxidation (i.e., biodegradation) of the petroleum hydrocarbons, which serves as an electron donor in the microbial metabolism reactions. Following the depletion of oxygen, alternative electron acceptors (i.e., nitrate, iron, manganese, sulfate, and carbon dioxide) are utilized in the continued anoxic/anaerobic oxidation of petroleum hydrocarbons. The anaerobic oxidation of petroleum hydrocarbons under various dominant electron-accepting processes (e.g., sulfate-reduction, iron-reducing, methanogenesis, etc.) is well-founded in the literature (Anderson, et al., 2000; Aronson and Howard, 1997; Beller et al., 1992; Bordon et al, 1997; Coyne and Smith, 1995; Cunningham et al, 2001; Davis et al, 1999; Schreiber et al., 2004; Wiedemeier, et al., 1999). Similar to enhanced aerobic systems, engineered anaerobic approaches rely on redox couples such as nitrate reduction, ferric iron reduction, sulfate reduction, and methanogenesis to facilitate cellular respiration using the petroleum hydrocarbon as an electron donor.

Anaerobic processes generally occur at slower kinetic rates than that observed with oxygen. Non-oxygen electron acceptors (i.e. sulfate) can be advantageous to oxygen injection approaches as they are highly soluble, can be supplied at elevated dissolved concentrations, and have minimal abiotic or non-target reactions that typically limit oxygen persistence in the subsurface. The higher concentrations of sulfate that can be maintained in a petroleum hydrocarbon impacted aquifer accompanied by electron acceptor persistence allows for effective hydrocarbon degradation. Comparatively, oxygen sparging approaches are fundamentally limited by low oxygen solubility in groundwater and gas transfer inefficiencies that limit the effective dissolved oxygen concentrations typically maintained in engineered aerobic reactive zones. Thus, while the kinetic rates of anaerobic hydrocarbon bio-oxidation may be slower than under aerobic conditions, the ability to deliver elevated concentrations of non-oxygen electron acceptors over a relatively long time period during infrequent events can be cost-effective compared to long-term operation of continuous oxygen sparging or other engineered aerobic treatment alternatives.

11.6.2 Anticipated Effects of Sulfate on Groundwater Chemistry

Short-term effects of Epsom salt injection on groundwater chemistry may include the following:

- Increase of sulfate concentrations to a calculated concentration of 5 grams per liter (g/L) prior to consumption by sulfate reducing bacteria (initially localized to the injection well vicinity)
- Increase in the population of sulfate reducing bacteria, and the reduced form of sulfate – hydrogen sulfide
- Precipitation of iron sulfides from sulfide ions in solution and iron in the groundwater
- Localized increases in groundwater total dissolved solids (TDS), before the effects of advection and dilution disseminate the delivered sulfate
- Further consumption of nitrate to oxidize sulfide back into sulfate (Londry and Suflita, 1999)

Long-term effects on groundwater chemistry are expected to be minimal due to diffusion, advection, and consumption of the sulfate and the reaction's byproducts.

11.6.3 Hydraulic Conductivity Testing

To determine if sulfate application will be feasible, hydraulic testing will need to be conducted at the Site. Rising-head aquifer testing (slug testing) will be conducted on monitoring wells MW-5 and VE-2. VE-2 has been included for slug test since it is a dual-purpose well (injection and extraction) and may be used for sulfate injection following AS/SVE treatment at onsite wells. The slug test will be conducted in accordance to ARCADIS SOP. The Slug Test SOP is attached in **Appendix E.**

11.6.4 Sulfate Injection

This remedial approach assumes injection at wells MW-5, MW-6, and MW-12 (Figure 5). During the last sampling round in July, 2011, only the concentration of GRO at MW-6 exceeded Method A CLs, however, during recent sampling rounds the concentrations of GRO and BTEX have fluctuated at these wells and exceeded

Method A CLs. For example, in January, 2011, the concentration of GRO, benzene, ethylbenzene and total xylenes was 21,100 µg/L, 567 µg/L, 1,790 µg/L, and 2,970 µg/L, respectively at MW-5. The Method A CLs for these compounds are 800 µg/L, 1,000 µg/L, 5 µg/L, 700 µg/L, and 1,000 µg/L, respectively. Historical groundwater data is summarized in **Table 1**.

11.6.4.1 Permitting

As shown on **Figure 2**, offsite monitoring wells MW-5, MW-6, and MW-12 are located in sidewalks, therefore, the necessary permitting will have to be completed to allow access to the sidewalks during injections. Due to space limitations, it is proposed that the injection trailer will be parked on the sidewalk during injections at MW-6 and MW-12.

11.6.4.2 Injection Setup

Each monitoring well that will be used for injection will be temporarily connected aboveground by 5/8-inch garden hose to a distribution manifold staged inside an injection trailer. The manifold will include flow control valves and flow meters to adjust the application rate and quantify injection volumes. Water will be supplied to the trailer via flexible 1-inch rubber hose via camlock fittings leading to a temporary onsite water tank. Batch mixtures of Epsom salt will be dissolved into four 275 gallon mixing tanks. An air lance will be connected to a portable air compressor and used to mix the dissolved Epsom salt solution with potable water within the injection trailer. Once the tanks are adequately mixed the Epsom salt solution will be initially pumped through the manifold to establish a siphon to the injection wells. The solution will then be gravity fed into the injection wells. ARCADIS personnel will be onsite to execute the injection process and record injection parameters throughout the event. Well head pressure will be closely monitored to ensure pressure build up does not exceed 5 psi, potentially causing soil to fracture and create a preferential pathway to the surface.

11.6.4.3 Estimated Injection Volumes

Arrangements will be made to use the onsite water source, however, if the onsite water source is not adequate for the large volumes of injection solution required, a truck mounted tank will be used to supply potable water to the Site. Approximately 6,345 gallons of potable water per injection will be used to dissolve approximately 1,355 pounds (lbs) Epsom salt. A target injection concentration of approximately 25.6 g/L of Epsom salt will be injected into the well. The target in-situ sulfate concentration is 5 g/L assuming a groundwater dilution factor of approximately 2 L/L along the flow path from the injection wells to the dose response monitoring well. Stoichiometric equations and estimations are summarized in **Table 5.**

Injection volumes are based on a target 15-foot ROI per well over 15 feet of vertical well screen and an estimated 8% mobile porosity, which results in an approximate injection volume of approximately 6,345 gallons at wells MW-5, MW-6, and MW-12.

11.6.4.4 Baseline Monitoring

Prior to sulfate injection, groundwater will be sampled to obtain baseline conditions from monitoring wells (MW-5, MW-6, and MW-12). Groundwater samples will be collected by purging one casing volume. Biogeochemical parameters will be collected with a downhole multi-parameter meter and include conductivity, pH, and temperature from these injection points. Groundwater samples will be submitted to a Washington state-certified laboratory for analysis. Chain-of-custody procedures will be followed from the time the samples are collected until the time the samples are relinquished to the laboratory. The samples will be analyzed for some or all of the following:

- GRO by Northwest Method NWTPH-Gx
- DRO and HO by Northwest Method NWTPH-Dx
- BTEX by EPA Method 8260B
- Sulfide by EPA Method 376.1
- Sulfate by EPA Method 300.0
- Nitrate by Nitrogen by EPA Method 300.0
- Total and Dissolved Iron and Lead by EPA Method 6020

The sampling matrix is presented in **Table 6**.

11.6.4.5 Injection Monitoring

During injection, a downhole multi-parameter meter will be used to collect conductivity, pH, and temperature measurements from downgradient wells MW-11 and MW-13. Measurements will be taken approximately every 500 gallons of injected solution. Once sustained conductivity measurements are observed at these wells, a groundwater sample will be collected for sulfate and sulfide analysis.

11.6.4.6 Post-Injection Monitoring

Groundwater sampling of injection wells MW-5, MW-6, and MW-12, and downgradient wells MW-11 and MW-13 will occur one week and two months following injection. Groundwater samples will be collected by purging one casing volume. At one week, monitoring wells will be sampled for sulfide and sulfate. At two months, the sampling schedule will be the same as baseline sampling two months following injection. A downhole multi-parameter meter will be used to measure conductivity, pH, and temperature from these wells during sampling events. Concentration trends of sulfate and COCs will be analyzed to determine the rate of sulfate reduction within the plume. If concentrations remain greater than Method A CLs but reducing conditions exist and sulfate is depleted, an additional injection event may be scheduled. Based on the rate of sulfate utilization by the subsurface microbial communities, sulfate concentrations may be adjusted for subsequent injection events. The sampling matrix is presented in **Table 6**.

12. Health and Safety Procedures

The Health and Safety Plan (HASP) will include methods for protection of site workers and visitors during the proposed remedial activities and will include:

- A list of COC, their characteristics, and the potential routes of exposure
- Action levels for the various COC
- Methods for field monitoring for the various COC
- Emergency procedures and contact information
- Air monitoring
- Identification of routes to emergency facilities
- Identification of potential physical hazards and response actions for specific remedial tasks
- Personal protective equipment (PPE) for specific remedial tasks

PPE will generally consist of hard hats, steel-toed boots, chemical resistant gloves, ear protection, and eye protection. Respiratory protection is not anticipated, but will be available should field particulate monitoring suggest such measures are necessary.

13. Schedule

Following RAP submittal and Ecology comments, ARCADIS will install additional wells during the first half of 2012. Following well installation, AS/SVE system installation will occur. As-built drawings along with system installation and optimization details will be submitted following completion of system installation and start up. The proposed schedule is subject to change based on equipment availability.

Injection at offsite wells will occur during onsite AS/SVE treatment. Based on sulfate utilization rates observed during groundwater monitoring, additional injections may occur. A progress report will be submitted to Ecology following injection and post-injection monitoring summarizing results of injection events.

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ARCADIS

Tables

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-1	3/24/2004	(P)	99.77	17.43	--	82.34	213	--	--	**11.5**	0.525	5.05	4.78	<5.00	--	--	**43.4**	2.94
MW-1	6/7/2004	(P)	99.77	17.61	--	82.16	**1,160**	--	--	**136**	52.8	28.8	83	<1.00	--	--	**32.6**	1.43
MW-1	11/12/2004	(P)	99.77	18.30	--	81.47	**926**	--	--	**24**	2.22	56.9	19.1	<2.00	<0.500	2.39	<1.00	<1.00
MW-1	12/9/2004	(NS)	99.77	17.89	--	81.88	--	--	--	--	--	--	--	--	--	--	--	--
MW-1	2/1/2005	(P)	99.77	18.14	--	81.63	**1,020**	--	--	**12**	0.91	28.4	52.6	<2.00	--	--	4.89	<1.00
MW-1	5/4/2005	(P)	99.77	18.25	--	81.52	**1,090**	--	--	**43**	<0.500	31.9	50.7	<2.00	<0.010	1.29	<1.00	<1.00
MW-1	6/30/2005	(NS)	99.77	18.24	--	81.53	--	--	--	--	--	--	--	--	--	--	--	--
MW-1	8/5/2005	(P)	99.77	18.40	--	81.37	300	--	--	**26**	<0.500	0.874	20.3	<2.00	<0.010	<1.00	<1.00	<1.00
MW-1	11/16/2005	(P)	99.77	18.71	--	81.06	165	--	--	0.51	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	<1.00	<1.00
MW-1	2/2/2006	(P)	99.77	17.81	--	81.96	**2,470**	--	--	**502**	61.9	58.7	82.2	<1.00	<0.010	1.11	<1.00	<1.00
MW-1	5/18/2006	(P)	99.77	17.31	--	82.46	**1,350**	--	--	**384**	<0.500	6.28	44.9	<1.00	<0.010	<1.00	<1.00	<1.00
MW-1	8/14/2006	(P)	99.77	17.75	--	82.02	294	--	--	**77.1**	<0.500	<0.500	9.13	<1.00	<0.010	<1.00	<1.00	--
MW-1	3/7/2007	(NP)	99.77	17.16	--	82.61	359	--	--	4.39	<0.500	7.17	18.7	--	--	--	--	--
MW-1	6/5/2007	(NP)	99.77	17.25	--	82.52	171	--	--	0.58	<0.500	0.66	2.03	--	--	--	--	--
MW-1	9/6/2007	(NP)	99.77	17.72	--	82.05	132	--	--	<0.500	<0.500	<0.500	<1.00	--	--	--	--	--
MW-1	11/21/2007	(NP)	99.77	18.04	--	81.73	152	--	--	<0.500	<0.500	<0.500	<3.00	--	--	--	--	--
MW-1	1/17/2008	(NP)	99.77	17.69	--	82.08	255	--	--	2.74	<0.500	<0.500	<3.00	<1.00	--	--	1.55	--
MW-1	4/10/2008	(NP)	99.77	17.63	--	82.14	341	--	--	1.49	<0.500	1.63	<3.00	<1.00	--	--	<1.00	--
MW-1	7/2/2008	(NP)	99.77	17.81	--	81.96	130	--	--	<0.500	<0.500	0.78	<3.00	<1.00	--	--	<1.00	--
MW-1	10/7/2008	(NP)	99.77	18.24	--	81.53	302	--	--	<0.500	<0.500	<0.500	<3.00	<1.00	--	--	1.13	--
MW-1	3/19/2009	(NP)	99.77	18.20	--	81.57	407	--	--	3.88	<0.500	1.64	1.56	5.93	--	--	<1.00	--
MW-1	6/15/2009	(NP)	99.77	18.05	--	81.72	220	--	--	<1.00	<1.00	13	8.4	<1.00	--	--	<2.00	--
MW-1	9/4/2009	(NP)	99.77	18.44	--	81.33	50	--	--	<1.00	<1.00	<1.00	<2.00	<1.00	--	--	<2.00	--
MW-1	12/3/2009	(NP)	99.77	18.21	--	81.56	580	--	--	**13**	<1.00	13	4.6	<1.00	--	--	<2.00	--
MW-1	3/17/2010	(NP)	99.77	17.93	--	81.84	**2,000**	--	--	**280**	33	120	200	<1.0	--	--	4.2	--
MW-1	3/17/2010	(Dup)(NP)	99.77	17.93	--	81.84	**2,200**	--	--	**280**	34	120	210	<1.0	--	--	4.8	--
MW-1	7/21/2010	(NP)	267.43	17.34	--	250.09	**813**	--	--	**221**	1.0	121	57.8	<1.0	--	--	<10.0	--
MW-1	7/21/2010	(Dup)(NP)	267.43	17.34	--	250.09	780	--	--	**193**	<1.0	86.8	37.4	<1.0	--	--	<10.0	--
MW-1	10/13/2010	(LF)	267.43	17.68	0.0	249.75	358	--	--	**20.9**	<1.0	31.0	4.6	<1.0	--	--	<10.0	--
MW-1	1/13/2011	(LFP)	267.43	17.15	0.0	250.28	632	--	--	**47.6**	4.6	36.6	21.2	<1.0	--	--	<10.0	--
MW-1	7/19/2011	(NP)	267.43	17.66	0.0	249.77	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	--	--	--	<10.0	--
MW-GW-1	5/4/2005	(P)	--	17.30	--	--	140	--	--	**6.94**	<0.500	2.94	<1.00	<2.00	<0.010	<0.500	**71.8**	<1.00
MW-GW-1	6/30/2005	(NS)	99.00	17.41	--	81.59	--	--	--	--	--	--	--	--	--	--	--	--
MW-GW-1	8/5/2005	(P)	99.00	17.53	--	81.47	218	--	--	**5.79**	<0.500	1.5	<1.00	<2.00	<0.010	<1.00	**45.3**	<1.00
MW-GW-1	11/16/2005	(P)	99.00	17.80	--	81.20	406	--	--	**7.22**	0.59	2.56	2.23	<1.00	<0.010	<1.00	5.96	<1.00
MW-GW-1	2/2/2006	(P)	99.00	16.75	--	82.25	193	--	--	**8.2**	1.2	1.06	7.85	<1.00	<0.010	<1.00	5.88	1.55

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-GW-1	5/18/2006	(P)	99.00	16.48	--	82.52	121	--	--	2.59	<0.500	0.92	<1.00	<1.00	<0.010	<1.00	8.58	<1.00
MW-GW-1	8/14/2006	(NS)	99.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-GW-1	3/7/2007	(NP)	99.00	16.34	--	82.66	98.8	--	--	3.04	<0.500	<0.500	<3.00	--	--	--	--	--
MW-GW-1	6/5/2007	(NS)	99.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-GW-1	9/6/2007	(NP)	99.00	16.88	--	82.12	260	--	--	**10.3**	3.02	1.93	12	--	--	--	--	--
MW-GW-1	11/21/2007	(NP)	99.00	7.18	--	91.82	604	--	--	**52.4**	3.91	4.6	56	--	--	--	--	--
MW-GW-1	1/17/2008	(NP)	99.00	16.75	--	82.25	366	--	--	**21.2**	1.17	1.51	18.4	<1.00	--	--	**46.4**	--
MW-GW-1	4/10/2008	(NP)	99.00	16.76	--	82.24	<50.0	--	--	<0.500	<0.500	<0.500	<3.00	<1.00	--	--	2.05	--
MW-GW-1	7/2/2008	(NP)	99.00	16.99	--	82.01	53	--	--	0.99	<0.500	<0.500	<3.00	<1.00	--	--	**28.3**	--
MW-GW-1	10/7/2008	(NP)	99.00	17.36	--	81.64	87	--	--	2.22	<0.500	<0.500	<3.00	<1.00	--	--	<1.00	--
MW-GW-1	3/23/2009	(NP)	99.00	17.33	--	81.67	111	--	--	1.32	<0.500	<0.500	<1.00	2.63	--	--	<1.00	--
MW-GW-1	6/15/2009	(NP)	99.00	17.19	--	81.81	<50.0	--	--	<1.00	<1.00	<1.00	<2.00	<1.00	--	--	<2.00	--
MW-GW-1	9/4/2009	(NP)	99.00	17.60	--	81.40	170	--	--	1.3	<1.00	<1.00	<2.00	<1.00	--	--	<2.00	--
MW-GW-1	12/3/2009	(NP)	99.00	17.26	--	81.74	110	--	--	4.4	<1.00	<1.00	<2.00	<1.00	--	--	<2.00	--
MW-GW-1	3/17/2010	(NP)	99.00	16.74	--	82.26	<50	--	--	<1.0	<1.0	<1.0	<2.0	<1.0	--	--	3.2	--
MW-GW-1	7/21/2010	(NP)	266.62	16.53	--	250.09	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-GW-1	10/13/2010	(LF)	266.62	16.84	0.0	249.78	68.9	--	--	1.5	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-GW-1	10/13/2010	(Dup)(LF)	266.62	16.84	0.0	249.78	75.7	--	--	1.7	<1.0	<1.0	<3.0	<1.0	--	--	--	--
MW-GW-1	1/13/2011	(NS NM)	266.62	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-GW-1	7/19/2011	(NP)	266.62	15.83	0.0	250.79	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	--	--	--	<10.0	--
MW-2	3/24/2004	(P)	99.36	17.24	--	82.12	**233,000**	--	--	**11,300**	**34,200**	**5,770**	**30,400**	<5,000	--	--	**222**	19.2
MW-2	6/7/2004	(P)	99.36	17.80	0.80	82.20	**452,000**	--	--	**27,300**	**62,400**	**7,190**	**38,600**	<1,000	--	--	**144**	106
MW-2	11/12/2004	(NS)	99.36	19.55	2.06	81.46	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	12/9/2004	(NS)	99.36	19.05	1.55	81.55	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	2/1/2005	(NS)	99.36	18.90	1.49	81.65	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	5/4/2005	(P)	99.36	18.93	1.50	81.63	**654,000**	--	--	**23,800**	**51,500**	**4,540**	**25,000**	<1,000	<250	<250	**124**	65.5
MW-2	6/30/2005	(NS)	99.36	19.13	1.64	81.54	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	8/5/2005	(NS)	99.36	18.20	0.29	81.39	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	11/16/2005	(NS)	99.36	19.65	1.83	81.17	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	2/2/2006	(NS)	99.36	17.18	0.17	82.32	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	5/18/2006	(NS)	99.36	17.38	0.63	82.48	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	8/14/2006	(NS)	99.36	17.81	0.70	82.11	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	3/7/2007	(NS)	99.36	17.86	0.14	81.61	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	6/5/2007	(NS)	99.36	16.82	0.10	82.62	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	9/6/2007	(NS)	99.36	17.66	0.42	82.04	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	11/21/2007	(NS)	99.36	18.55	1.15	81.73	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	1/17/2008	(NS)	99.36	17.30	0.12	82.16	--	--	--	--	--	--	--	--	--	--	--	--

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-2	4/10/2008	(NS)	99.36	17.36	0.16	82.13	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	7/2/2008	(NS)	99.36	17.68	0.36	81.97	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	10/7/2008	(NS)	99.36	18.45	0.81	81.56	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	3/19/2009	(NS)	99.36	18.90	--	80.46	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	6/15/2009	(NS)	99.36	18.17	0.65	81.71	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	9/4/2009	(NS)	99.36	18.51	0.56	81.30	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	12/3/2009	(NS)	99.36	18.86	1.42	81.64	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	3/17/2010	(NS)	99.36	17.25	0.15	82.22	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	7/21/2010	(NS)	267.03	17.01	0.06	250.01	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	10/13/2010	(ABD)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-2	1/13/2011	(ABD)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	3/24/2004	(P)	100.83	18.45	--	82.38	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	--	--	**42**	2.69
MW-3	6/7/2004	(P)	100.83	16.50	--	84.33	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	--	--	**22.3**	<1.00
MW-3	11/12/2004	(P)	100.83	19.27	--	81.56	<80.0	--	--	<0.200	0.69	<0.500	<1.00	<2.00	<0.500	<0.500	<1.00	<1.00
MW-3	12/9/2004	(NS)	100.83	19.10	--	81.73	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	2/1/2005	(P)	100.83	19.06	--	81.77	<80.0	--	--	2.72	<0.500	<0.500	<1.00	<2.00	--	--	**24**	<1.00
MW-3	5/4/2005	(P)	100.83	19.27	--	81.56	<80.0	--	--	0.29	<0.500	<0.500	<1.00	<2.00	<0.010	<0.500	3.81	<1.00
MW-3	6/30/2005	(NS)	100.83	19.28	--	81.55	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	8/5/2005	(P)	100.83	19.39	--	81.44	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	3.96	<1.00
MW-3	11/16/2005	(P)	100.83	19.72	--	81.11	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	3.84	<1.00
MW-3	2/2/2006	(P)	100.83	18.71	--	82.12	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	3.6	<1.00
MW-3	5/18/2006	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	8/14/2006	(NS)	100.83	16.39	--	84.44	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	3/7/2007	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	6/5/2007	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	9/6/2007	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	11/21/2007	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	1/17/2008	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	4/10/2008	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	7/2/2008	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	10/7/2008	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	3/19/2009	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	6/15/2009	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	9/4/2009	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	12/3/2009	(NS)	100.83	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	7/21/2010	(NP)	268.49	18.36	--	250.13	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-3	10/13/2010	(NS)	268.49	18.72	0.0	249.77	--	--	--	--	--	--	--	--	--	--	--	--

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-3	1/13/2011	(NS)	268.49	18.15	0.0	250.34	--	--	--	--	--	--	--	--	--	--	--	--
MW-3	7/19/2011	(NS)	268.49	17.67	0.0	250.82	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	3/24/2004	(P)	98.73	16.35	--	82.38	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	--	--	**20**	6.32
MW-4	6/7/2004	(P)	98.73	16.55	--	82.18	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	--	--	**22.6**	<1.00
MW-4	11/12/2004	(P)	98.73	17.20	--	81.53	<80.0	--	--	<0.200	1.13	<0.500	1.04	<2.00	<0.500	<0.500	<1.00	<1.00
MW-4	12/9/2004	(NS)	98.73	17.36	--	81.37	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	2/1/2005	(P)	98.73	17.20	--	81.53	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	--	--	**15.1**	<1.00
MW-4	5/4/2005	(P)	98.73	17.11	--	81.62	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	<0.010	<0.500	8.89	<1.00
MW-4	6/30/2005	(NS)	98.73	17.14	--	81.59	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	8/5/2005	(P)	98.73	17.29	--	81.44	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	8.4	<1.00
MW-4	11/16/2005	(P)	98.73	17.60	--	81.13	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	13	<1.00
MW-4	2/2/2006	(P)	98.73	16.53	--	82.20	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	4.65	<1.00
MW-4	5/18/2006	(NS)	98.73	16.22	--	82.51	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	8/14/2006	(NS)	98.73	17.02	--	81.71	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	3/7/2007	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	6/5/2007	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	9/6/2007	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	11/21/2007	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	1/17/2008	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	4/10/2008	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	7/2/2008	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	10/7/2008	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	3/19/2009	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	6/15/2009	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	9/4/2009	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	12/3/2009	(NS)	98.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	7/21/2010	(NP)	266.40	16.26	--	250.14	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-4	10/13/2010	(NS)	266.40	16.60	0.0	249.80	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	1/13/2011	(NS)	266.40	16.05	0.0	250.35	--	--	--	--	--	--	--	--	--	--	--	--
MW-4	7/19/2011	(NS)	266.40	15.60	0.0	250.80	--	--	--	--	--	--	--	--	--	--	--	--
MW-5	11/12/2004	(P)	99.13	17.80	--	81.33	**36,500**	--	--	**5,520**	246	**3,550**	**10,500**	<1.00	<25.0	<25.0	3.81	1.33
MW-5	12/9/2004	(NS)	99.13	17.67	--	81.46	--	--	--	--	--	--	--	--	--	--	--	--
MW-5	2/1/2005	(P)	99.13	17.50	--	81.63	**43,800**	--	--	**6,960**	298	**3,970**	**11,500**	<100	--	--	**40**	3.86
MW-5	5/4/2005	(P)	99.13	17.60	--	81.53	**40,200**	--	--	**5,900**	384	**3,190**	**9,100**	<100	**0.037**	<25.0	**17.6**	2.85
MW-5	6/30/2005	(NS)	99.13	17.62	--	81.51	--	--	--	--	--	--	--	--	--	--	--	--
MW-5	8/5/2005	(P)	99.13	17.78	--	81.35	**61,500**	--	--	**5,610**	681	**4,080**	**12,700**	<2.00	**0.032**	<1.00	**58.5**	1.95
MW-5	11/16/2005	(P)	99.13	18.01	--	81.12	**34,300**	--	--	**3,840**	408	**3,180**	**8,920**	<1.00	**0.043**	<1.00	**40.6**	1.88

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-5	2/2/2006	(P)	99.13	17.63	--	81.50	**53,900**	--	--	**3,520**	611	**3,070**	**9,160**	<1.00	<0.010	<1.00	9.83	2.19
MW-5	5/18/2006	(P)	99.13	17.81	--	81.32	**19,400**	--	--	**1,650**	197	**1,280**	**3,770**	<1.00	<0.010	<1.00	1.42	<1.00
MW-5	8/14/2006	(P)	99.13	17.10	--	82.03	**24,900**	--	--	**2,450**	169	**2,180**	**5,930**	<1.00	<0.010	<1.00	**38.4**	14.6
MW-5	3/7/2007	(NP)	99.13	16.49	--	82.64	**3,770**	--	--	**111**	3.25	92	165	--	--	--	--	--
MW-5	6/5/2007	(NP)	99.13	16.61	--	82.52	395	--	--	**88.5**	1.03	43.6	76.1	--	--	--	--	--
MW-5	9/6/2007	(NP)	99.13	17.07	--	82.06	**4,940**	--	--	<20.0	6.05	**955**	**4,070**	--	--	--	--	--
MW-5	11/21/2007	(NP)	99.13	17.35	--	81.78	**4,100**	--	--	**2,820**	49.6	**3,130**	**5,180**	--	--	--	--	--
MW-5	1/17/2008	(NP)	99.13	16.93	--	82.20	**27,200**	--	--	**1,700**	68.5	**2,170**	**4,130**	<1.00	--	--	14.4	--
MW-5	4/10/2008	(NP)	99.13	17.00	--	82.13	**8,010**	--	--	**400**	14	673	876	<1.00	--	--	5.01	--
MW-5	7/2/2008	(NP)	99.13	17.22	--	81.91	**44,800**	--	--	**2,150**	57.8	**3,100**	**5,700**	<1.00	--	--	6.07	--
MW-5	10/7/2008	(NP)	99.13	17.57	--	81.56	**30,800**	--	--	**1,200**	22.1	**2,200**	**2,970**	<1.00	--	--	3.84	--
MW-5	3/19/2009	(NP)	99.13	17.50	--	81.63	**36,600**	--	--	**1,360**	82.6	**2,860**	**6,020**	**23.5**	--	--	2.81	--
MW-5	6/15/2009	(NP)	99.13	17.40	--	81.73	**28,000**	--	--	**1,300**	63	**2,600**	**5,500**	<1.00	--	--	4.3	--
MW-5	9/4/2009	(NP)	99.13	17.81	--	81.32	**42,000**	--	--	**1,400**	70	**3,100**	**6,800**	<1.00	--	--	3.5	--
MW-5	12/3/2009	(NP)	99.13	17.47	--	81.66	**32,000**	--	--	**1,100**	53	**2,500**	**5,500**	<1.00	--	--	3.8	--
MW-5	3/17/2010	(NP)	99.13	17.00	--	82.13	790	--	--	**18**	1.0	63	69	<1.0	--	--	<2.0	--
MW-5	7/21/2010	(NP)	266.76	16.71	--	250.05	**20,200**	--	--	**578**	83.1	**1,790**	**3,930**	<1.0	--	--	**21.2**	--
MW-5	10/13/2010	(NS)	266.76	17.04	0.0	249.72	--	--	--	--	--	--	--	--	--	--	--	--
MW-5	10/14/2010	(LF)	266.76	17.04	0.0	249.72	**28,600**	--	--	**1,100**	72.1	**2,760**	**4,890**	<1.0	--	--	<10.0	--
MW-5	1/13/2011	(LFP)	266.76	16.42	0.0	250.34	**21,100**	--	--	**567**	18.5	**1,790**	**2,970**	<1.0	<0.0098	<1.0	<10.0	--
MW-5	7/19/2011	(NP)	266.76	16.01	0.0	250.75	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	--	--	--	<10.0	--
MW-6	11/12/2004	(P)	98.62	17.25	--	81.37	**29,200**	--	--	**89**	**1,700**	**1,270**	**9,920**	<40.0	<10.0	<10.0	7.65	3.37
MW-6	12/9/2004	(NS)	98.62	17.32	--	81.30	--	--	--	--	--	--	--	--	--	--	--	--
MW-6	2/1/2005	(P)	98.62	16.99	--	81.63	**7,060**	--	--	**12.8**	23.4	350	987	<10.0	--	--	**27.6**	1.76
MW-6	5/4/2005	(P)	98.62	17.04	--	81.58	**3,850**	--	--	**9.8**	9.44	239	237	<4.00	**0.032**	<1.00	13.9	1.65
MW-6	6/30/2005	(NS)	98.62	17.00	--	81.62	--	--	--	--	--	--	--	--	--	--	--	--
MW-6	8/5/2005	(P)	98.62	17.25	--	81.37	**5,500**	--	--	**18.4**	35.7	433	489	<10.0	**0.013**	<1.00	**56.7**	1.25
MW-6	11/16/2005	(P)	98.62	17.50	--	81.12	**2,950**	--	--	3.35	3.8	232	53.2	<5.00	<0.010	<5.00	**15.2**	<1.00
MW-6	2/2/2006	(P)	98.62	16.87	--	81.75	261	--	--	1.3	<0.500	1.74	1.5	<1.00	<0.010	<1.00	13.1	<1.00
MW-6	5/18/2006	(P)	98.62	16.28	--	82.34	**2,970**	--	--	**5.49**	16.3	145	462	<1.00	<0.010	<1.00	8.76	1.66
MW-6	8/14/2006	(P)	98.62	16.59	--	82.03	**7,110**	--	--	**16.8**	38.7	516	**1,520**	<1.00	<0.010	<1.00	**18.5**	<1.00
MW-6	3/7/2007	(NP)	98.62	16.10	--	82.52	**2,940**	--	--	**5.4**	<2.50	204	118	--	--	--	--	--
MW-6	6/5/2007	(NP)	98.62	16.12	--	82.50	**4,460**	--	--	**8.39**	13.2	332	659	--	--	--	--	--
MW-6	9/6/2007	(NP)	98.62	16.58	--	82.04	**19,200**	--	--	**13.3**	62.5	**735**	645	--	--	--	--	--
MW-6	11/21/2007	(NP)	98.62	16.87	--	81.75	**24,000**	--	--	**16.5**	98.6	**974**	**4,790**	--	--	--	--	--
MW-6	1/17/2008	(NP)	98.62	16.41	--	82.21	**2,870**	--	--	4.6	1.72	214	190	<1.00	--	--	13.2	--
MW-6	4/10/2008	(NP)	98.62	16.41	--	82.21	**4,330**	--	--	<10.0	5.62	268	424	<1.00	--	--	4.05	--

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-6	7/2/2008	(NP)	98.62	16.62	--	82.00	**12,900**	--	--	**6.01**	27.1	613	**1,920**	<1.00	--	--	5.56	--
MW-6	10/7/2008	(NP)	98.62	17.05	--	81.57	**20,100**	--	--	**5.48**	27.9	**998**	**3,800**	<1.00	--	--	2.91	--
MW-6	3/19/2009	(NP)	98.62	16.98	--	81.64	**1,940**	--	--	3.29	<2.50	219	33.6	<5.00	--	--	1.32	--
MW-6	6/15/2009	(NP)	98.62	16.90	--	81.72	**5,600**	--	--	<10	12	420	700	<1.00	--	--	<2.00	--
MW-6	9/4/2009	(NP)	98.62	17.31	--	81.31	**13,000**	--	--	1.5	20	**910**	**2,500**	<1.00	--	--	4.5	--
MW-6	12/3/2009	(NP)	98.62	16.93	--	81.69	120	--	--	<1.00	<1.00	13	<2.00	<1.00	--	--	5.6	--
MW-6	3/17/2010	(NP)	98.62	16.56	--	82.06	290	--	--	<1.0	<1.0	15	3.0	<1.0	--	--	7.3	--
MW-6	7/21/2010	(NP)	266.26	16.23	--	250.03	**5,860**	--	--	1.3	22.4	453	**1,150**	<1.0	--	--	10	--
MW-6	10/13/2010	(NS)	266.26	16.54	0.0	249.72	--	--	--	--	--	--	--	--	--	--	--	--
MW-6	10/14/2010	(LF)	266.26	16.54	0.0	249.72	**7,290**	--	--	1.2	15.0	323	**1,580**	<1.0	--	--	<10.0	--
MW-6	1/13/2011	(LFP)	266.26	15.90	0.0	250.36	417	--	--	<1.0	<1.0	23.9	32.9	<1.0	<0.0099	<1.0	<10.0	--
MW-6	7/19/2011	(NP)	266.26	15.55	0.0	250.71	**7,870**	--	--	3.2	5.4	238	766	--	--	--	<10.0	--
MW-6	7/19/2011	(Dup)(NP)	266.26	15.55	0.0	250.71	**7,830**	--	--	<1.0	5.5	254	837	--	--	--	<10.0	--
MW-7	12/9/2004	(P)	97.17	15.80	--	81.37	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	--	--	<1.00	<1.00
MW-7	2/1/2005	(P)	97.17	15.46	--	81.71	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	--	--	1.88	<1.00
MW-7	5/4/2005	(P)	97.17	15.62	--	81.55	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	<0.010	<0.500	**15.4**	<1.00
MW-7	6/30/2005	(NS)	97.17	15.61	--	81.56	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	8/5/2005	(P)	97.17	15.76	--	81.41	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	**49.8**	<1.00
MW-7	11/16/2005	(P)	97.17	16.00	--	81.17	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<2.00	<0.010	<1.00	13.6	<1.00
MW-7	2/2/2006	(P)	97.17	14.90	--	82.27	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	10.5	<1.00
MW-7	5/18/2006	(NS)	97.17	15.22	--	81.95	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	8/14/2006	(NS)	97.17	15.80	--	81.37	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	3/7/2007	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	6/5/2007	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	9/6/2007	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	11/21/2007	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	1/17/2008	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	4/10/2008	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	7/2/2008	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	10/7/2008	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	3/19/2009	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	6/15/2009	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	9/4/2009	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	12/3/2009	(NS)	97.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	7/21/2010	(NP)	264.83	14.72	--	250.11	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-7	10/13/2010	(NS)	264.83	15.04	0.0	249.79	--	--	--	--	--	--	--	--	--	--	--	--
MW-7	1/13/2011	(NS)	264.83	15.48	0.0	249.35	--	--	--	--	--	--	--	--	--	--	--	--

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-7	7/19/2011	(NS)	264.83	14.08	0.0	250.75	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	12/9/2004	(P)	97.52	16.05	--	81.47	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	--	--	1.33	<1.00
MW-8	2/1/2005	(P)	97.52	15.80	--	81.72	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	--	--	1.42	<1.00
MW-8	5/4/2005	(P)	97.52	15.99	--	81.53	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	<0.010	<0.500	12.4	<1.00
MW-8	6/30/2005	(NS)	97.52	16.01	--	81.51	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	8/5/2005	(P)	97.52	16.15	--	81.37	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	**22.6**	<1.00
MW-8	11/16/2005	(P)	97.52	16.55	--	80.97	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	**23.2**	<1.00
MW-8	2/2/2006	(P)	97.52	15.15	--	82.37	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	13.9	<1.00
MW-8	5/18/2006	(NS)	97.52	15.27	--	82.25	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	8/14/2006	(NS)	97.52	16.27	--	81.25	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	3/7/2007	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	6/5/2007	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	9/6/2007	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	11/21/2007	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	1/17/2008	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	4/10/2008	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	7/2/2008	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	10/7/2008	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	3/19/2009	(NP)	97.52	15.85	--	81.67	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	--	--	1.36	--
MW-8	6/15/2009	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	9/4/2009	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	12/3/2009	(NS)	97.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	7/21/2010	(NP)	265.18	15.12	--	250.06	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-8	10/13/2010	(NS)	265.18	15.41	0.0	249.77	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	1/13/2011	(NS)	265.18	14.79	0.0	250.39	--	--	--	--	--	--	--	--	--	--	--	--
MW-8	7/19/2011	(NS)	265.18	14.47	0.0	250.71	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	12/9/2004	(P)	98.24	16.81	--	81.43	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	--	--	3.35	<1.00
MW-9	2/1/2005	(P)	98.24	16.52	--	81.72	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	--	--	<1.00	<1.00
MW-9	5/4/2005	(P)	98.24	16.55	--	81.69	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	<0.010	<0.500	4.2	<1.00
MW-9	6/30/2005	(NS)	98.24	16.62	--	81.62	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	8/5/2005	(P)	98.24	16.77	--	81.47	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	**34.3**	<1.00
MW-9	11/16/2005	(P)	98.24	17.09	--	81.15	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	14.4	<1.00
MW-9	2/2/2006	(P)	98.24	16.05	--	82.19	<50.0	--	--	<0.500	<0.500	<0.500	1.02	<1.00	<0.010	<1.00	13.8	<1.00
MW-9	5/18/2006	(NS)	98.24	16.62	--	81.62	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	8/14/2006	(NS)	98.24	16.89	--	81.35	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	3/7/2007	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	6/5/2007	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-9	9/6/2007	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	11/21/2007	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	1/17/2008	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	4/10/2008	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	7/2/2008	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	10/7/2008	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	3/19/2009	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	6/15/2009	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	9/4/2009	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	12/3/2009	(NS)	98.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	7/21/2010	(NP)	265.89	15.77	--	250.12	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-9	10/13/2010	(NS)	265.89	16.10	0.0	249.79	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	1/13/2011	(NS)	265.89	15.53	0.0	250.36	--	--	--	--	--	--	--	--	--	--	--	--
MW-9	7/19/2011	(NS)	265.89	15.09	0.0	250.80	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	12/9/2004	(P)	98.11	16.71	--	81.40	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	--	--	8.79	<1.00
MW-10	2/1/2005	(P)	98.11	16.24	--	81.87	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	--	--	2.41	<1.00
MW-10	5/4/2005	(P)	98.11	16.40	--	81.71	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	<0.010	<0.500	9.58	<1.00
MW-10	6/30/2005	(NS)	98.11	16.19	--	81.92	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	8/5/2005	(P)	98.11	16.46	--	81.65	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	12.3	<1.00
MW-10	11/16/2005	(P)	98.11	16.69	--	81.42	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	<1.00	<1.00
MW-10	2/2/2006	(P)	98.11	15.80	--	82.31	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	1.61	<1.00
MW-10	5/18/2006	(NS)	98.11	15.94	--	82.17	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	8/14/2006	(NS)	98.11	16.57	--	81.54	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	3/7/2007	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	6/5/2007	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	9/6/2007	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	11/21/2007	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	1/17/2008	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	4/10/2008	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	7/2/2008	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	10/7/2008	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	3/19/2009	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	6/15/2009	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	9/4/2009	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	12/3/2009	(NS)	98.11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	7/21/2010	(NP)	265.41	15.35	--	250.06	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	**91.9**	--
MW-10	10/13/2010	(NS)	265.41	15.66	0.0	249.75	--	--	--	--	--	--	--	--	--	--	--	--

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-10	1/13/2011	(NS)	265.41	15.19	0.0	250.22	--	--	--	--	--	--	--	--	--	--	--	--
MW-10	7/19/2011	(NS)	265.41	14.85	0.0	250.56	--	--	--	--	--	--	--	--	--	--	--	--
MW-11	6/30/2005	(P)	100.06	18.79	--	81.27	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	<0.010	<0.500	**28.9**	<1.00
MW-11	8/5/2005	(P)	100.06	18.80	--	81.26	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	**43.3**	<1.00
MW-11	11/16/2005	(P)	100.06	19.10	--	80.96	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	13.6	<1.00
MW-11	2/2/2006	(P)	100.06	18.59	--	81.47	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	12.6	<1.00
MW-11	5/18/2006	(P)	100.06	18.71	--	81.35	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	<1.00	<1.00
MW-11	8/14/2006	(P)	100.06	18.20	--	81.86	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	7.82	<1.00
MW-11	3/7/2007	(NS)	100.06	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-11	6/5/2007	(NS)	100.06	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-11	9/6/2007	(NS)	100.06	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-11	11/21/2007	(NS)	100.06	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-11	1/17/2008	(NP)	100.06	18.01	--	82.05	<50.0	--	--	<0.500	<0.500	0.8	<3.00	<1.00	--	--	**52.8**	--
MW-11	4/10/2008	(NP)	100.06	18.02	--	82.04	<50.0	--	--	<0.500	<0.500	<0.500	<3.00	<1.00	--	--	8.71	--
MW-11	7/2/2008	(NP)	100.06	18.19	--	81.87	<50.0	--	--	<0.500	<0.500	1.01	3	<1.00	--	--	4.35	--
MW-11	10/7/2008	(NP)	100.06	18.62	--	81.44	<50.0	--	--	<0.500	<0.500	<0.500	<3.00	<1.00	--	--	**19.1**	--
MW-11	3/19/2009	(NP)	100.06	18.62	--	81.44	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	--	--	<1.00	--
MW-11	6/15/2009	(NP)	100.06	18.47	--	81.59	<50.0	--	--	<1.00	<1.00	<1.00	<2.00	<1.00	--	--	<2.00	--
MW-11	9/4/2009	(NP)	100.06	18.88	--	81.18	<50.0	--	--	<1.00	<1.00	<1.00	<2.00	<1.00	--	--	4	--
MW-11	12/3/2009	(NP)	100.06	18.65	--	81.41	<50.0	--	--	<1.00	<1.00	<1.00	<2.00	<1.00	--	--	3.6	--
MW-11	3/17/2010	(NP)	100.06	18.00	--	82.06	<50	--	--	<1.0	<1.0	<1.0	<2.0	<1.0	--	--	2.3	--
MW-11	7/21/2010	(NP)	267.70	17.72	--	249.98	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-11	10/13/2010	(LF)	267.70	18.06	0.0	249.64	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-11	1/13/2011	(LFP)	267.70	17.50	0.0	250.20	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-11	7/19/2011	(NP)	267.70	17.00	0.0	250.70	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	--	--	--	<10.0	--
MW-12	6/30/2005	(P)	100.01	18.50	--	81.51	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	<0.010	<0.500	**23.8**	<1.00
MW-12	8/5/2005	(P)	100.01	18.70	--	81.31	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	**56.2**	<1.00
MW-12	11/16/2005	(P)	100.01	18.92	--	81.09	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	7.49	<1.00
MW-12	2/2/2006	(P)	100.01	17.82	--	82.19	96.1	--	--	1.74	<0.500	<0.500	<1.00	<1.00	<0.010	1.78	6.78	<1.00
MW-12	5/18/2006	(P)	100.01	18.03	--	81.98	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	4.39	<1.00
MW-12	8/14/2006	(P)	100.01	18.05	--	81.96	<50.0	--	--	<0.500	<0.500	<0.500	1.32	<1.00	<0.010	<1.00	**30.9**	--
MW-12	3/7/2007	(NS)	100.01	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-12	6/5/2007	(NS)	100.01	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-12	9/6/2007	(NS)	100.01	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-12	11/21/2007	(NS)	100.01	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-12	1/17/2008	(NP)	100.01	17.84	--	82.17	<50.0	--	--	0.5	<0.500	<0.500	<3.00	<1.00	--	--	**87.7**	--
MW-12	4/10/2008	(NP)	100.01	17.84	--	82.17	<50.0	--	--	<0.500	<0.500	<0.500	<3.00	<1.00	--	--	5.72	--

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Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-12	7/2/2008	(NP)	100.01	18.07	--	81.94	<50.0	--	--	<0.500	<0.500	<0.500	<3.00	<1.00	--	--	3.46	--
MW-12	10/7/2008	(NP)	100.01	18.48	--	81.53	<50.0	--	--	<0.500	<0.500	<0.500	<3.00	<1.00	--	--	2.54	--
MW-12	3/19/2009	(NP)	100.01	18.42	--	81.59	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	--	--	<1.00	--
MW-12	6/15/2009	(NP)	100.01	18.33	--	81.68	<50.0	--	--	<1.00	<1.00	<1.00	<2.00	<1.00	--	--	<2.00	--
MW-12	9/4/2009	(NP)	100.01	18.74	--	81.27	<50.0	--	--	<1.00	<1.00	<1.00	<2.00	<1.00	--	--	<2.00	--
MW-12	12/3/2009	(NP)	100.01	18.37	--	81.64	<50.0	--	--	<1.00	<1.00	<1.00	<2.00	<1.00	--	--	2.4	--
MW-12	3/17/2010	(NP)	100.01	17.91	--	82.10	<50	--	--	<1.0	<1.0	<1.0	<2.0	<1.0	--	--	<2.0	--
MW-12	7/21/2010	(NP)	267.67	17.65	--	250.01	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-12	10/13/2010	(LF)	267.67	17.96	0.0	249.71	682	--	--	**56.7**	<1.0	23.0	16.0	<1.0	--	--	<10.0	--
MW-12	1/13/2011	(LFP)	267.67	17.33	0.0	250.34	304	--	--	**9.3**	<1.0	3.4	3.8	<1.0	--	--	<10.0	--
MW-12	7/19/2011	(NP)	267.67	16.95	0.0	250.72	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	--	--	--	<10.0	--
MW-13	6/30/2005	(P)	98.02	16.52	--	81.50	<80.0	--	--	<0.200	<0.500	<0.500	<1.00	<2.00	<0.010	<0.500	5.82	<1.00
MW-13	8/5/2005	(P)	98.02	16.66	--	81.36	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	**26.7**	<1.00
MW-13	11/16/2005	(P)	98.02	16.86	--	81.16	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	13.4	<1.00
MW-13	2/2/2006	(P)	98.02	16.26	--	81.76	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	**32.8**	<1.00
MW-13	5/18/2006	(P)	98.02	15.68	--	82.34	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	6.27	<1.00
MW-13	8/14/2006	(P)	98.02	16.10	--	81.92	<50.0	--	--	<0.500	<0.500	<0.500	<1.00	<1.00	<0.010	<1.00	3.76	<1.00
MW-13	3/7/2007	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	6/5/2007	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	9/6/2007	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	11/21/2007	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	1/17/2008	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	4/10/2008	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	7/2/2008	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	10/7/2008	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	3/19/2009	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	6/15/2009	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	9/4/2009	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	12/3/2009	(NS)	98.02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	7/21/2010	(NP)	265.68	15.65	--	250.03	<50.0	--	--	<1.0	<1.0	<1.0	<3.0	<1.0	--	--	<10.0	--
MW-13	10/13/2010	(NS)	265.68	15.93	0.0	249.75	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	1/13/2011	(NS)	265.68	15.20	0.0	250.48	--	--	--	--	--	--	--	--	--	--	--	--
MW-13	7/19/2011	(NS)	265.68	14.99	0.0	250.69	--	--	--	--	--	--	--	--	--	--	--	--
MW-16	10/13/2010	(NS)	267.04	17.30	0.0	249.74	--	--	--	--	--	--	--	--	--	--	--	--
MW-16	10/14/2010	(LF)	267.04	17.30	0.0	249.74	**180,000**	--	--	**24,800**	**47,400**	**3,440**	**21,200**	<1.0	--	--	**111**	--
MW-16	1/13/2011	(LFP)	267.04	16.71	0.0	250.33	**220,000**	--	--	**23,500**	**44,300**	**3,720**	**21,300**	<1.0	--	--	**168**	--
MW-16	1/13/2011	(Dup)(LFP)	267.04	16.71	0.0	250.33	**237,000**	--	--	**22,700**	**44,000**	**3,630**	**20,800**	<1.0	--	--	**167**	--

Table 1
Groundwater Gauging Data and Select Analytical Results
WA-00977

155 N W 85th St, Seattle, WA 98107

All analytical results are presented in micrograms per liter (εg/L)

Well	Date	Notes	TOC	DTW	NAPL	GWE	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	EDB	EDC	Total Lead	Dissolved Lead
Model Toxics Control Act (MTCA) Method A Cleanup Levels (CULs) in µg/L							**800/1,000**	**500**	**500**	**5**	**1,000**	**700**	**1,000**	**20**	**0.01**	**5**	**15**	**--**
MW-16	7/19/2011	(NP)	267.04	16.28	0.0	250.76	**167,000**	--	--	**15,200**	**29,000**	**2,680**	**18,400**	--	--	--	**246**	--

msl = Mean sea level
TOC = Top of casing
GWE = Groundwater elevation above msl
DTW = Depth to water below TOC
ABD = Well abandoned
All analytical results are in micrograms per liter (µg/L)
TOC/DTW/LNAPL/GWE measurements are in feet (ft)
ND = Not detected at or above the laboratory reporting limit
-- = Not analyzed/not applicable
NA = Not analyzed
NM = Not measured
NE = Top of casing not established
DUP = Duplicate sample
NS = Not Sampled
NAPL = Non-Aqueous Phase Liquid
GRO = Total Petroleum Hydrocarbons - Gasoline Range Organics
DRO = Total Petroleum Hydrocarbons - Diesel Range Organics
HO = Total Petroleum Hydrocarbons- Heavy Oil Range Organics
EDB = Ethylene Dibromide
EDC = 1,2-Dichloroethane
MTBE = Methyl Tertiary Butyl Ether
BTEX = Benzene, Toluene, Ethylbenzene and Total Xylenes
P = Purge sampling
LFP = Low flow purge sampling
NP = No purge sampling
GRO, DRO, HO methods by Ecology NW Methods; BTEX, MTBE and EDB by 8260B, lead by EPA 6000/7000 Series, EDC by EPA 8011
Historic analysis by former consultant of BTEX, MTBE and EDB by EPA 8021B and confirmed with EPA 8260B if necessary
Groundwater Elevation - If NAPL is present, the elevation is corrected according to the following formula, (TOC elevation - depth to water) + (0.8 X NAPL Thickness)
800/1,000 = GRO MTCA cleanup levels with benzene present (800) and without (1,000)
Data collected prior to 2010 have been provided by previous consultants and are included as historical reference only
Site resurveyed in 2010. TOC elevation in reference to vertical datum N.A.V.D. 88 and horizontal datum NAD 83/98

BOLD constituent detected above MTCA Cleanup Levels

Table 2
Soil Analytical Data - Petroleum Hydrocarbons and Lead
WA-00977
155 Northwest 85th Street, Seattle, Washington 98107

Sample ID	Date	Depth	GRO	DRO	HO	Benzene	Toluene	Ethylbenzene	Total Xylenes	MTBE	Total Lead
Model Toxics Control Act (MTCA) Cleanup Levels			**100 [1]**	**2,000 [1]**	**2,000 [1]**	**18 [2]**	**6,400 [2]**	**8,000 [2]**	**16,000 [2]**	**0.1 [1]**	**250 [1]**
MW-1-6.0	3/22/2004	6	ND < 5.00	NA	NA	ND < 0.0300	ND < 0.0500	ND < 0.0500	ND < 0.1	ND < 1.0	2.22
MW-1-16.0	3/22/2004	16	ND < 5.00	NA	NA	ND < 0.0300	ND < 0.0500	ND < 0.0500	ND < 0.1	ND < 1.0	1.99
MW-2-6.0	3/22/2004	6	ND < 5.00	NA	NA	ND < 0.0300	ND < 0.0500	ND < 0.0500	ND < 0.1	ND < 1.0	2.01
MW-2-16.0	3/22/2004	16	ND < 5.00	NA	NA	ND < 0.0300	0.0628	ND < 0.0500	0.185	ND < 1.0	3.73
MW-3-6.0	3/22/2004	6	ND < 5.00	NA	NA	ND < 0.0300	ND < 0.0500	ND < 0.0500	ND < 0.1	ND < 1.0	3.21
MW-3-16.0	3/22/2004	16	ND < 5.00	NA	NA	ND < 0.0300	ND < 0.0500	ND < 0.0500	ND < 0.1	ND < 1.0	1.55
MW-4-6.0	3/22/2004	6	ND < 5.00	NA	NA	ND < 0.0300	ND < 0.0500	ND < 0.0500	ND < 0.1	ND < 1.0	1.81
MW-4-16.0	3/22/2004	16	ND < 5.00	NA	NA	ND < 0.0300	ND < 0.0500	ND < 0.0500	ND < 0.1	ND < 1.0	1.55
MW-5-5.0	10/22/2004	5	ND < 3.32	NA	NA	ND < 0.0166	ND < 0.0208	ND <0.0208	ND < 0.0416	ND < 0.0166	2.39
MW-5-15.0	10/22/2004	15	ND < 3.20	NA	NA	0.143	ND < 0.0200	0.0732	0.18	ND < 0.0160	1.75
MW-6-10.0	10/22/2004	10	ND < 4.00	NA	NA	ND < 0.0200	ND < 0.0250	ND < 0.0250	ND < 0.0500	ND < 0.0200	2.3
MW-6-15.0	10/22/2004	15	ND < 3.06	NA	NA	ND < 0.0153	0.0595	0.0462	0.368	ND < 0.0153	7.26
MW-7-15.5	12/6/2004	15.5	ND < 3.37	NA	NA	ND < 0.0168	ND < 0.0210	ND < 0.0210	ND < 0.0421	ND < 0.0168	1.49
MW-8-16.0	12/6/2004	16	ND < 3.13	NA	NA	ND < 0.0157	ND < 0.0196	ND < 0.0196	ND < 0.0392	ND < 0.0157	1.48
MW-9-15.5	12/6/2004	15.5	ND < 3.12	NA	NA	ND < 0.0156	ND < 0.0195	ND < 0.0195	ND < 0.0390	ND < 0.0156	1.41
MW-10-16.0	12/6/2004	16	ND < 3.56	NA	NA	ND < 0.0178	ND < 0.0222	ND < 0.0222	ND < 0.0445	ND < 0.0178	1.32
MW-11-6.5	6/21/2005	6.5	ND < 3.11	NA	NA	ND < 0.0155	ND < 0.0194	ND < 0.0194	ND < 0.0389	ND < 0.0155	3.62
MW-11-15.0	6/21/2005	15	ND < 3.00	NA	NA	ND < 0.0150	ND < 0.0187	ND < 0.0187	ND < 0.0375	ND < 0.0150	2.09
MW-12-15.0	6/21/2005	15	ND < 3.33	NA	NA	ND < 0.0167	ND < 0.0208	ND < 0.0208	ND < 0.0417	ND < 0.0167	1.87
MW-13-15.0	6/21/2005	15	ND < 3.03	NA	NA	ND < 0.0152	ND < 0.0190	ND < 0.0190	ND < 0.0379	ND < 0.0152	1.92
MW-16-18-18.5	9/24/2010	18-18.5	**3,230**	87	ND < 30.1	**33.7**	219	64.6	385	ND<0.0026	4.0
MW-16-22.5-23.0	9/24/2010	22.5-23.0	17.3	ND < 8.8	ND < 35.3	1.43	0.363	0.636	2.44	ND<0.003	2.5
MW-16-22.5-23.0 (Dup-1)	9/24/2010	22.5-23.0	20.4	ND < 8.4	ND < 33.7	1.38	0.822	0.652	2.84	ND<0.0027	2.5

All analytical data is in mg/kg
BOLD = Constituent detected above MTCA cleanup levels
GRO = Total Petroleum Hydrocarbons in the gasoline range
DRO = Total Petroleum Hydrocarbons in the diesel range
HO = Total Petroleum Hydrocarbons in the oil range
MTBE = Methyl Tertiary Butyl Ether
ND = Not detected at or above the laboratory reporting limit
[1] = MTCA Method A CLs
[2] = MTCA Method B CLs

Table 3
Soil Analytical Data - PAHs
WA-00977
155 NW 85th Street, Seattle, Washington

Sample ID	Date	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)Anthracene	Benzo(a)Pyrene	Benzo(b) fluoranthene	Benzo(g,h,i) Perylene	Benzo(k) Fluoranthene	Chrysene	Dibenzo(a,h) Anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd) Pyrene	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Phenanthrene	Pyrene	Total Adjusted cPAHs	Total Naphthalenes
Model Toxics Control Act (MTCA) Method A Cleanup Levels		**ND**	**ND**	**ND**	**ND**	**100**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**100**	**5,000**
MW-16-18-18.5	9/24/2010	21.3	19.6	16.4	8.1	ND<6.6	ND<6.6	ND<6.6	ND<6.6	ND<6.6	ND<6.6	9.4	39.4	ND<6.6	4,750	9,670	9,680	54.8	16.5	5.5	**24,100**

Notes:

All analytical results are in micrograms per kilogram (µg/kg)

Bold and shaded cells represent concentrations greater than MTCA Method A Cleanup Levels

NA = Not analyzed

< = Not detected greater than laboratory detection limit. Value listed is laboratory detection limit.

Depths are listed in feet below ground surface

Analytical Method = EPA Method 8270 SIM

ND = Not determined.

cPAHs adjusted for toxicity according to WAC 173-340-708(8) and *Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II Technical Support Document for Describing Available Cancer Potency Factors* . Office of Environmental Health Hazard Assessment, California EPA, May 2005. If one or more adjusted cPAH constituents were reported as Non-Detect, half of the reporting limt was used in calculations.

Total Naphthalenes are a total of naphthalene, 1-methylnaphthalene and 2-methylnaphthalene according to MTCA Table 740-1.

Table 4
Biogeochemical Parameters
WA-0977
155 Northwest 85th Street, Seattle, Washington, 98107

Relative Location[8]	Monitoring Well ID	Date Sampled	Total Alkalinity (mg/L as $CaCO_3$)[1]	Sulfate (mg/L)[2]	Nitrogen, Nitrite/Nitrate (mg/L)[3]	Methane (µg/L)[4]	Total Manganese (µg/L)[5]	Dissolved Manganese (µg/L)[5]	Total Iron (µg/L)[5]	Dissolved Iron (µg/L)[5]	Total Organic Carbon (mg/L)[6]	Sulfide (mg/L)[7]
Within Plume	**MW-12**	10/13/2010	195	24.4	2	96	724	880	440	ND < 100	4.1	ND < 0.50
Down gradient	**MW-11**	10/13/2010	100	20.4	9.1	ND < 10.0	21.4	ND < 15.0	297	ND < 100	1.3	ND < 0.50
Within Plume	**MW-6**	10/13/2010	191	5.4	ND < 0.050	621	2,820	2,650	3,410	837	2.8	0.6
Within Plume	**MW-6 (Dup)**	10/13/2010	--	--	--	--	--	--	--	--	--	0.55
Within Plume	**MW-5**	10/13/2010	393	1.2	0.18	9,110	6,170	5,910	2,410	178	9.3	ND < 0.50
Within Plume	**MW-16**	10/13/2010	598	2.2	0.08	43	6,540	6,250	625	ND < 100	30.6	ND < 0.50
Up gradient	**MW-4**	10/13/2010	73.3	15.7	5.5	ND < 10.0	ND < 15.0	ND < 15.0	133	ND < 100	1.4	ND < 0.50
Within Plume	**MW-1**	10/13/2010	276	6.4	0.13	ND < 10.0	1,570	1,410	ND < 100	ND < 100	1.8	ND < 0.50

[1]: Total alkalinity analyzed using SM method 2320B.
[2]: Sulfate analyzed by EPA method 300.0.
[3]: Nitrogen, Nitrite/Nitrate analyzed by EPA method 353.2.
[4]: Methane analyzed using method RSK 175.
[5]: Total and dissolved manganese and iron anayzed by EPA method 6010.
[6]: Total organic carbon analyzed by SM method 5310C
[7]: Sulfide analyzed by SM method 4500-S^{2-}F
[8]: Relative location based on groundwater samples collected in October 2010.

DO = Dissolved oxygen
"<" = Indicates analyte not detected above MRL
"--" = Indicates analyte was not sampled or analyzed
mS/cm = microseimens per centermeter
$CaCO_2$ = Calcium carbonate
mg/L = Miligrams per liter
µg/L = Micrograms per Liter

Table 5
Sulfate Loading Conceptual Design

WA-0977
155 Northwest 85th Street, Seattle, Washington 98107

Design Elements	Quantity	Units	Notes
Aquifer Characteristics			
Mobile Porosity (θ_m)	8%		Assumed
Total Porosity (θ_t)	30%		Assumed
Hydraulic Gradient (i)	0.0005	ft/ft	Calculated from 1Q2011 data
Injection Wells and Volume			
Screened Interval (h)	15	ft	Assumed
Total Number of Injection Wells Required (#IW)	3	wells	MW-5, MW-6, and MW-12
Radius of Influence (ROI)	15	ft	Assumed
	283		
Required injection volume per foot of screen (V_{inj}/ft)	423	gal	$V_{inj}/ft = (\pi * ROI^2 * h * \theta_m * 7.48)/h$
Total required injection volume per well (V_{inj})	6,345	gal	$V_{inj} = V_{inj}/ft * h$
Total required injection volume per event (V_{tot})	19,034	gal	$V_{tot} = V_{inj} * \#IW$
Mass Loading			
Average GRO Concentration	7830	µg/L	Based on 3Q2011 data for MW-6
Average Soil Concentration	3230	mg/kg	Max GRO results from the Site. MW-16-18-18.5
Estimate fraction of Organic Carbon	0.001	f_{oc}	
Sorbed phase partitioning coefficeint	5000	k_{oc}	
Estimated soil bulk density	1.5	kg/L	
Sorbed Phase Mass TPH per Injection well	35.77	lbs	Sorbed Mass = {[Aqueous Concentration (ug/L)*K_{oc}(L/kg)*f_{oc}]/1000} * {treatment volume of soil (ft^3)*soil density (kg/L)*28.32 (L/ft^3)} / 453592.4 (mg/lbs)
Aqueous Phase Mass TPH per Injection well	0.14	lbs	Aqueous Mass = Treatement volume pore space (ft^3) * 28.32 (L/ft^3)*Average GRO Concentration (µg/L)/1000 (µg/mg)*2.20x10^{-6}(lbs/mg)
Target in situ concentration of SO_4	5.00	g/L	Assumed
Sulfate Loading			
Target Sulfate Concentration in Aquifer (AC_{SO42-})	5,000	mg/L	
Target Sulfate Concentration in Aquifer (AC_{SO42-})	0.042	lb/gal	Conversion
Unit Weight of Water (γ_w)	8.3	lb/gal	Assumed
Target Sulfate Mass Percentage in Aquifer $AM\%_{SO42-}$	0.50%	%	$M\%_{SO42-} = AC_{SO42-}/\gamma_w$
Dilution in Aquifer (D)	2	X	Assumed aquifer dilution of 2X
Formula Weight of Magnesium Sulfate Heptahydrate ($FW_{MgSO4*7H2O}$)	246	g/mol	$FW_{MgSo4*7H20} = MW_{Mg}+MW_S+4*MW_O+7*MW_{H20}$
Formula Weight of Sulfate (FW_{SO42-})	96	g/mol	$FW_{SO42-} = MW_S+4*MW_O$
Formula Weight of Magnesium (FW_{Mg})	24	g/mol	$FW_{Mg} = MW_{Mg}$
Magnesium Sulfate Hepta Hydrate:Sulfate Mass Ratio ($FW_{MgSO4*7H2O}$:FW_{SO42-})	2.6	--	$FW_{MgSO4*7H2O}:FW_{SO42-} = FWMg_{SO4}/FW_{SO42-}$
Magnesium:Magnesium Sulfate Hepta Hydrate Mass Ratio (FW_{Na}:$FW_{Na2S2O8}$)	0.098	--	$FW_{Mg}:FW_{MgSO4*7H2O} = FW_{Mg}/FW_{MgSO4}$
Mass Percentage of Injection Strength as Sulfate ($IM\%_{SO42-}$)	1.0%	%	$IM\%_{SO42-} = D*M\%_{SO42-}$
Injection Strength as Sulfate (IC_{SO42-})	0.083	lb/gal	$IC_{SO42-} = IM\%_{SO42-}*\gamma_w$
Injection Strength as Sulfate (IC_{SO42-})	10,000	mg/L	Conversion
Injection Strength of Magnesium Sulfate Hepta Hydrate ($C_{MgSO4*7H2O}$)	25,625	mg/L	$C_{MgSO4} = IC_{SO42-}*FW_{MgSO4*7H2O}:FW_{SO42-}$ (approximate solubility @ 20°C = 710 g/L)
Injection Strength of Magnesium Sulfate Hepta Hydrate (C_{MgSOe})	0.21	lb/gal	
Injection Strength of Magnesium Sulfate Hepta Hydrate (C_{MgSO4})	0.21	lb/gal	Check
Mass Percentage of Injection Strength as Magnesium Sulfate Hepta Hydrate ($IM\%_{MgSO4}$)	2.6%	%	
Sulfate requirement per well ($SO4^{2-}$/W)	529	lbs	$SO4^{2-}/W = (IC_{SO42-})*V_{inj}$
Sulfate requirement per event ($SO4^{2-}$/Event)	1,586	lbs	$SO_4^{2-}/Event = SO_4^{2-}/W*\#IW$
Magnesium Sulfate Hepta Hydrate requirement per event ($MgSO_4$/event)	**4,065**	lbs	$MgSO_4/Event = SO_4^{2-}/Event*FWMgSO_4:FWSO_4^{2-}$
Magnesium Sulfate Hepta Hydrate requirement per event ($MgSO_4$/event)	**4,065**	lbs	CHECK: $MgSO_{4*7H2O}/Event = CMgSO_{4*7H2O}*V_{tot}$
Injection Timeframe			
Assumed per well injection rate (Q_{inj})	3	gpm	Design Parameter
Assumed hours worked per day	10	hr/d	Assumed
Injection hours per day (t_{labor})	10	hr/d	Assumed - continuous gravity feed not possible
Time to complete injection at one well (t_{inj})	36	hours	$t_{inj} = (V_{inj})/(Q_{inj}*60)$
Number of wells for Simultaneous Injection	2		
Length of continuous injection	4	days	Not possible
Time required for travel, setup/teardown, mix batches each day (t_{setup})	1	hours	Change this with local site knowledge
Required Technician Oversight	100%		Assumed
Field Technician Oversight Time	111	hours	
Total time to complete injection (t_{tot})	12	days	$t_{tot} = (t_{inj}+t_{setup})/t_{labor}$

Table 6
Sulfate Injection Sampling Matrix

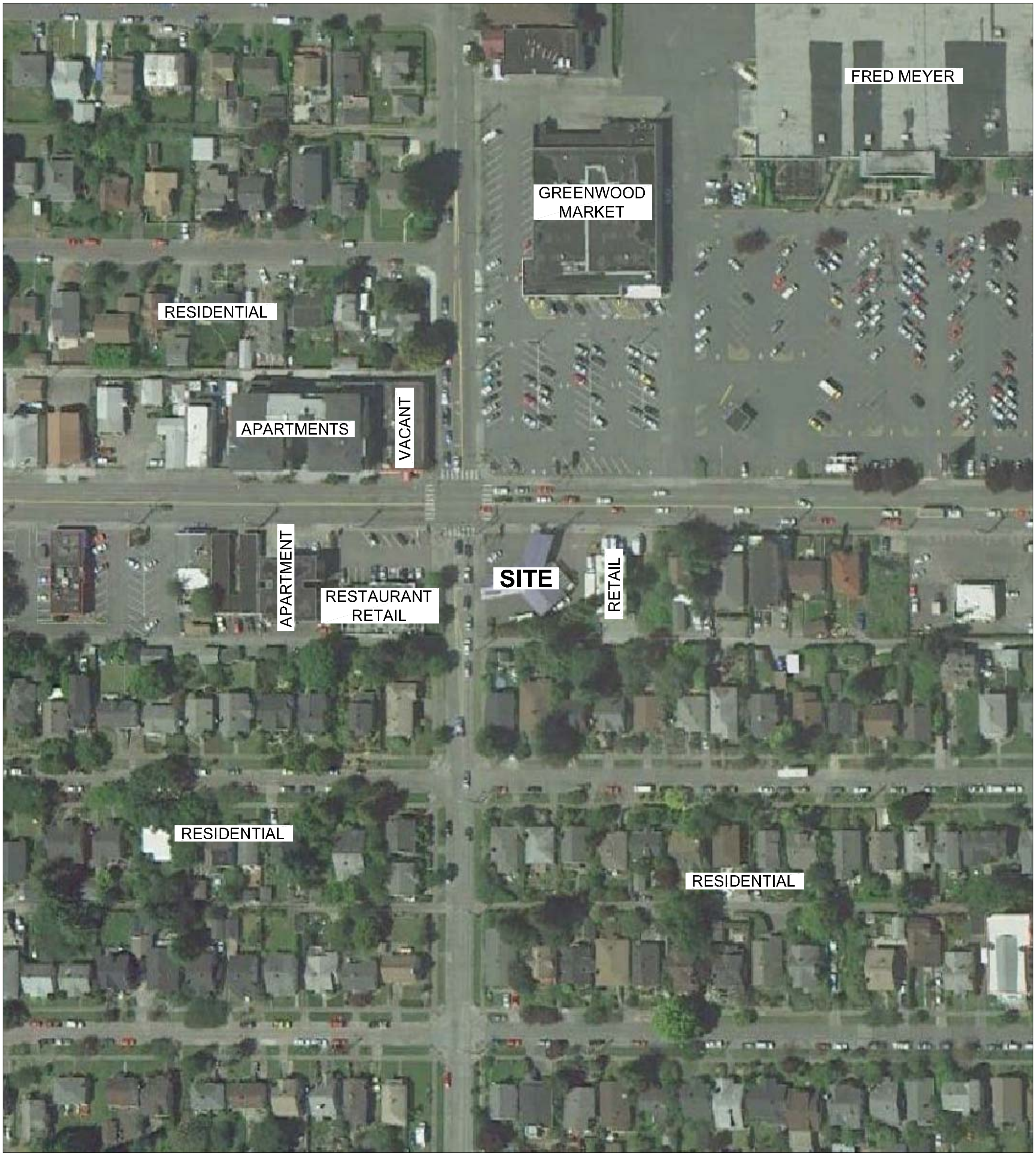
Former ARCO Facility WA-0977
155 Northwest 85th Street, Seattle, Washington 98107

Well ID	GRO by NWTPH-GX	DRO by NWTPH-Dx	HO by NWTPH-Dx	BTEX and MTBE by EPA 8260	Sulfide by EPA 376.1	Sulfate by EPA 300.0	Nitrate as Nitrogen by EPA 300.0	Total/Dissolved Iron and Lead by EPA 6020	Conductivity by downhole meter	Temperature by downhole meter	pH by downhole meter
Baseline Sampling											
MW-5	x	x	x	x	x	x	x	x	x	x	x
MW-6	x	x	x	x	x	x	x	x	x	x	x
MW-12	x	x	x	x	x	x	x	x	x	x	x
Injection Monitoring (Initally at 250 gallons injected and then every 500 gallons of injected solution per well)											
MW-1					BC	BC			x	x	x
MW-5					BC	BC			x	x	x
MW-16					BC	BC			x	x	x
Week 1 Sampling											
MW-5					x	x			x	x	x
MW-6					x	x			x	x	x
MW-12					x	x			x	x	x
IW-1					x	x			x	x	x
IW-2					x	x			x	x	x
VE-2					x	x			x	x	x
Month 2 Sampling											
MW-5	x	x	x	x	x	x	x	x	x	x	x
MW-6	x	x	x	x	x	x	x	x	x	x	x
MW-12	x	x	x	x	x	x	x	x	x	x	x

BC- Sampling based on observed spike and sustained elevated conductivity measurements.

ARCADIS

Figures



SOURCE: GOOGLE EARTH PRO

0 150' 300'

Approximate Scale: 1 in. = 300 ft.

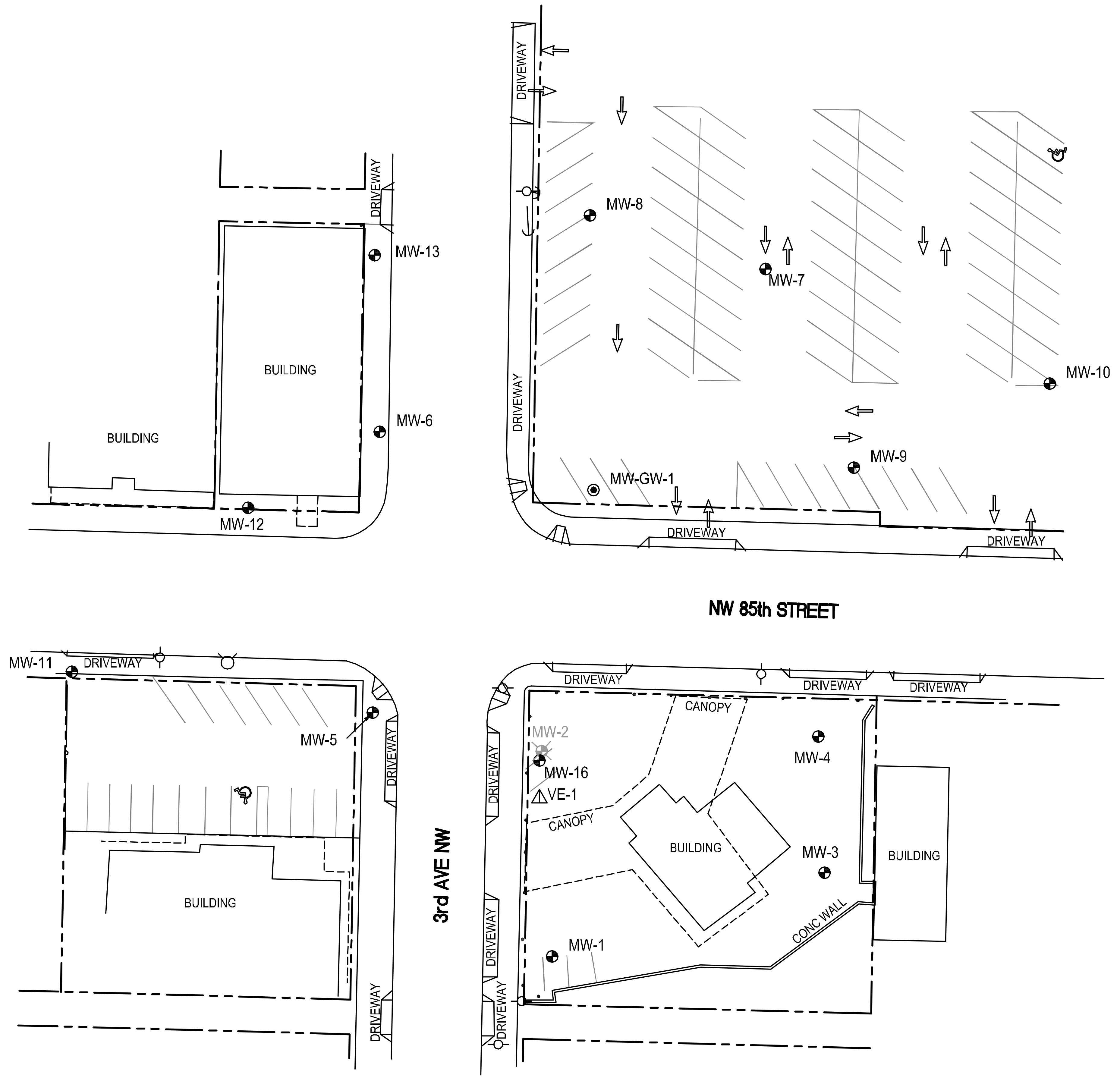
FORMER ARCO FACILITY No. 0977
155 NW 85th STREET, SEATTLE, WASHINGTON
REMEDIAL ACTION PLAN

SITE AERIAL MAP

ARCADIS

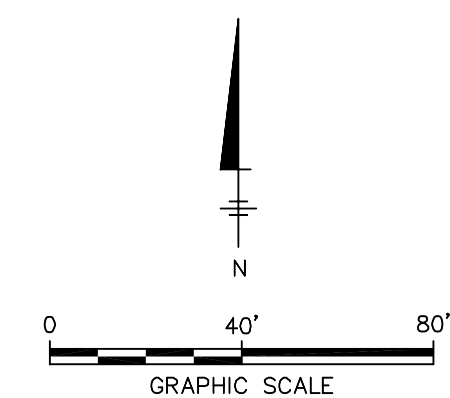
FIGURE
1

CITY: PETALUMA, CA DIV/GROUP: ENV DB: J. HARRIS LD:-- PIC:-- PM: S. DAVIS TM: T. POTTER LYR:(Opt)ON=*;OFF=*REF*
G:\ENVCAD\Emeryville\ACT\GP09BPNAWA08\E0000\RAP\GP09BPNAWA08-N02.dwg LAYOUT: 1 SAVED: 6/17/2011 4:47 PM ACADVER: 18.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: ARCADIS.CTB PLOTTED: 6/22/2011 10:20 AM BY: REYES, ALEC



LEGEND

- GROUNDWATER MONITORING WELL (DELTA)
- GROUNDWATER MONITORING WELL (INSTALLED BY OTHERS)
- ABANDONED GROUNDWATER MONITORING WELL
- VE-1 SOIL VAPOR EXTRACTION WELL



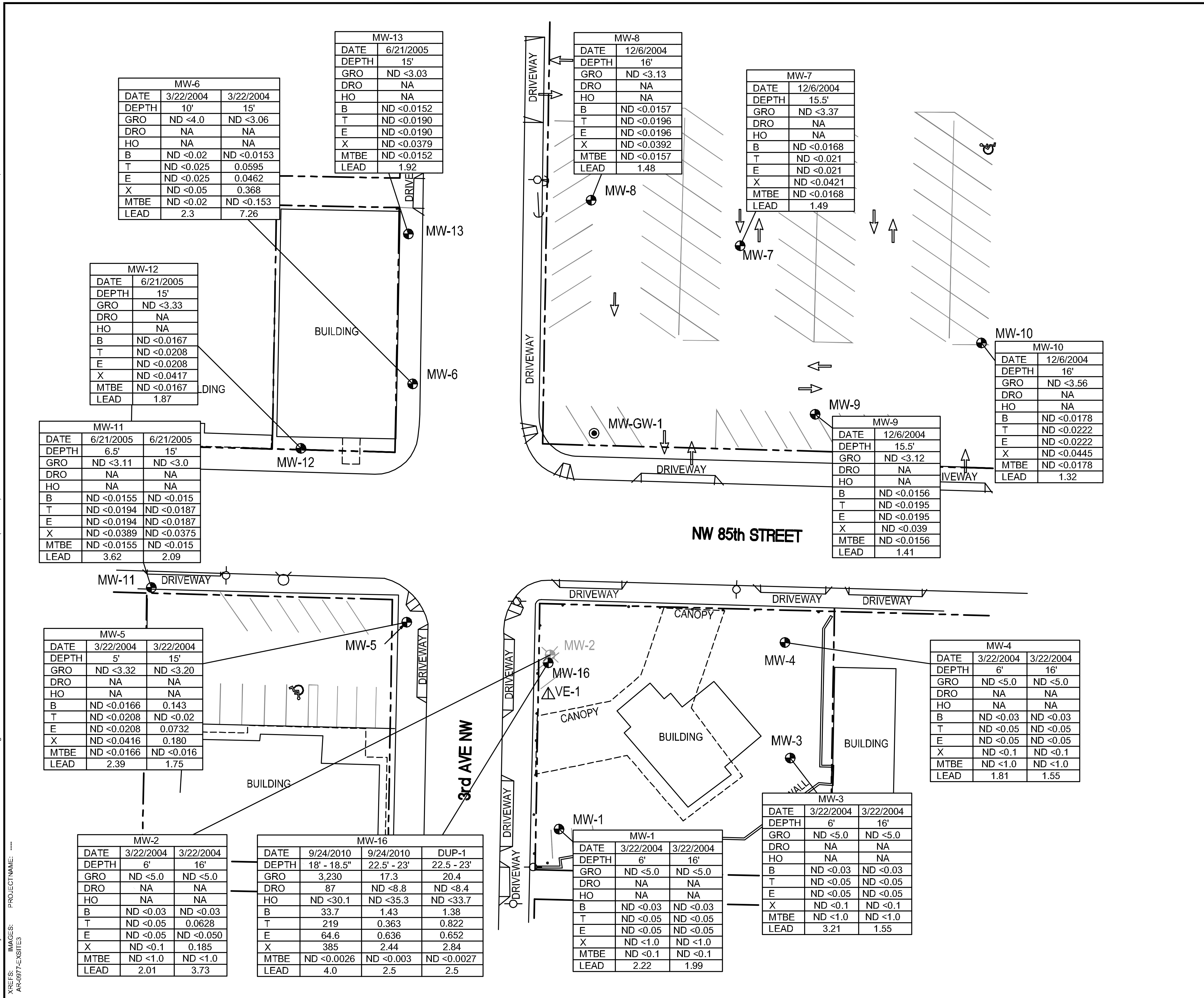
NOTES:
BASEMAP SUPPLIED BY OTAK, INC., IN 2010. SUPPLEMENTAL HISTORICAL INFORMATION SUPPLIED BY DELTA ENVIRONMENTAL CONSULTANTS, INC
LOCATION OF VE-1 IS APPROXIMATE.
VE-1 WILL BE SURVEYED LATER THIS YEAR.

FORMER ARCO FACILITY No. 0977
155 NW 85th STREET, SEATTLE, WASHINGTON
REMEDIAL ACTION PLAN

SITE PLAN

ARCADIS

FIGURE
2



MW-13	
DATE	6/21/2005
DEPTH	15'
GRO	ND <3.03
DRO	NA
HO	NA
B	ND <0.0152
T	ND <0.0190
E	ND <0.0190
X	ND <0.0379
MTBE	ND <0.0152
LEAD	1.92

MW-6		
DATE	3/22/2004	3/22/2004
DEPTH	10'	15'
GRO	ND <4.0	ND <3.06
DRO	NA	NA
HO	NA	NA
B	ND <0.02	ND <0.0153
T	ND <0.025	0.0595
E	ND <0.025	0.0462
X	ND <0.05	0.368
MTBE	ND <0.02	ND <0.153
LEAD	2.3	7.26

MW-8	
DATE	12/6/2004
DEPTH	16'
GRO	ND <3.13
DRO	NA
HO	NA
B	ND <0.0157
T	ND <0.0196
E	ND <0.0196
X	ND <0.0392
MTBE	ND <0.0157
LEAD	1.48

MW-7	
DATE	12/6/2004
DEPTH	15.5'
GRO	ND <3.37
DRO	NA
HO	NA
B	ND <0.0168
T	ND <0.021
E	ND <0.021
X	ND <0.0421
MTBE	ND <0.0168
LEAD	1.49

MW-12	
DATE	6/21/2005
DEPTH	15'
GRO	ND <3.33
DRO	NA
HO	NA
B	ND <0.0167
T	ND <0.0208
E	ND <0.0208
X	ND <0.0417
MTBE	ND <0.0167
LEAD	1.87

MW-11		
DATE	6/21/2005	6/21/2005
DEPTH	6.5'	15'
GRO	ND <3.11	ND <3.0
DRO	NA	NA
HO	NA	NA
B	ND <0.0155	ND <0.015
T	ND <0.0194	ND <0.0187
E	ND <0.0194	ND <0.0187
X	ND <0.0389	ND <0.0375
MTBE	ND <0.0155	ND <0.015
LEAD	3.62	2.09

MW-10	
DATE	12/6/2004
DEPTH	16'
GRO	ND <3.56
DRO	NA
HO	NA
B	ND <0.0178
T	ND <0.0222
E	ND <0.0222
X	ND <0.0445
MTBE	ND <0.0178
LEAD	1.32

MW-9	
DATE	12/6/2004
DEPTH	15.5'
GRO	ND <3.12
DRO	NA
HO	NA
B	ND <0.0156
T	ND <0.0195
E	ND <0.0195
X	ND <0.039
MTBE	ND <0.0156
LEAD	1.41

MW-5		
DATE	3/22/2004	3/22/2004
DEPTH	5'	15'
GRO	ND <3.32	ND <3.20
DRO	NA	NA
HO	NA	NA
B	ND <0.0166	0.143
T	ND <0.0208	ND <0.02
E	ND <0.0208	0.0732
X	ND <0.0416	0.180
MTBE	ND <0.0166	ND <0.016
LEAD	2.39	1.75

MW-4		
DATE	3/22/2004	3/22/2004
DEPTH	6'	16'
GRO	ND <5.0	ND <5.0
DRO	NA	NA
HO	NA	NA
B	ND <0.03	ND <0.03
T	ND <0.05	ND <0.05
E	ND <0.05	ND <0.05
X	ND <0.1	ND <0.1
MTBE	ND <1.0	ND <1.0
LEAD	1.81	1.55

MW-3		
DATE	3/22/2004	3/22/2004
DEPTH	6'	16'
GRO	ND <5.0	ND <5.0
DRO	NA	NA
HO	NA	NA
B	ND <0.03	ND <0.03
T	ND <0.05	ND <0.05
E	ND <0.05	ND <0.05
X	ND <0.1	ND <0.1
MTBE	ND <1.0	ND <1.0
LEAD	3.21	1.55

MW-2		
DATE	3/22/2004	3/22/2004
DEPTH	6'	16'
GRO	ND <5.0	ND <5.0
DRO	NA	NA
HO	NA	NA
B	ND <0.03	ND <0.03
T	ND <0.05	0.0628
E	ND <0.05	ND <0.050
X	ND <0.1	0.185
MTBE	ND <1.0	ND <1.0
LEAD	2.01	3.73

MW-16			
DATE	9/24/2010	9/24/2010	DUP-1
DEPTH	18' - 18.5'	22.5' - 23'	22.5 - 23'
GRO	3,230	17.3	20.4
DRO	87	ND <8.8	ND <8.4
HO	ND <30.1	ND <35.3	ND <33.7
B	33.7	1.43	1.38
T	219	0.363	0.822
E	64.6	0.636	0.652
X	385	2.44	2.84
MTBE	ND <0.0026	ND <0.003	ND <0.0027
LEAD	4.0	2.5	2.5

MW-1		
DATE	3/22/2004	3/22/2004
DEPTH	6'	16'
GRO	ND <5.0	ND <5.0
DRO	NA	NA
HO	NA	NA
B	ND <0.03	ND <0.03
T	ND <0.05	ND <0.05
E	ND <0.05	ND <0.05
X	ND <1.0	ND <1.0
MTBE	ND <0.1	ND <0.1
LEAD	2.22	1.99

LEGEND

GROUNDWATER MONITORING WELL (DELTA)

GROUNDWATER MONITORING WELL (INSTALLED BY OTHERS)

ABANDONED GROUNDWATER MONITORING WELL

VE-1 SOIL VAPOR EXTRACTION WELL

(mg/kg) MILLIGRAMS PER KILOGRAM

DATE	DATE SAMPLE COLLECTED
DEPTH	DEPTH BELOW GROUND SURFACE (feet)
GRO	GASOLINE RANGE ORGANICS (mg/kg)
DRO	DIESEL RANGE ORGANICS (mg/kg)
HO	HEATING OIL RANGE ORGANICS (mg/kg)
B	BENZENE (mg/kg)
T	TOLUENE (mg/kg)
E	ETHYLBENZENE (mg/kg)
X	XYLENES, TOTAL (mg/kg)
MTBE	METHYL TERTIARY BUTYL ETHER (mg/kg)
LEAD	TOTAL LEAD (mg/kg)

NOTES:
BASEMAP SUPPLIED BY OTAK, INC., IN 2010. SUPPLEMENTAL HISTORICAL INFORMATION SUPPLIED BY DELTA ENVIRONMENTAL CONSULTANTS, INC
LOCATION OF VE-1 IS APPROXIMATE.
VE-1 WILL BE SURVEYED LATER THIS YEAR.

FORMER ARCO FACILITY No. 0977
155 NW 85th STREET, SEATTLE, WASHINGTON
REMEDIAL ACTION PLAN

HISTORICAL SOIL ANALYTICAL MAP

ARCADIS

FIGURE
3

PLOTSTYLETABLE: ARCADIS.CTB PLOTTED: 6/24/2011 11:08 AM BY: REYES, ALEC
XREFS: AR-0977-EXSITE3 IMAGES: PROJECTNAME: ----

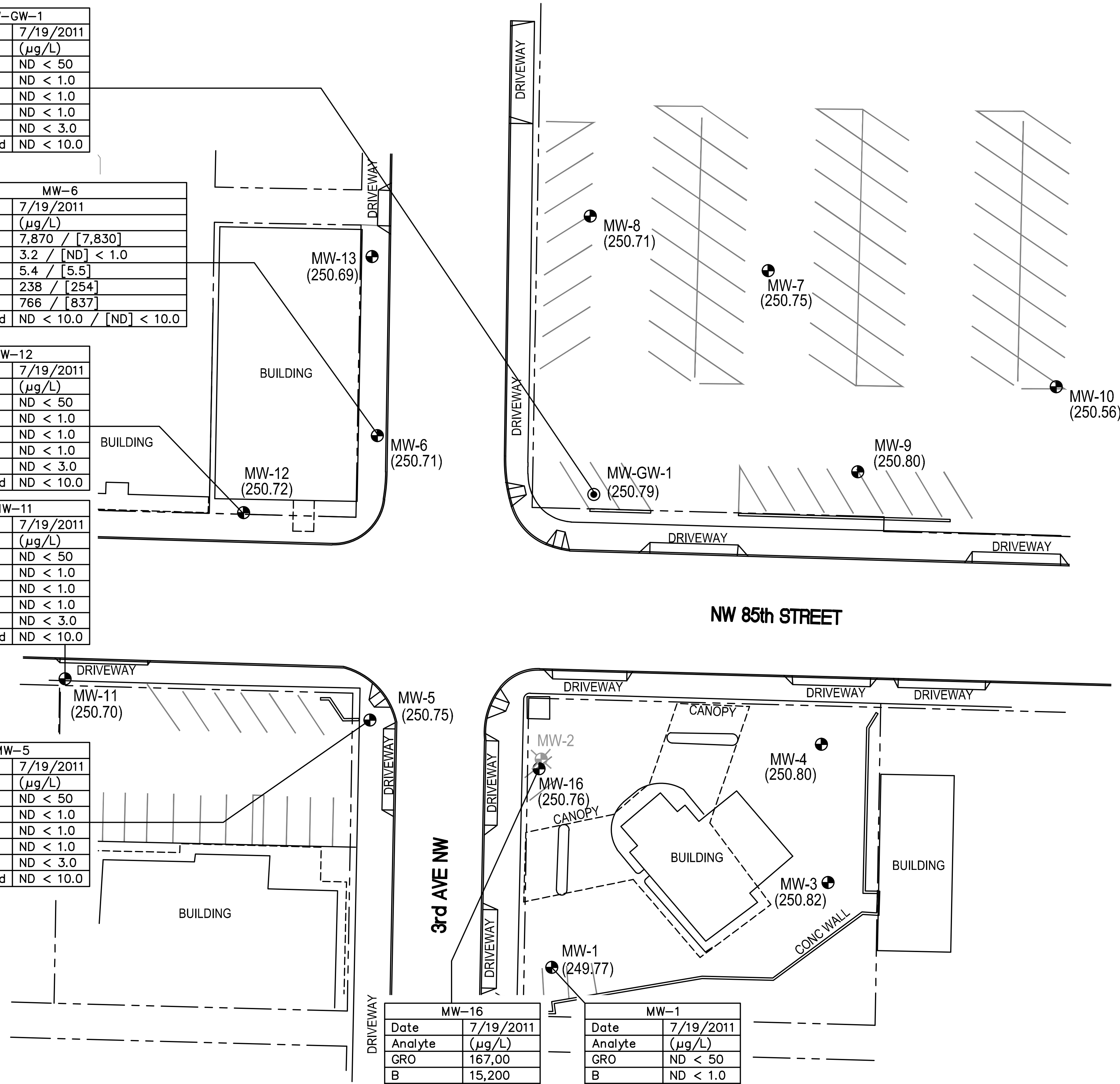
MW-GW-1	
Date	7/19/2011
Analyte	(µg/L)
GRO	ND < 50
B	ND < 1.0
T	ND < 1.0
E	ND < 1.0
X	ND < 3.0
Total Lead	ND < 10.0

MW-6	
Date	7/19/2011
Analyte	(µg/L)
GRO	7,870 / [7,830]
B	3.2 / [ND] < 1.0
T	5.4 / [5.5]
E	238 / [254]
X	766 / [837]
Total Lead	ND < 10.0 / [ND] < 10.0

MW-12	
Date	7/19/2011
Analyte	(µg/L)
GRO	ND < 50
B	ND < 1.0
T	ND < 1.0
E	ND < 1.0
X	ND < 3.0
Total Lead	ND < 10.0

MW-11	
Date	7/19/2011
Analyte	(µg/L)
GRO	ND < 50
B	ND < 1.0
T	ND < 1.0
E	ND < 1.0
X	ND < 3.0
Total Lead	ND < 10.0

MW-5	
Date	7/19/2011
Analyte	(µg/L)
GRO	ND < 50
B	ND < 1.0
T	ND < 1.0
E	ND < 1.0
X	ND < 3.0
Total Lead	ND < 10.0



MW-16	
Date	7/19/2011
Analyte	(µg/L)
GRO	167,00
B	15,200
T	29,000
E	2,680
X	18,400
Total Lead	246

MW-1	
Date	7/19/2011
Analyte	(µg/L)
GRO	ND < 50
B	ND < 1.0
T	ND < 1.0
E	ND < 1.0
X	ND < 3.0
Total Lead	ND < 10.0

LEGEND

- GROUNDWATER MONITORING WELL (DELTA)
- GROUNDWATER MONITORING WELL (INSTALLED BY OTHERS)
- ABANDONED GROUNDWATER MONITORING WELL
- (250.56) GROUNDWATER ELEVATION (FEET ABOVE MSL)

LOCATION ID	
DATE	Date Sample Taken
GRO	Gasoline Range Organics (µg/L / [Duplicate (µg/L)]
B	Benzene (µg/L) / [Duplicate (µg/L)]
T	Toluene (µg/L) / [Duplicate (µg/L)]
E	Ethylbenzene (µg/L) / [Duplicate (µg/L)]
X	Total Xylenes (µg/L) / [Duplicate (µg/L)]
MTBE	Methyl Tertiary Butyl Ether (µg/L) / [Duplicate (µg/L)]
Total Lead	Total Lead (µg/L) / [Duplicate (µg/L)]

µg/L	MICROGRAMS PER LITER
MSL	MEAN SEA LEVEL
ND	NOT DETECTED, VALUE SHOWN IS DETECTION LIMIT
NM	NOT MEASURED
NS	NOT SAMPLED

NOTE: BASEMAP SUPPLIED BY OTAK, INC., IN 2010. SUPPLEMENTAL HISTORICAL INFORMATION SUPPLIED BY DELTA ENVIRONMENTAL CONSULTANTS, INC

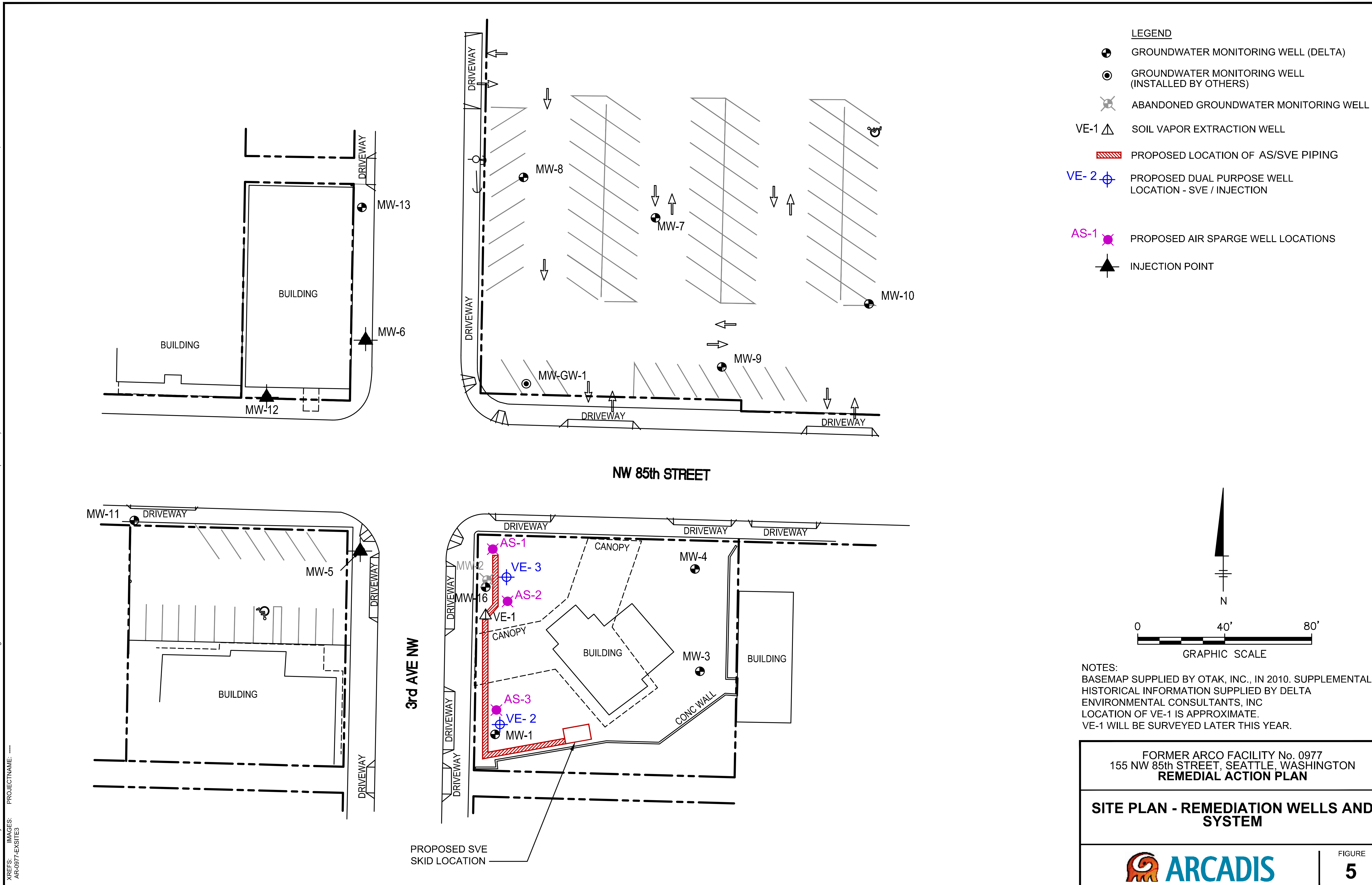
FORMER ARCO FACILITY No. 0977
155 NW 85th STREET, SEATTLE, WASHINGTON
REMEDIAL ACTION PLAN

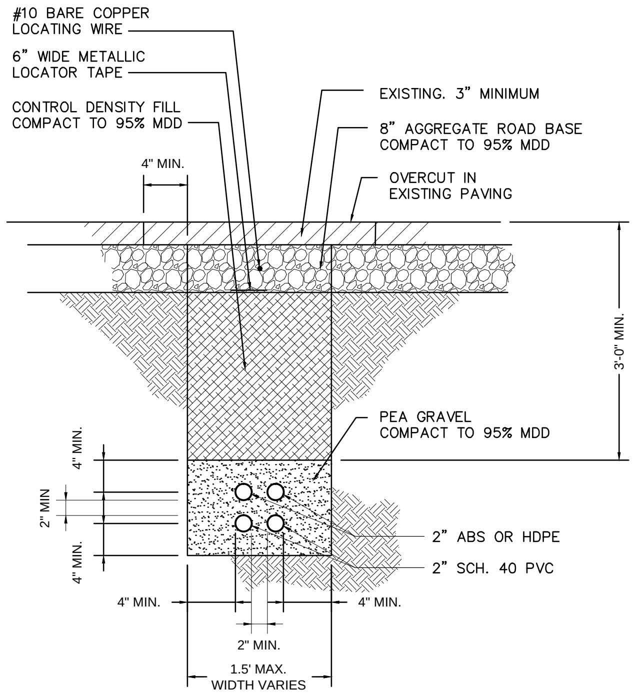
GROUNDWATER MAP WITH ANALYTICAL RESULTS

ARCADIS

FIGURE 4

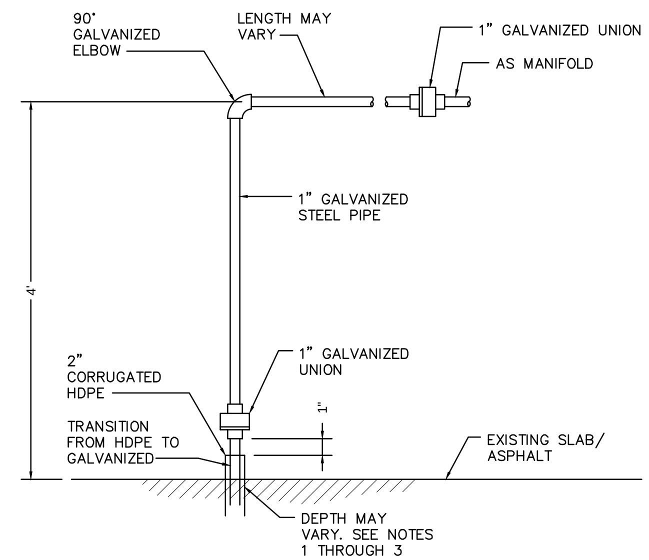
CITY:(Reqd) DIV/GROUP:(Reqd) DB:(Reqd) LD:(Opt) PIC:(Opt) PM:(Reqd) TM:(Opt) LYR:(Opt)ON=*;OFF=*REF*
G:\ENVCAD\Emeryville\ACT\GP09BPNA\WA08\E0000\RAP\GP09BPNAWA08-C04.dwg LAYOUT: 4 SAVED: 9/21/2011 10:58 AM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: ARCADIS.CTB PLOTTED: 9/21/2011 11:07 AM BY: REYES, ALEC


LEGEND
GROUNDWATER MONITORING WELL (DELTA)
GROUNDWATER MONITORING WELL (INSTALLED BY OTHERS)
ABANDONED GROUNDWATER MONITORING WELL
VE-1 SOIL VAPOR EXTRACTION WELL
PROPOSED LOCATION OF AS/SVE PIPING
VE- 2 PROPOSED DUAL PURPOSE WELL LOCATION - SVE / INJECTION
AS-1 PROPOSED AIR SPARGE WELL LOCATIONS
INJECTION POINT
NW 85th STREET
3rd AVE NW
BUILDING
DRIVEWAY
CANOPY
CONC WALL
MW-1
MW-2
MW-3
MW-4
MW-5
MW-6
MW-7
MW-8
MW-9
MW-10
MW-11
MW-12
MW-13
MW-16
MW-GW-1
AS-1
AS-2
AS-3
VE-1
VE- 2
VE- 3
PROPOSED SVE SKID LOCATION
N
0
40'
80'
GRAPHIC SCALE
NOTES:
BASEMAP SUPPLIED BY OTAK, INC., IN 2010. SUPPLEMENTAL HISTORICAL INFORMATION SUPPLIED BY DELTA ENVIRONMENTAL CONSULTANTS, INC
LOCATION OF VE-1 IS APPROXIMATE.
VE-1 WILL BE SURVEYED LATER THIS YEAR.
FORMER ARCO FACILITY No. 0977
155 NW 85th STREET, SEATTLE, WASHINGTON
REMEDIAL ACTION PLAN
SITE PLAN - REMEDIATION WELLS AND SYSTEM
ARCADIS
FIGURE
5



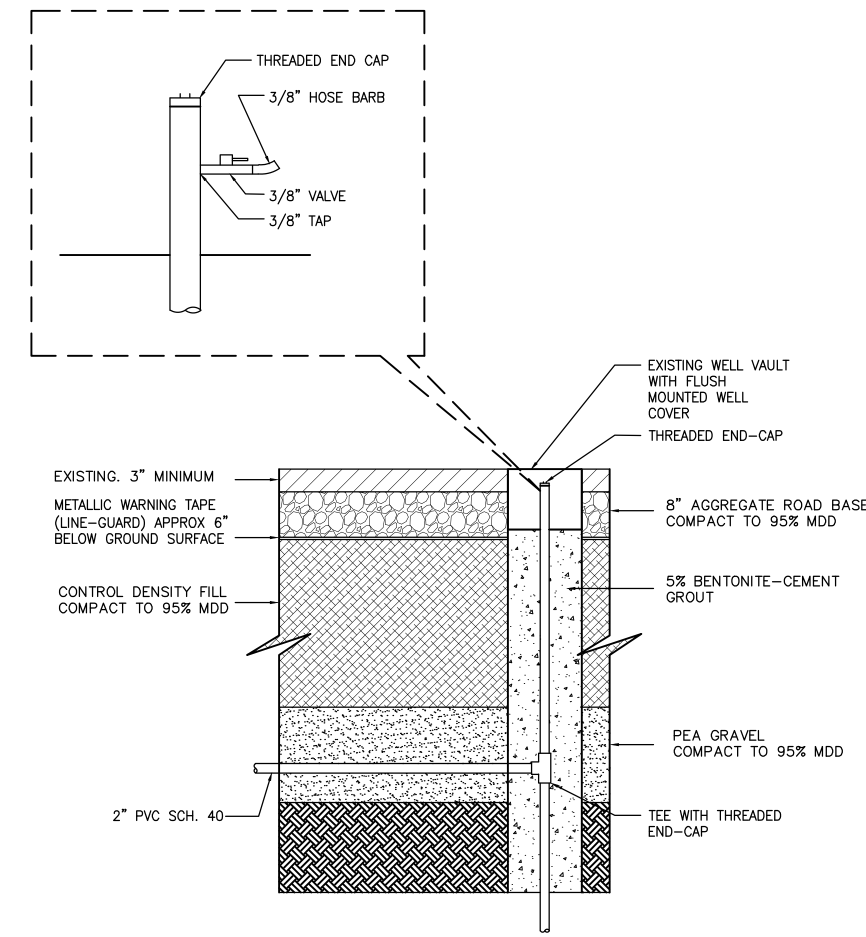
MULTIPLE AS/SVE PIPING TRENCH DETAILS

NOT TO SCALE



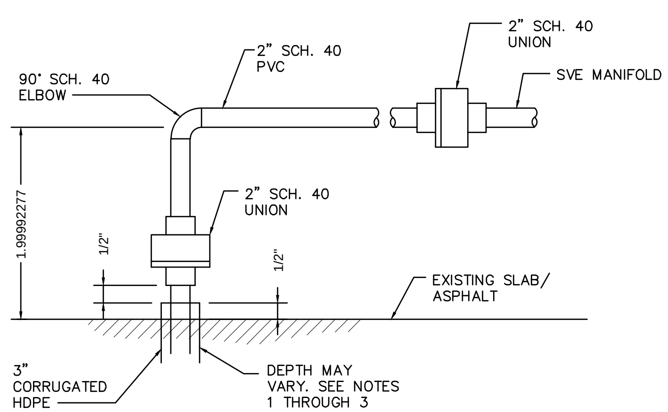
AS MANIFOLD CONNECTION DETAIL

NOT TO SCALE



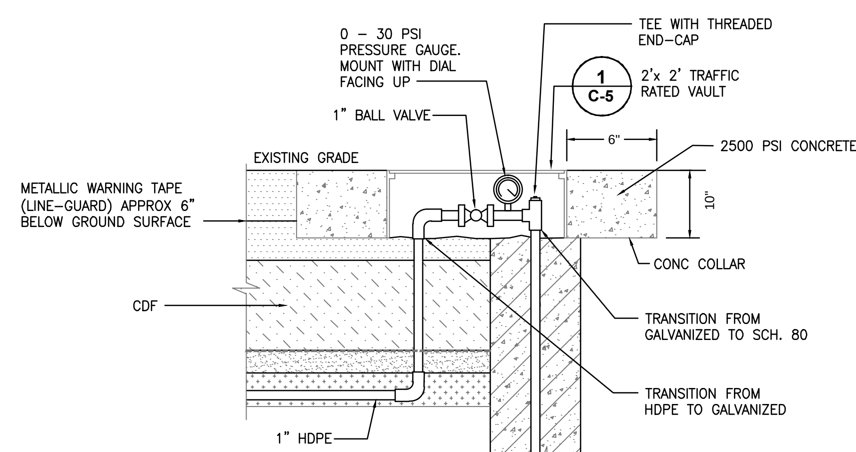
SVE WELLHEAD DETAIL

NOT TO SCALE



SVE MANIFOLD CONNECTION DETAIL

NOT TO SCALE



AIR SPARGE WELLHEAD DETAIL

NOT TO SCALE

NOTES:

1. PROVIDE CORRUGATED HDPE PIPE SLEEVES AT ALL SLAB/ASPHALT PENETRATIONS.
2. SLEEVES FOR SVE TO EXTEND 1" ABOVE AND 3" BELOW SLAB/ASPHALT.
3. SLEEVE TO BE 1" LARGER THAN RISER DIAMETER.

FORMER ARCO FACILITY No. 0977
155 NW 85th STREET, SEATTLE, WASHINGTON
REMEDIAL ACTION PLAN

SVE TREATMENT SYSTEM INSTALLATION DETAILS

ARCADIS

FIGURE
6

ARCADIS

Appendix **A**

Laboratory Analytical Data Reports–
Biogeochemical data from
October 2010

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

October 28, 2010

Scott Zorn
Arcadis U.S., Inc.
2300 Eastlake Ave E. Ste. 200
Seattle, WA 98102

RE: Project: WA-0977
Pace Project No.: 255347

Dear Scott Zorn:

Enclosed are the analytical results for sample(s) received by the laboratory on October 15, 2010. The results relate only to the samples included in this report. Results reported herein conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Regina SteMarie

regina.stemarie@pacelabs.com
Project Manager

Enclosures

cc: David Rasar, Arcadis U.S., Inc.

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

CERTIFICATIONS

Project: WA-0977
Pace Project No.: 255347

Washington Certification IDs

940 South Harney Street, Seattle, WA 98108
Alaska CS Certification #: UST-025
Alaska Drinking Water VOC Certification #: WA01230
Alaska Drinking Water Micro Certification #: WA01230
California Certification #: 01153CA
Florida/NELAP Certification #: E87617
Oregon Certification #: WA200007
Washington Certification #: C1229

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

SAMPLE ANALYTE COUNT

Project: WA-0977
Pace Project No.: 255347

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
255347001	**MW-12**	NWTPH-Gx	AY1	3	PASI-S
		EPA 6010	BGA	1	PASI-S
		EPA 5030B/8260	LPM	9	PASI-S
255347002	**MW-11**	NWTPH-Gx	AY1	3	PASI-S
		EPA 6010	BGA	1	PASI-S
		EPA 5030B/8260	LPM	9	PASI-S
255347003	**MW-1**	NWTPH-Gx	AY1	3	PASI-S
		EPA 6010	BGA	1	PASI-S
		EPA 5030B/8260	LPM	9	PASI-S
255347004	**MW-GW-1**	NWTPH-Gx	AY1	3	PASI-S
		EPA 6010	BGA	1	PASI-S
		EPA 5030B/8260	LPM	9	PASI-S
255347005	**Dup-1**	NWTPH-Gx	AY1	3	PASI-S
		EPA 5030B/8260	LPM	9	PASI-S
255347006	**MW-6**	NWTPH-Gx	AY1	3	PASI-S
		EPA 6010	BGA	1	PASI-S
		EPA 5030B/8260	LPM	9	PASI-S
255347007	**MW-5**	NWTPH-Gx	AY1	3	PASI-S
		EPA 6010	BGA	1	PASI-S
		EPA 5030B/8260	LPM	9	PASI-S
255347008	**MW-16**	NWTPH-Gx	AY1	3	PASI-S
		EPA 6010	BGA	1	PASI-S
		EPA 5030B/8260	LPM	9	PASI-S
255347009	**Trip Blank**	NWTPH-Gx	AY1	3	PASI-S
		EPA 5030B/8260	LPM	9	PASI-S

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255347

Method: **NWTPH-Gx**
Description: NWTPH-Gx GCV
Client: Arcadis U.S., Inc.
Date: October 28, 2010

General Information:
9 samples were analyzed for NWTPH-Gx. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Internal Standards:
All internal standards were within QC limits with any exceptions noted below.

Surrogates:
All surrogates were within QC limits with any exceptions noted below.

QC Batch: GCV/1967

S5: Surrogate recovery outside control limits due to matrix interferences (not confirmed by re-analysis).
- DUP (Lab ID: 46255)
  - 4-Bromofluorobenzene (S)

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

QC Batch: GCV/1967

R1: RPD value was outside control limits.
- DUP (Lab ID: 46255)
  - Gasoline Range Organics

Additional Comments:

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255347

Method: **NWTPH-Gx**
Description: NWTPH-Gx GCV
Client: Arcadis U.S., Inc.
Date: October 28, 2010

Analyte Comments:

QC Batch: GCV/1967

1n: RPD value was outside control limits due to carryover from previously analyzed sample.

- DUP (Lab ID: 46260)
    - Gasoline Range Organics

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255347

Method: **EPA 6010**
Description: 6010 MET ICP
Client: Arcadis U.S., Inc.
Date: October 28, 2010

General Information:
7 samples were analyzed for EPA 6010. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Sample Preparation:
The samples were prepared in accordance with EPA 3010 with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255347

Method: **EPA 5030B/8260**
Description: 8260 MSV
Client: Arcadis U.S., Inc.
Date: October 28, 2010

General Information:
9 samples were analyzed for EPA 5030B/8260. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Internal Standards:
All internal standards were within QC limits with any exceptions noted below.

Surrogates:
All surrogates were within QC limits with any exceptions noted below.

QC Batch: MSV/3306

S5: Surrogate recovery outside control limits due to matrix interferences (not confirmed by re-analysis).
- MW-16 (Lab ID: 255347008)
  - 1,2-Dichloroethane-d4 (S)
  - Toluene-d8 (S)

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

This data package has been reviewed for quality and completeness and is approved for release.

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255347

Sample: MW-12 | **Lab ID: 255347001** | Collected: 10/13/10 11:55 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
Gasoline Range Organics	**682**	ug/L	50.0	1		10/19/10 14:24		
a,a,a-Trifluorotoluene (S)	103	%	50-150	1		10/19/10 14:24	98-08-8	
4-Bromofluorobenzene (S)	135	%	50-150	1		10/19/10 14:24	460-00-4	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Lead	ND	ug/L	10.0	1	10/20/10 08:28	10/20/10 16:54	7439-92-1	
8260 MSV	Analytical Method: EPA 5030B/8260							
Benzene	**56.7**	ug/L	1.0	1		10/21/10 01:01	71-43-2	
Ethylbenzene	**23.0**	ug/L	1.0	1		10/21/10 01:01	100-41-4	
Methyl-tert-butyl ether	ND	ug/L	1.0	1		10/21/10 01:01	1634-04-4	
Toluene	ND	ug/L	1.0	1		10/21/10 01:01	108-88-3	
Xylene (Total)	**16.0**	ug/L	3.0	1		10/21/10 01:01	1330-20-7	
4-Bromofluorobenzene (S)	97	%	80-120	1		10/21/10 01:01	460-00-4	
Dibromofluoromethane (S)	104	%	80-122	1		10/21/10 01:01	1868-53-7	
1,2-Dichloroethane-d4 (S)	117	%	80-124	1		10/21/10 01:01	17060-07-0	
Toluene-d8 (S)	85	%	80-123	1		10/21/10 01:01	2037-26-5	

Sample: MW-11 | **Lab ID: 255347002** | Collected: 10/13/10 13:25 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
Gasoline Range Organics	ND	ug/L	50.0	1		10/19/10 15:12		
a,a,a-Trifluorotoluene (S)	103	%	50-150	1		10/19/10 15:12	98-08-8	
4-Bromofluorobenzene (S)	97	%	50-150	1		10/19/10 15:12	460-00-4	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Lead	ND	ug/L	10.0	1	10/20/10 08:28	10/20/10 16:57	7439-92-1	
8260 MSV	Analytical Method: EPA 5030B/8260							
Benzene	ND	ug/L	1.0	1		10/21/10 01:21	71-43-2	
Ethylbenzene	ND	ug/L	1.0	1		10/21/10 01:21	100-41-4	
Methyl-tert-butyl ether	ND	ug/L	1.0	1		10/21/10 01:21	1634-04-4	
Toluene	ND	ug/L	1.0	1		10/21/10 01:21	108-88-3	
Xylene (Total)	ND	ug/L	3.0	1		10/21/10 01:21	1330-20-7	
4-Bromofluorobenzene (S)	99	%	80-120	1		10/21/10 01:21	460-00-4	
Dibromofluoromethane (S)	105	%	80-122	1		10/21/10 01:21	1868-53-7	
1,2-Dichloroethane-d4 (S)	117	%	80-124	1		10/21/10 01:21	17060-07-0	
Toluene-d8 (S)	82	%	80-123	1		10/21/10 01:21	2037-26-5	

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ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255347

Sample: MW-1 | **Lab ID: 255347003** | Collected: 10/13/10 14:30 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
Gasoline Range Organics	**358**	ug/L	50.0	1		10/19/10 15:36		
a,a,a-Trifluorotoluene (S)	109	%	50-150	1		10/19/10 15:36	98-08-8	
4-Bromofluorobenzene (S)	97	%	50-150	1		10/19/10 15:36	460-00-4	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Lead	ND	ug/L	10.0	1	10/20/10 08:28	10/20/10 17:00	7439-92-1	
8260 MSV	Analytical Method: EPA 5030B/8260							
Benzene	**20.9**	ug/L	1.0	1		10/21/10 01:41	71-43-2	
Ethylbenzene	**31.0**	ug/L	1.0	1		10/21/10 01:41	100-41-4	
Methyl-tert-butyl ether	ND	ug/L	1.0	1		10/21/10 01:41	1634-04-4	
Toluene	ND	ug/L	1.0	1		10/21/10 01:41	108-88-3	
Xylene (Total)	**4.6**	ug/L	3.0	1		10/21/10 01:41	1330-20-7	
4-Bromofluorobenzene (S)	98	%	80-120	1		10/21/10 01:41	460-00-4	
Dibromofluoromethane (S)	106	%	80-122	1		10/21/10 01:41	1868-53-7	
1,2-Dichloroethane-d4 (S)	122	%	80-124	1		10/21/10 01:41	17060-07-0	
Toluene-d8 (S)	83	%	80-123	1		10/21/10 01:41	2037-26-5	

Sample: MW-GW-1 | **Lab ID: 255347004** | Collected: 10/13/10 15:35 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
Gasoline Range Organics	**68.9**	ug/L	50.0	1		10/19/10 16:01		
a,a,a-Trifluorotoluene (S)	96	%	50-150	1		10/19/10 16:01	98-08-8	
4-Bromofluorobenzene (S)	92	%	50-150	1		10/19/10 16:01	460-00-4	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Lead	ND	ug/L	10.0	1	10/20/10 08:28	10/20/10 17:03	7439-92-1	
8260 MSV	Analytical Method: EPA 5030B/8260							
Benzene	**1.5**	ug/L	1.0	1		10/21/10 02:01	71-43-2	
Ethylbenzene	ND	ug/L	1.0	1		10/21/10 02:01	100-41-4	
Methyl-tert-butyl ether	ND	ug/L	1.0	1		10/21/10 02:01	1634-04-4	
Toluene	ND	ug/L	1.0	1		10/21/10 02:01	108-88-3	
Xylene (Total)	ND	ug/L	3.0	1		10/21/10 02:01	1330-20-7	
4-Bromofluorobenzene (S)	94	%	80-120	1		10/21/10 02:01	460-00-4	
Dibromofluoromethane (S)	106	%	80-122	1		10/21/10 02:01	1868-53-7	
1,2-Dichloroethane-d4 (S)	119	%	80-124	1		10/21/10 02:01	17060-07-0	
Toluene-d8 (S)	85	%	80-123	1		10/21/10 02:01	2037-26-5	

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ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255347

Sample: Dup-1 | **Lab ID: 255347005** | Collected: 10/13/10 00:00 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
Gasoline Range Organics	**75.7**	ug/L	50.0	1		10/19/10 16:25		
a,a,a-Trifluorotoluene (S)	105	%	50-150	1		10/19/10 16:25	98-08-8	
4-Bromofluorobenzene (S)	101	%	50-150	1		10/19/10 16:25	460-00-4	
8260 MSV	Analytical Method: EPA 5030B/8260							
Benzene	**1.7**	ug/L	1.0	1		10/21/10 02:21	71-43-2	
Ethylbenzene	ND	ug/L	1.0	1		10/21/10 02:21	100-41-4	
Methyl-tert-butyl ether	ND	ug/L	1.0	1		10/21/10 02:21	1634-04-4	
Toluene	ND	ug/L	1.0	1		10/21/10 02:21	108-88-3	
Xylene (Total)	ND	ug/L	3.0	1		10/21/10 02:21	1330-20-7	
4-Bromofluorobenzene (S)	95	%	80-120	1		10/21/10 02:21	460-00-4	
Dibromofluoromethane (S)	102	%	80-122	1		10/21/10 02:21	1868-53-7	
1,2-Dichloroethane-d4 (S)	118	%	80-124	1		10/21/10 02:21	17060-07-0	
Toluene-d8 (S)	84	%	80-123	1		10/21/10 02:21	2037-26-5	

Sample: MW-6 | **Lab ID: 255347006** | Collected: 10/14/10 11:20 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
Gasoline Range Organics	**7290**	ug/L	250	5		10/22/10 13:29		
a,a,a-Trifluorotoluene (S)	107	%	50-150	5		10/22/10 13:29	98-08-8	
4-Bromofluorobenzene (S)	102	%	50-150	5		10/22/10 13:29	460-00-4	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Lead	ND	ug/L	10.0	1	10/20/10 08:28	10/20/10 17:06	7439-92-1	
8260 MSV	Analytical Method: EPA 5030B/8260							
Benzene	**1.2**	ug/L	1.0	1		10/21/10 10:13	71-43-2	
Ethylbenzene	**323**	ug/L	5.0	5		10/21/10 05:26	100-41-4	
Methyl-tert-butyl ether	ND	ug/L	1.0	1		10/21/10 10:13	1634-04-4	
Toluene	**15.0**	ug/L	1.0	1		10/21/10 10:13	108-88-3	
Xylene (Total)	**1580**	ug/L	15.0	5		10/21/10 05:26	1330-20-7	
4-Bromofluorobenzene (S)	103	%	80-120	1		10/21/10 10:13	460-00-4	
Dibromofluoromethane (S)	102	%	80-122	1		10/21/10 10:13	1868-53-7	
1,2-Dichloroethane-d4 (S)	111	%	80-124	1		10/21/10 10:13	17060-07-0	
Toluene-d8 (S)	90	%	80-123	1		10/21/10 10:13	2037-26-5	

Sample: MW-5 | **Lab ID: 255347007** | Collected: 10/14/10 12:25 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
Gasoline Range Organics	**28600**	ug/L	250	5		10/19/10 19:13		

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ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255347

Sample: MW-5 | **Lab ID: 255347007** | Collected: 10/14/10 12:25 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
a,a,a-Trifluorotoluene (S)	107	%	50-150	5		10/19/10 19:13	98-08-8	
4-Bromofluorobenzene (S)	124	%	50-150	5		10/19/10 19:13	460-00-4	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Lead	ND	ug/L	10.0	1	10/20/10 08:28	10/20/10 17:09	7439-92-1	
8260 MSV	Analytical Method: EPA 5030B/8260							
Benzene	**1100**	ug/L	10.0	10		10/21/10 09:13	71-43-2	
Ethylbenzene	**2760**	ug/L	20.0	20		10/22/10 07:00	100-41-4	
Methyl-tert-butyl ether	ND	ug/L	1.0	1		10/21/10 10:33	1634-04-4	
Toluene	**72.1**	ug/L	1.0	1		10/21/10 10:33	108-88-3	
Xylene (Total)	**4890**	ug/L	60.0	20		10/22/10 07:00	1330-20-7	
4-Bromofluorobenzene (S)	99	%	80-120	1		10/21/10 10:33	460-00-4	
Dibromofluoromethane (S)	97	%	80-122	1		10/21/10 10:33	1868-53-7	
1,2-Dichloroethane-d4 (S)	111	%	80-124	1		10/21/10 10:33	17060-07-0	
Toluene-d8 (S)	92	%	80-123	1		10/21/10 10:33	2037-26-5	

Sample: MW-16 | **Lab ID: 255347008** | Collected: 10/14/10 14:20 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
Gasoline Range Organics	**180000**	ug/L	5000	100		10/20/10 19:07		
a,a,a-Trifluorotoluene (S)	87	%	50-150	100		10/20/10 19:07	98-08-8	
4-Bromofluorobenzene (S)	82	%	50-150	100		10/20/10 19:07	460-00-4	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Lead	**111**	ug/L	10.0	1	10/20/10 08:28	10/20/10 17:13	7439-92-1	
8260 MSV	Analytical Method: EPA 5030B/8260							
Benzene	**24800**	ug/L	200	200		10/22/10 06:59	71-43-2	
Ethylbenzene	**3440**	ug/L	200	200		10/22/10 06:59	100-41-4	
Methyl-tert-butyl ether	ND	ug/L	1.0	1		10/22/10 07:23	1634-04-4	
Toluene	**47400**	ug/L	200	200		10/22/10 06:59	108-88-3	
Xylene (Total)	**21200**	ug/L	600	200		10/22/10 06:59	1330-20-7	
4-Bromofluorobenzene (S)	103	%	80-120	1		10/22/10 07:23	460-00-4	
Dibromofluoromethane (S)	95	%	80-122	1		10/22/10 07:23	1868-53-7	
1,2-Dichloroethane-d4 (S)	13	%	80-124	1		10/22/10 07:23	17060-07-0	S5
Toluene-d8 (S)	43	%	80-123	1		10/22/10 07:23	2037-26-5	S5

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ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255347

Sample: Trip Blank **Lab ID: 255347009** Collected: 10/13/10 00:00 Received: 10/15/10 10:45 Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
NWTPH-Gx GCV	Analytical Method: NWTPH-Gx							
Gasoline Range Organics	ND	ug/L	50.0	1		10/19/10 13:37		
a,a,a-Trifluorotoluene (S)	102	%	50-150	1		10/19/10 13:37	98-08-8	
4-Bromofluorobenzene (S)	96	%	50-150	1		10/19/10 13:37	460-00-4	
8260 MSV	Analytical Method: EPA 5030B/8260							
Benzene	ND	ug/L	1.0	1		10/21/10 00:41	71-43-2	
Ethylbenzene	ND	ug/L	1.0	1		10/21/10 00:41	100-41-4	
Methyl-tert-butyl ether	ND	ug/L	1.0	1		10/21/10 00:41	1634-04-4	
Toluene	ND	ug/L	1.0	1		10/21/10 00:41	108-88-3	
Xylene (Total)	ND	ug/L	3.0	1		10/21/10 00:41	1330-20-7	
4-Bromofluorobenzene (S)	98	%	80-120	1		10/21/10 00:41	460-00-4	
Dibromofluoromethane (S)	101	%	80-122	1		10/21/10 00:41	1868-53-7	
1,2-Dichloroethane-d4 (S)	117	%	80-124	1		10/21/10 00:41	17060-07-0	
Toluene-d8 (S)	83	%	80-123	1		10/21/10 00:41	2037-26-5	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255347

QC Batch: GCV/1967 — Analysis Method: NWTPH-Gx
QC Batch Method: NWTPH-Gx — Analysis Description: NWTPH-Gx GCV Water
Associated Lab Samples: 255347001, 255347002, 255347003, 255347004, 255347005, 255347007, 255347009

METHOD BLANK: 46069 — Matrix: Water
Associated Lab Samples: 255347001, 255347002, 255347003, 255347004, 255347005, 255347007, 255347009

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Gasoline Range Organics	ug/L	ND	50.0	10/19/10 13:04	
4-Bromofluorobenzene (S)	%	93	50-150	10/19/10 13:04	
a,a,a-Trifluorotoluene (S)	%	99	50-150	10/19/10 13:04	

LABORATORY CONTROL SAMPLE: 46070

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Gasoline Range Organics	ug/L	250	226	90	50-163	
4-Bromofluorobenzene (S)	%			93	50-150	
a,a,a-Trifluorotoluene (S)	%			93	50-150	

SAMPLE DUPLICATE: 46255

Parameter	Units	255347001 Result	Dup Result	RPD	Qualifiers
Gasoline Range Organics	ug/L	682	964	34	R1
4-Bromofluorobenzene (S)	%	135	155	14	S5
a,a,a-Trifluorotoluene (S)	%	103	109	6	

SAMPLE DUPLICATE: 46260

Parameter	Units	255391001 Result	Dup Result	RPD	Qualifiers
Gasoline Range Organics	ug/L	66.4	288	125	1n
4-Bromofluorobenzene (S)	%	105	101	4	
a,a,a-Trifluorotoluene (S)	%	110	107	3	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255347

QC Batch: GCV/1970 — Analysis Method: NWTPH-Gx
QC Batch Method: NWTPH-Gx — Analysis Description: NWTPH-Gx GCV Water
Associated Lab Samples: 255347008

METHOD BLANK: 46276 — Matrix: Water
Associated Lab Samples: 255347008

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Gasoline Range Organics	ug/L	ND	50.0	10/20/10 14:24	
4-Bromofluorobenzene (S)	%	85	50-150	10/20/10 14:24	
a,a,a-Trifluorotoluene (S)	%	95	50-150	10/20/10 14:24	

LABORATORY CONTROL SAMPLE: 46277

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Gasoline Range Organics	ug/L	250	245	98	50-163	
4-Bromofluorobenzene (S)	%			88	50-150	
a,a,a-Trifluorotoluene (S)	%			93	50-150	

SAMPLE DUPLICATE: 46278

Parameter	Units	255346002 Result	Dup Result	RPD	Qualifiers
Gasoline Range Organics	ug/L	ND	26.5J		
4-Bromofluorobenzene (S)	%	95	77	21	
a,a,a-Trifluorotoluene (S)	%	103	87	16	

SAMPLE DUPLICATE: 46279

Parameter	Units	255346008 Result	Dup Result	RPD	Qualifiers
Gasoline Range Organics	ug/L	89.9	112	22	
4-Bromofluorobenzene (S)	%	87	83	5	
a,a,a-Trifluorotoluene (S)	%	98	89	10	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255347

QC Batch: GCV/1973 | Analysis Method: NWTPH-Gx
QC Batch Method: NWTPH-Gx | Analysis Description: NWTPH-Gx GCV Water
Associated Lab Samples: 255347006

METHOD BLANK: 46537 | Matrix: Water
Associated Lab Samples: 255347006

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Gasoline Range Organics	ug/L	ND	50.0	10/22/10 12:05	
4-Bromofluorobenzene (S)	%	91	50-150	10/22/10 12:05	
a,a,a-Trifluorotoluene (S)	%	100	50-150	10/22/10 12:05	

LABORATORY CONTROL SAMPLE: 46538

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Gasoline Range Organics	ug/L	250	244	98	50-163	
4-Bromofluorobenzene (S)	%			97	50-150	
a,a,a-Trifluorotoluene (S)	%			102	50-150	

SAMPLE DUPLICATE: 46648

Parameter	Units	255405003 Result	Dup Result	RPD	Qualifiers
Gasoline Range Organics	ug/L	874	849	3	
4-Bromofluorobenzene (S)	%	104	96	9	
a,a,a-Trifluorotoluene (S)	%	103	98	6	

SAMPLE DUPLICATE: 46649

Parameter	Units	255395001 Result	Dup Result	RPD	Qualifiers
Gasoline Range Organics	ug/L	83.5	77.5	7	
4-Bromofluorobenzene (S)	%	81	102	22	
a,a,a-Trifluorotoluene (S)	%	88	105	18	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255347

QC Batch: MPRP/1841 | Analysis Method: EPA 6010
QC Batch Method: EPA 3010 | Analysis Description: 6010 MET
Associated Lab Samples: 255347001, 255347002, 255347003, 255347004, 255347006, 255347007, 255347008

METHOD BLANK: 46191 | Matrix: Water
Associated Lab Samples: 255347001, 255347002, 255347003, 255347004, 255347006, 255347007, 255347008

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Lead	ug/L	ND	10.0	10/20/10 16:48	

LABORATORY CONTROL SAMPLE: 46192

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Lead	ug/L	500	513	103	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 46193 46194

Parameter	Units	255334025 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Qual
Lead	ug/L	414	500	500	885	876	94	92	75-125	1	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255347

QC Batch: MSV/3300 | Analysis Method: EPA 5030B/8260
QC Batch Method: EPA 5030B/8260 | Analysis Description: 8260 MSV Water 10 mL Purge
Associated Lab Samples: 255347001, 255347002, 255347003, 255347004, 255347005, 255347006, 255347007, 255347009

METHOD BLANK: 46346 Matrix: Water
Associated Lab Samples: 255347001, 255347002, 255347003, 255347004, 255347005, 255347006, 255347007, 255347009

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Benzene	ug/L	ND	1.0	10/21/10 00:21	
Ethylbenzene	ug/L	ND	1.0	10/21/10 00:21	
Methyl-tert-butyl ether	ug/L	ND	1.0	10/21/10 00:21	
Toluene	ug/L	ND	1.0	10/21/10 00:21	
Xylene (Total)	ug/L	ND	3.0	10/21/10 00:21	
1,2-Dichloroethane-d4 (S)	%	118	80-124	10/21/10 00:21	
4-Bromofluorobenzene (S)	%	96	80-120	10/21/10 00:21	
Dibromofluoromethane (S)	%	104	80-122	10/21/10 00:21	
Toluene-d8 (S)	%	82	80-123	10/21/10 00:21	

LABORATORY CONTROL SAMPLE & LCSD: 46347 46348

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
Benzene	ug/L	20	19.3	18.7	96	93	76-127	3	30	
Ethylbenzene	ug/L	20	18.9	17.8	95	89	72-125	6	30	
Methyl-tert-butyl ether	ug/L	20	23.1	22.3	116	112	58-145	4	30	
Toluene	ug/L	20	17.3	16.7	87	83	69-125	4	30	
Xylene (Total)	ug/L	60	56.1	53.5	93	89	74-124	5	30	
1,2-Dichloroethane-d4 (S)	%				113	115	80-124			
4-Bromofluorobenzene (S)	%				95	97	80-120			
Dibromofluoromethane (S)	%				105	104	80-122			
Toluene-d8 (S)	%				87	86	80-123			

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255347

QC Batch: MSV/3306 Analysis Method: EPA 5030B/8260
QC Batch Method: EPA 5030B/8260 Analysis Description: 8260 MSV Water 10 mL Purge
Associated Lab Samples: 255347008

METHOD BLANK: 46421 Matrix: Water
Associated Lab Samples: 255347008

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Benzene	ug/L	ND	1.0	10/21/10 23:12	
Ethylbenzene	ug/L	ND	1.0	10/21/10 23:12	
Methyl-tert-butyl ether	ug/L	ND	1.0	10/21/10 23:12	
Toluene	ug/L	ND	1.0	10/21/10 23:12	
Xylene (Total)	ug/L	ND	3.0	10/21/10 23:12	
1,2-Dichloroethane-d4 (S)	%	93	80-124	10/21/10 23:12	
4-Bromofluorobenzene (S)	%	105	80-120	10/21/10 23:12	
Dibromofluoromethane (S)	%	97	80-122	10/21/10 23:12	
Toluene-d8 (S)	%	102	80-123	10/21/10 23:12	

LABORATORY CONTROL SAMPLE & LCSD: 46422 46497

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
Benzene	ug/L	20	19.2	18.0	96	90	76-127	6	30	
Ethylbenzene	ug/L	20	17.8	16.9	89	84	72-125	5	30	
Methyl-tert-butyl ether	ug/L	20	20.1	18.8	100	94	58-145	7	30	
Toluene	ug/L	20	17.5	16.7	88	83	69-125	5	30	
Xylene (Total)	ug/L	60	53.1	50.7	88	85	74-124	4	30	
1,2-Dichloroethane-d4 (S)	%				93	91	80-124			
4-Bromofluorobenzene (S)	%				106	105	80-120			
Dibromofluoromethane (S)	%				101	100	80-122			
Toluene-d8 (S)	%				100	102	80-123			

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QUALIFIERS

Project: WA-0977
Pace Project No.: 255347

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to changes in sample preparation, dilution of the sample aliquot, or moisture content.

ND - Not Detected at or above adjusted reporting limit.

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

S - Surrogate

1,2-Diphenylhydrazine (8270 listed analyte) decomposes to Azobenzene.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is NELAP accredited. Contact your Pace PM for the current list of accredited analytes.

LABORATORIES

PASI-S	Pace Analytical Services - Seattle

ANALYTE QUALIFIERS

1n	RPD value was outside control limits due to carryover from previously analyzed sample.
R1	RPD value was outside control limits.
S5	Surrogate recovery outside control limits due to matrix interferences (not confirmed by re-analysis).

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QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: WA-0977
Pace Project No.: 255347

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
255347001	**MW-12**	NWTPH-Gx	GCV/1967		
255347002	**MW-11**	NWTPH-Gx	GCV/1967		
255347003	**MW-1**	NWTPH-Gx	GCV/1967		
255347004	**MW-GW-1**	NWTPH-Gx	GCV/1967		
255347005	**Dup-1**	NWTPH-Gx	GCV/1967		
255347006	**MW-6**	NWTPH-Gx	GCV/1973		
255347007	**MW-5**	NWTPH-Gx	GCV/1967		
255347008	**MW-16**	NWTPH-Gx	GCV/1970		
255347009	**Trip Blank**	NWTPH-Gx	GCV/1967		
255347001	**MW-12**	EPA 3010	MPRP/1841	EPA 6010	ICP/1754
255347002	**MW-11**	EPA 3010	MPRP/1841	EPA 6010	ICP/1754
255347003	**MW-1**	EPA 3010	MPRP/1841	EPA 6010	ICP/1754
255347004	**MW-GW-1**	EPA 3010	MPRP/1841	EPA 6010	ICP/1754
255347006	**MW-6**	EPA 3010	MPRP/1841	EPA 6010	ICP/1754
255347007	**MW-5**	EPA 3010	MPRP/1841	EPA 6010	ICP/1754
255347008	**MW-16**	EPA 3010	MPRP/1841	EPA 6010	ICP/1754
255347001	**MW-12**	EPA 5030B/8260	MSV/3300		
255347002	**MW-11**	EPA 5030B/8260	MSV/3300		
255347003	**MW-1**	EPA 5030B/8260	MSV/3300		
255347004	**MW-GW-1**	EPA 5030B/8260	MSV/3300		
255347005	**Dup-1**	EPA 5030B/8260	MSV/3300		
255347006	**MW-6**	EPA 5030B/8260	MSV/3300		
255347007	**MW-5**	EPA 5030B/8260	MSV/3300		
255347008	**MW-16**	EPA 5030B/8260	MSV/3306		
255347009	**Trip Blank**	EPA 5030B/8260	MSV/3300		

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(206)767-5060

November 02, 2010

Scott Zorn
Arcadis U.S., Inc.
2300 Eastlake Ave E. Ste. 200
Seattle, WA 98102

RE: Project: WA-0977
Pace Project No.: 255348

Dear Scott Zorn:

Enclosed are the analytical results for sample(s) received by the laboratory on October 15, 2010. The results relate only to the samples included in this report. Results reported herein conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

Sample 001 has a Dissolved Mn result higher than the Total Mn result. The lab re-analyzed the sample on 11/02/10 and obtained confirming results.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Regina Ste. Marie

Regina SteMarie

regina.stemarie@pacelabs.com
Project Manager

Enclosures

cc: David Rasar, Arcadis U.S., Inc.

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

CERTIFICATIONS

Project: WA-0977
Pace Project No.: 255348

Minnesota Certification IDs

1700 Elm Street SE Suite 200, Minneapolis, MN 55414
Alaska Certification #: UST-078
Alaska Certification #MN00064
Arizona Certification #: AZ-0014
Arkansas Certification #: 88-0680
California Certification #: 01155CA
EPA Region 8 Certification #: Pace
Florida/NELAP Certification #: E87605
Georgia Certification #: 959
Idaho Certification #: MN00064
Illinois Certification #: 200011
Iowa Certification #: 368
Kansas Certification #: E-10167
Louisiana Certification #: 03086
Louisiana Certification #: LA080009
Maine Certification #: 2007029
Maryland Certification #: 322
Michigan DEQ Certification #: 9909
Minnesota Certification #: 027-053-137
Mississippi Certification #: Pace
Montana Certification #: MT CERT0092
Nevada Certification #: MN_00064
Nebraska Certification #: Pace
New Jersey Certification #: MN-002
New Mexico Certification #: Pace
New York Certification #: 11647
North Carolina Certification #: 530
North Dakota Certification #: R-036
North Dakota Certification #: R-036A
Ohio VAP Certification #: CL101
Oklahoma Certification #: D9921
Oklahoma Certification #: 9507
Oregon Certification #: MN200001
Pennsylvania Certification #: 68-00563
Puerto Rico Certification
Tennessee Certification #: 02818
Texas Certification #: T104704192
Washington Certification #: C754
Wisconsin Certification #: 999407970

Washington Certification IDs

940 South Harney Street, Seattle, WA 98108
Alaska CS Certification #: UST-025
Alaska Drinking Water VOC Certification #: WA01230
Alaska Drinking Water Micro Certification #: WA01230
California Certification #: 01153CA
Florida/NELAP Certification #: E87617
Oregon Certification #: WA200007
Washington Certification #: C1229

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SAMPLE ANALYTE COUNT

Project: WA-0977
Pace Project No.: 255348

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
255348001	**MW-12**	RSK 175	SK3	1	PASI-M
		EPA 6010	BGA	2	PASI-S
		EPA 6010	BGA	2	PASI-S
		SM 2320B	BPR	1	PASI-S
		EPA 300.0	CMS	1	PASI-S
		EPA 353.2	CMS	1	PASI-S
		SM 5310C	KMT	1	PASI-S
255348002	**MW-11**	RSK 175	SK3	1	PASI-M
		EPA 6010	BGA	2	PASI-S
		EPA 6010	BGA	2	PASI-S
		SM 2320B	BPR	1	PASI-S
		EPA 300.0	CMS	1	PASI-S
		EPA 353.2	CMS	1	PASI-S
		SM 5310C	KMT	1	PASI-S
255348003	**MW-1**	RSK 175	SK3	1	PASI-M
		EPA 6010	BGA	2	PASI-S
		EPA 6010	BGA	2	PASI-S
		SM 2320B	BPR	1	PASI-S
		EPA 300.0	CMS	1	PASI-S
		EPA 353.2	CMS	1	PASI-S
		SM 5310C	KMT	1	PASI-S
255348004	**MW-6**	RSK 175	SK3	1	PASI-M
		EPA 6010	BGA	2	PASI-S
		EPA 6010	BGA	2	PASI-S
		SM 2320B	BPR	1	PASI-S
		EPA 300.0	CMS	1	PASI-S
		EPA 353.2	CMS	1	PASI-S
		SM 5310C	KMT	1	PASI-S
255348005	**MW-5**	RSK 175	SK3	1	PASI-M
		EPA 6010	BGA	2	PASI-S
		EPA 6010	BGA	2	PASI-S
		SM 2320B	BPR	1	PASI-S
		EPA 300.0	CMS	1	PASI-S
		EPA 353.2	CMS	1	PASI-S
		SM 5310C	KMT	1	PASI-S
255348006	**MW-16**	RSK 175	SK3	1	PASI-M
		EPA 6010	BGA	2	PASI-S

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SAMPLE ANALYTE COUNT

Project: WA-0977
Pace Project No.: 255348

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
		EPA 6010	BGA	2	PASI-S
		SM 2320B	BPR	1	PASI-S
		EPA 300.0	CMS	1	PASI-S
		EPA 353.2	CMS	1	PASI-S
		SM 5310C	KMT	1	PASI-S
255348007	**MW-4**	RSK 175	SK3	1	PASI-M
		EPA 6010	BGA	2	PASI-S
		EPA 6010	BGA	2	PASI-S
		SM 2320B	BPR	1	PASI-S
		EPA 300.0	CMS	1	PASI-S
		EPA 353.2	CMS	1	PASI-S
		SM 5310C	KMT	1	PASI-S

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PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255348

Method: **RSK 175**
Description: RSK 175 AIR Headspace
Client: Arcadis U.S., Inc.
Date: November 02, 2010

General Information:
7 samples were analyzed for RSK 175. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Internal Standards:
All internal standards were within QC limits with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project:	WA-0977
Pace Project No.:	255348

Method: **EPA 6010**
Description: 6010 MET ICP
Client: Arcadis U.S., Inc.
Date: November 02, 2010

General Information:
7 samples were analyzed for EPA 6010. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Sample Preparation:
The samples were prepared in accordance with EPA 3010 with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255348

Method: **EPA 6010**
Description: 6010 MET ICP, Dissolved (LF)
Client: Arcadis U.S., Inc.
Date: November 02, 2010

General Information:
7 samples were analyzed for EPA 6010. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Sample Preparation:
The samples were prepared in accordance with EPA 3010 with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255348

Method: **SM 2320B**
Description: 2320B Alkalinity
Client: Arcadis U.S., Inc.
Date: November 02, 2010

General Information:
7 samples were analyzed for SM 2320B. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255348

Method: **EPA 300.0**
Description: 300.0 IC Anions 28 Days
Client: Arcadis U.S., Inc.
Date: November 02, 2010

General Information:
7 samples were analyzed for EPA 300.0. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

QC Batch: WETA/1753

A matrix spike and matrix spike duplicate (MS/MSD) were performed on the following sample(s): 255348001,255404001

M1: Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.

- MS (Lab ID: 46904)
  - Sulfate
- MSD (Lab ID: 46905)
  - Sulfate

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255348

Method: **EPA 353.2**
Description: 353.2 Nitrogen, NO2/NO3 pres.
Client: Arcadis U.S., Inc.
Date: November 02, 2010

General Information:
7 samples were analyzed for EPA 353.2. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project: WA-0977
Pace Project No.: 255348

Method: **SM 5310C**
Description: 5310C TOC
Client: Arcadis U.S., Inc.
Date: November 02, 2010

General Information:
7 samples were analyzed for SM 5310C. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

This data package has been reviewed for quality and completeness and is approved for release.

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ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255348

Sample: MW-12 **Lab ID: 255348001** Collected: 10/13/10 11:55 Received: 10/15/10 10:45 Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
RSK 175 AIR Headspace	Analytical Method: RSK 175							
Methane	**96.0**	ug/L	10.0	1		10/20/10 09:56	74-82-8	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron	**440**	ug/L	100	1	10/21/10 08:15	10/21/10 13:19	7439-89-6	
Manganese	**724**	ug/L	15.0	1	10/21/10 08:15	10/21/10 13:19	7439-96-5	
6010 MET ICP, Dissolved (LF)	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron, Dissolved	ND	ug/L	100	1	10/21/10 08:15	10/21/10 14:15	7439-89-6	
Manganese, Dissolved	**880**	ug/L	15.0	1	10/21/10 08:15	10/21/10 14:15	7439-96-5	
2320B Alkalinity	Analytical Method: SM 2320B							
Alkalinity, Total as CaCO3	**195**	mg/L	2.0	1		10/20/10 19:00		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0							
Sulfate	**24.4**	mg/L	5.0	5		10/27/10 11:38	14808-79-8	
353.2 Nitrogen, NO2/NO3 pres.	Analytical Method: EPA 353.2							
Nitrogen, NO2 plus NO3	**2.0**	mg/L	0.050	1		10/27/10 13:49		
5310C TOC	Analytical Method: SM 5310C							
Total Organic Carbon	**4.1**	mg/L	1.0	1		10/28/10 12:30	7440-44-0	

Sample: MW-11 **Lab ID: 255348002** Collected: 10/13/10 13:25 Received: 10/15/10 10:45 Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
RSK 175 AIR Headspace	Analytical Method: RSK 175							
Methane	ND	ug/L	10.0	1		10/20/10 10:22	74-82-8	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron	**297**	ug/L	100	1	10/21/10 08:15	10/21/10 13:28	7439-89-6	
Manganese	**21.4**	ug/L	15.0	1	10/21/10 08:15	10/21/10 13:28	7439-96-5	
6010 MET ICP, Dissolved (LF)	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron, Dissolved	ND	ug/L	100	1	10/21/10 08:15	10/21/10 14:30	7439-89-6	
Manganese, Dissolved	ND	ug/L	15.0	1	10/21/10 08:15	10/21/10 14:30	7439-96-5	
2320B Alkalinity	Analytical Method: SM 2320B							
Alkalinity, Total as CaCO3	**100**	mg/L	2.0	1		10/20/10 19:00		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0							
Sulfate	**20.4**	mg/L	2.0	2		10/27/10 12:30	14808-79-8	

ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255348

Sample: MW-11 | **Lab ID: 255348002** | Collected: 10/13/10 13:25 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
353.2 Nitrogen, NO2/NO3 pres.	Analytical Method: EPA 353.2							
Nitrogen, NO2 plus NO3	**9.1**	mg/L	0.25	5		10/27/10 14:26		
5310C TOC	Analytical Method: SM 5310C							
Total Organic Carbon	**1.3**	mg/L	1.0	1		10/28/10 12:30	7440-44-0	

Sample: MW-1 | **Lab ID: 255348003** | Collected: 10/13/10 14:30 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
RSK 175 AIR Headspace	Analytical Method: RSK 175							
Methane	ND	ug/L	10.0	1		10/20/10 10:47	74-82-8	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron	ND	ug/L	100	1	10/21/10 08:15	10/21/10 13:31	7439-89-6	
Manganese	**1570**	ug/L	15.0	1	10/21/10 08:15	10/21/10 13:31	7439-96-5	
6010 MET ICP, Dissolved (LF)	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron, Dissolved	ND	ug/L	100	1	10/21/10 08:15	10/21/10 14:33	7439-89-6	
Manganese, Dissolved	**1410**	ug/L	15.0	1	10/21/10 08:15	10/21/10 14:33	7439-96-5	
2320B Alkalinity	Analytical Method: SM 2320B							
Alkalinity, Total as CaCO3	**276**	mg/L	2.0	1		10/20/10 19:00		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0							
Sulfate	**6.4**	mg/L	1.0	1		10/27/10 12:47	14808-79-8	
353.2 Nitrogen, NO2/NO3 pres.	Analytical Method: EPA 353.2							
Nitrogen, NO2 plus NO3	**0.13**	mg/L	0.050	1		10/27/10 13:55		
5310C TOC	Analytical Method: SM 5310C							
Total Organic Carbon	**1.8**	mg/L	1.0	1		10/28/10 12:30	7440-44-0	

Sample: MW-6 | **Lab ID: 255348004** | Collected: 10/14/10 11:20 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
RSK 175 AIR Headspace	Analytical Method: RSK 175							
Methane	**621**	ug/L	10.0	1		10/20/10 11:13	74-82-8	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron	**3410**	ug/L	100	1	10/21/10 08:15	10/21/10 13:34	7439-89-6	
Manganese	**2820**	ug/L	15.0	1	10/21/10 08:15	10/21/10 13:34	7439-96-5	

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ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255348

Sample: MW-6 | **Lab ID: 255348004** | Collected: 10/14/10 11:20 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP, Dissolved (LF)	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron, Dissolved	**837**	ug/L	100	1	10/21/10 08:15	10/21/10 14:36	7439-89-6	
Manganese, Dissolved	**2650**	ug/L	15.0	1	10/21/10 08:15	10/21/10 14:36	7439-96-5	
2320B Alkalinity	Analytical Method: SM 2320B							
Alkalinity, Total as CaCO3	**191**	mg/L	2.0	1		10/20/10 19:00		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0							
Sulfate	**5.4**	mg/L	1.0	1		10/27/10 13:04	14808-79-8	
353.2 Nitrogen, NO2/NO3 pres.	Analytical Method: EPA 353.2							
Nitrogen, NO2 plus NO3	ND	mg/L	0.050	1		10/27/10 13:56		
5310C TOC	Analytical Method: SM 5310C							
Total Organic Carbon	**2.8**	mg/L	1.0	1		10/28/10 12:30	7440-44-0	

Sample: MW-5 | **Lab ID: 255348005** | Collected: 10/14/10 12:25 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
RSK 175 AIR Headspace	Analytical Method: RSK 175							
Methane	**9110**	ug/L	10.0	1		10/20/10 11:38	74-82-8	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron	**2410**	ug/L	100	1	10/21/10 08:15	10/21/10 13:37	7439-89-6	
Manganese	**6170**	ug/L	15.0	1	10/21/10 08:15	10/21/10 13:37	7439-96-5	
6010 MET ICP, Dissolved (LF)	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron, Dissolved	**178**	ug/L	100	1	10/21/10 08:15	10/21/10 14:39	7439-89-6	
Manganese, Dissolved	**5910**	ug/L	15.0	1	10/21/10 08:15	10/21/10 14:39	7439-96-5	
2320B Alkalinity	Analytical Method: SM 2320B							
Alkalinity, Total as CaCO3	**393**	mg/L	2.0	1		10/20/10 19:00		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0							
Sulfate	**1.2**	mg/L	1.0	1		10/27/10 13:22	14808-79-8	
353.2 Nitrogen, NO2/NO3 pres.	Analytical Method: EPA 353.2							
Nitrogen, NO2 plus NO3	**0.18**	mg/L	0.050	1		10/27/10 13:58		
5310C TOC	Analytical Method: SM 5310C							
Total Organic Carbon	**9.3**	mg/L	1.0	1		10/28/10 12:30	7440-44-0	

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ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255348

Sample: MW-16 | **Lab ID: 255348006** | Collected: 10/14/10 14:20 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
RSK 175 AIR Headspace	Analytical Method: RSK 175							
Methane	**42.7**	ug/L	10.0	1		10/20/10 12:04	74-82-8	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron	**625**	ug/L	100	1	10/21/10 08:15	10/21/10 13:40	7439-89-6	
Manganese	**6540**	ug/L	15.0	1	10/21/10 08:15	10/21/10 13:40	7439-96-5	
6010 MET ICP, Dissolved (LF)	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron, Dissolved	ND	ug/L	100	1	10/21/10 08:15	10/21/10 14:42	7439-89-6	
Manganese, Dissolved	**6250**	ug/L	15.0	1	10/21/10 08:15	10/21/10 14:42	7439-96-5	
2320B Alkalinity	Analytical Method: SM 2320B							
Alkalinity, Total as CaCO3	**598**	mg/L	2.0	1		10/20/10 19:00		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0							
Sulfate	**2.2**	mg/L	1.0	1		10/27/10 13:39	14808-79-8	
353.2 Nitrogen, NO2/NO3 pres.	Analytical Method: EPA 353.2							
Nitrogen, NO2 plus NO3	**0.080**	mg/L	0.050	1		10/27/10 14:04		
5310C TOC	Analytical Method: SM 5310C							
Total Organic Carbon	**30.6**	mg/L	2.0	1		10/29/10 11:55	7440-44-0	

Sample: MW-4 | **Lab ID: 255348007** | Collected: 10/14/10 15:10 | Received: 10/15/10 10:45 | Matrix: Water

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
RSK 175 AIR Headspace	Analytical Method: RSK 175							
Methane	ND	ug/L	10.0	1		10/20/10 12:29	74-82-8	
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron	**133**	ug/L	100	1	10/21/10 08:15	10/21/10 13:50	7439-89-6	
Manganese	ND	ug/L	15.0	1	10/21/10 08:15	10/21/10 13:50	7439-96-5	
6010 MET ICP, Dissolved (LF)	Analytical Method: EPA 6010 Preparation Method: EPA 3010							
Iron, Dissolved	ND	ug/L	100	1	10/21/10 08:15	10/21/10 14:45	7439-89-6	
Manganese, Dissolved	ND	ug/L	15.0	1	10/21/10 08:15	10/21/10 14:45	7439-96-5	
2320B Alkalinity	Analytical Method: SM 2320B							
Alkalinity, Total as CaCO3	**73.3**	mg/L	2.0	1		10/20/10 19:00		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0							
Sulfate	**15.7**	mg/L	1.0	1		10/26/10 20:41	14808-79-8	

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ANALYTICAL RESULTS

Project: WA-0977
Pace Project No.: 255348

Sample: MW-4	Lab ID: 255348007		Collected: 10/14/10 15:10		Received: 10/15/10 10:45		Matrix: Water	
Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
353.2 Nitrogen, NO2/NO3 pres.	Analytical Method: EPA 353.2							
Nitrogen, NO2 plus NO3	**5.5**	mg/L	0.25	5		10/27/10 14:28		
5310C TOC	Analytical Method: SM 5310C							
Total Organic Carbon	**1.4**	mg/L	1.0	1		10/28/10 12:30	7440-44-0	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255348

QC Batch: AIR/11092 Analysis Method: RSK 175
QC Batch Method: RSK 175 Analysis Description: RSK 175 AIR HEADSPACE
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

METHOD BLANK: 874477 Matrix: Water
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Methane	ug/L	ND	10.0	10/20/10 09:31	

LABORATORY CONTROL SAMPLE & LCSD: 874478 874479

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
Methane	ug/L	60.7	60.4	50.6	100	83	70-130	18	30	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255348

QC Batch: MPRP/1846 | Analysis Method: EPA 6010
QC Batch Method: EPA 3010 | Analysis Description: 6010 MET
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

METHOD BLANK: 46360 Matrix: Water
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Iron	ug/L	ND	100	10/21/10 13:13	
Manganese	ug/L	ND	15.0	10/21/10 13:13	

LABORATORY CONTROL SAMPLE: 46361

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Iron	ug/L	10000	9600	96	80-120	
Manganese	ug/L	500	469	94	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 46362 46363

Parameter	Units	255348001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Qual
Iron	ug/L	440	10000	10000	9890	10200	95	98	75-125	3	
Manganese	ug/L	724	500	500	1160	1180	87	91	75-125	2	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255348

QC Batch: MPRP/1847 Analysis Method: EPA 6010
QC Batch Method: EPA 3010 Analysis Description: 6010 MET Dissolved
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

METHOD BLANK: 46364 Matrix: Water
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Iron, Dissolved	ug/L	ND	100	10/21/10 14:08	
Manganese, Dissolved	ug/L	ND	15.0	10/21/10 14:08	

LABORATORY CONTROL SAMPLE: 46365

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Iron, Dissolved	ug/L	10000	8900	89	80-120	
Manganese, Dissolved	ug/L	500	454	91	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 46366 46367

Parameter	Units	255348001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Qual
Iron, Dissolved	ug/L	ND	10000	10000	9510	8830	94	88	75-125	7	
Manganese, Dissolved	ug/L	880	500	500	1340	1270	92	79	75-125	5	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255348

QC Batch: WET/2356 Analysis Method: SM 2320B
QC Batch Method: SM 2320B Analysis Description: 2320B Alkalinity
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

METHOD BLANK: 46238 Matrix: Water
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Alkalinity, Total as CaCO3	mg/L	ND	2.0	10/20/10 19:00	

LABORATORY CONTROL SAMPLE: 46239

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Alkalinity, Total as CaCO3	mg/L	100	96.1	96	90-110	

SAMPLE DUPLICATE: 46240

Parameter	Units	255348001 Result	Dup Result	RPD	Qualifiers
Alkalinity, Total as CaCO3	mg/L	195	199	2	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255348

QC Batch: WETA/1753 Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0 Analysis Description: 300.0 IC Anions
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

METHOD BLANK: 46902 Matrix: Water
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Sulfate	mg/L	ND	1.0	10/26/10 18:05	

LABORATORY CONTROL SAMPLE: 46903

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Sulfate	mg/L	15	15.5	103	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 46904 46905

Parameter	Units	255348001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Qual
Sulfate	mg/L	24.4	75	75	125	126	133	136	90-110	1	M1

MATRIX SPIKE SAMPLE: 46906

Parameter	Units	255404001 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Sulfate	mg/L	40.5	75	116	101	90-110	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255348

QC Batch: WETA/1752 | Analysis Method: EPA 353.2
QC Batch Method: EPA 353.2 | Analysis Description: 353.2 Nitrate + Nitrite, preserved
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

METHOD BLANK: 46896 Matrix: Water
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348006, 255348007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Nitrogen, NO2 plus NO3	mg/L	ND	0.050	10/27/10 13:44	

LABORATORY CONTROL SAMPLE: 46897

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Nitrogen, NO2 plus NO3	mg/L	1	0.97	97	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 46898 46899

Parameter	Units	255348001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Qual
Nitrogen, NO2 plus NO3	mg/L	2.0	1	1	3.0	3.1	101	102	90-110	.4	

MATRIX SPIKE SAMPLE: 46900

Parameter	Units	255435001 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Nitrogen, NO2 plus NO3	mg/L	0.039J	1	1.1	104	90-110	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255348

QC Batch: WETA/1751 Analysis Method: SM 5310C
QC Batch Method: SM 5310C Analysis Description: 5310C Total Organic Carbon
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348007

METHOD BLANK: 46802 Matrix: Water
Associated Lab Samples: 255348001, 255348002, 255348003, 255348004, 255348005, 255348007

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Total Organic Carbon	mg/L	ND	1.0	10/28/10 12:30	

LABORATORY CONTROL SAMPLE & LCSD: 46803 46806

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
Total Organic Carbon	mg/L	10	10.6	10.8	106	108	90-110	2	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 46804 46805

Parameter	Units	255348002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Qual
Total Organic Carbon	mg/L	1.3	10	10	11.7	11.7	104	105	70-119	.2	

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QUALITY CONTROL DATA

Project: WA-0977
Pace Project No.: 255348

QC Batch: WETA/1762 Analysis Method: SM 5310C
QC Batch Method: SM 5310C Analysis Description: 5310C Total Organic Carbon
Associated Lab Samples: 255348006

METHOD BLANK: 47385 Matrix: Water
Associated Lab Samples: 255348006

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Total Organic Carbon	mg/L	ND	1.0	10/29/10 11:55	

LABORATORY CONTROL SAMPLE & LCSD: 47386 47387

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
Total Organic Carbon	mg/L	10	10.2	9.8	102	98	90-110	4	20	

MATRIX SPIKE SAMPLE: 47388

Parameter	Units	255473005 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Total Organic Carbon	mg/L	3.5	10	12.9	93	70-119	

MATRIX SPIKE SAMPLE: 47389

Parameter	Units	255498001 Result	Spike Conc.	MS Result	MS % Rec	% Rec Limits	Qualifiers
Total Organic Carbon	mg/L	4.6	10	14.1	95	70-119	

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QUALIFIERS

Project: WA-0977
Pace Project No.: 255348

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to changes in sample preparation, dilution of the sample aliquot, or moisture content.

ND - Not Detected at or above adjusted reporting limit.

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

S - Surrogate

1,2-Diphenylhydrazine (8270 listed analyte) decomposes to Azobenzene.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

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LABORATORIES

PASI-M	Pace Analytical Services - Minneapolis
PASI-S	Pace Analytical Services - Seattle

ANALYTE QUALIFIERS

M1	Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.

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QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: WA-0977
Pace Project No.: 255348

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
255348001	**MW-12**	RSK 175	AIR/11092		
255348002	**MW-11**	RSK 175	AIR/11092		
255348003	**MW-1**	RSK 175	AIR/11092		
255348004	**MW-6**	RSK 175	AIR/11092		
255348005	**MW-5**	RSK 175	AIR/11092		
255348006	**MW-16**	RSK 175	AIR/11092		
255348007	**MW-4**	RSK 175	AIR/11092		
255348001	**MW-12**	EPA 3010	MPRP/1846	EPA 6010	ICP/1757
255348002	**MW-11**	EPA 3010	MPRP/1846	EPA 6010	ICP/1757
255348003	**MW-1**	EPA 3010	MPRP/1846	EPA 6010	ICP/1757
255348004	**MW-6**	EPA 3010	MPRP/1846	EPA 6010	ICP/1757
255348005	**MW-5**	EPA 3010	MPRP/1846	EPA 6010	ICP/1757
255348006	**MW-16**	EPA 3010	MPRP/1846	EPA 6010	ICP/1757
255348007	**MW-4**	EPA 3010	MPRP/1846	EPA 6010	ICP/1757
255348001	**MW-12**	EPA 3010	MPRP/1847	EPA 6010	ICP/1758
255348002	**MW-11**	EPA 3010	MPRP/1847	EPA 6010	ICP/1758
255348003	**MW-1**	EPA 3010	MPRP/1847	EPA 6010	ICP/1758
255348004	**MW-6**	EPA 3010	MPRP/1847	EPA 6010	ICP/1758
255348005	**MW-5**	EPA 3010	MPRP/1847	EPA 6010	ICP/1758
255348006	**MW-16**	EPA 3010	MPRP/1847	EPA 6010	ICP/1758
255348007	**MW-4**	EPA 3010	MPRP/1847	EPA 6010	ICP/1758
255348001	**MW-12**	SM 2320B	WET/2356		
255348002	**MW-11**	SM 2320B	WET/2356		
255348003	**MW-1**	SM 2320B	WET/2356		
255348004	**MW-6**	SM 2320B	WET/2356		
255348005	**MW-5**	SM 2320B	WET/2356		
255348006	**MW-16**	SM 2320B	WET/2356		
255348007	**MW-4**	SM 2320B	WET/2356		
255348001	**MW-12**	EPA 300.0	WETA/1753		
255348002	**MW-11**	EPA 300.0	WETA/1753		
255348003	**MW-1**	EPA 300.0	WETA/1753		
255348004	**MW-6**	EPA 300.0	WETA/1753		
255348005	**MW-5**	EPA 300.0	WETA/1753		
255348006	**MW-16**	EPA 300.0	WETA/1753		
255348007	**MW-4**	EPA 300.0	WETA/1753		
255348001	**MW-12**	EPA 353.2	WETA/1752		
255348002	**MW-11**	EPA 353.2	WETA/1752		
255348003	**MW-1**	EPA 353.2	WETA/1752		
255348004	**MW-6**	EPA 353.2	WETA/1752		
255348005	**MW-5**	EPA 353.2	WETA/1752		
255348006	**MW-16**	EPA 353.2	WETA/1752		
255348007	**MW-4**	EPA 353.2	WETA/1752		
255348001	**MW-12**	SM 5310C	WETA/1751		
255348002	**MW-11**	SM 5310C	WETA/1751		
255348003	**MW-1**	SM 5310C	WETA/1751		
255348004	**MW-6**	SM 5310C	WETA/1751		

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: WA-0977
Pace Project No.: 255348

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
255348005	**MW-5**	SM 5310C	WETA/1751		
255348006	**MW-16**	SM 5310C	WETA/1762		
255348007	**MW-4**	SM 5310C	WETA/1751		

2930 Westlake Ave N Suite 100
Seattle, WA 98109
T: (206) 352-3790
F: (206) 352-7178
info@fremontanalytical.com

Pace Analytical
Attn: Regina SteMarie
940 South Harney
Seattle, WA 98108

RE: WA-0977
Project ID: CHM101019-2
Work Order: 255348

October 22nd, 2010

Regina:

Enclosed are the analytical results for the ***WA-0977*** water samples delivered to Fremont Analytical on October 19th, 2010.

Sample Receipt:
The sample was received in good condition - in the proper containers (7 – 500mL Poly preserved with Zn Acetate and NaOH), properly sealed, labeled and within holding time. The samples were received in a cooler with wet ice, with a cooler temperature of 4.4°C, which is within the laboratory recommended cooler temperature range (<4°C - 10°C). The sample was stored in a refrigeration unit at the USEPA-recommended temperature of 4°C ± 2°C. There were no sample receipt issues to report.

Sample Analysis:
Examination of these samples was conducted for the presence of the following:

- ***Sulfide by SM 4500-*** S^{2-}***F***

This application was performed under Washington State Department of Ecology accreditation parameters. All appropriate Quality Assurance / Quality Control method parameters have been applied. There were no sample analysis issues to report.

Please contact the laboratory if you should have any questions about the report.

Thank you for using Fremont Analytical.

Sincerely,

M Clements

Michelle Clements
Lab Manager / Sr. Chemist

mclements@fremontanalytical.com

2930 Westlake Ave. N., Suite 100
Seattle, WA 98109

T: 206.352.3790
F: 206.352.7178
email: info@fremontanalytical.com

Analysis of Sulfide by SM 4500-S^{2-}F

Project: WA-0977
Client: Pace Analytical
Client Project #: 255348
Lab Project #: CHM101019-2

SM 4500- S^{2-}F (mg/L)	MRL	Method Blank	LCS	MW-12	MW-11	MW-1
Date Analyzed		10/19/10	10/19/10	10/19/10	10/19/10	10/19/10
Matrix				Water	Water	Water
Date Collected						
Sulfide	0.5	nd	110%	nd	nd	nd

"nd" Indicates no detection at the listed reporting limits
"int" Indicates that interference prevents determination
"J" Indicates estimated value
"MRL" Indicates Method Reporting Limit
"RPD" Indicates Relative Percent Difference

Acceptable RPD is determined to be less than 30%

2930 Westlake Ave. N., Suite 100
Seattle, WA 98109

T: 206.352.3790
F: 206.352.7178
email: info@fremontanalytical.com

Analysis of Sulfide by SM 4500-S^{2-}F

Project: WA-0977
Client: Pace Analytical
Client Project #: 255348
Lab Project #: CHM101019-2

SM 4500- S^{2-}F (mg/L)	MRL	MW-6	Duplicate MW-6	RPD %	MW-5	MW-16	MW-4
Date Analyzed		10/19/10	10/19/10		10/19/10	10/19/10	10/19/10
Matrix		Water	Water		Water	Water	Water
Date Collected							
Sulfide	0.5	**0.55**	**0.60**	9%	nd	nd	nd

"nd" Indicates no detection at the listed reporting limits
"int" Indicates that interference prevents determination
"J" Indicates estimated value
"MRL" Indicates Method Reporting Limit
"RPD" Indicates Relative Percent Difference

Acceptable RPD is determined to be less than 30%

CHM101019-2

Chain of Custody

Pace Analytical®
www.pacelabs.com

Workorder: 255348 **Workorder Name:** WA-0977 **Results Requested** 10/27/2010

Report / Invoice To	Subcontract To
Regina SteMarie Pace Analytical Seattle 940 South Harney Seattle, WA 98108 Phone (206)767-5060 Email: regina.stemarie@pacelabs.com	Fremont P.O. ______

Item	Sample ID	Collect Date/Time	Lab ID	Matrix	Preserved Containers: Other	BP2Z	Requested Analysis: Sulfide	LAB USE ONLY
1	MW-12	10/13/2010 11:55	255348001	Water		+	+	
2	MW-11	10/13/2010 13:25	255348002	Water		+	+	
3	MW-1	10/13/2010 14:30	255348003	Water		+	+	
4	MW-6	10/14/2010 11:20	255348004	Water		+	+	
5	MW-5	10/14/2010 12:25	255348005	Water		+	+	
6	MW-16	10/14/2010 14:20	255348006	Water		+	+	
7	MW-4	10/14/2010 15:10	255348007	Water		+	+	

Transfers	Released By	Date/Time	Received By	Date/Time
1	Colette Weaver	10/18/10/1800	[illegible signature]	10/18/10 1800
2				
3				
4				
5				

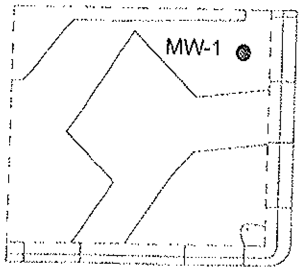
Comments

ARCADIS

Appendix **B**

Soil Boring Logs

WELL/BORING LOCATION MAP



Delta Environmental Consultants, Inc.

WELL/BORING: MW-1

INSTALLATION DATE: 3/22/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-T/WR 67226	SAMPLING METHOD: DM Split Spoon
CLIENT: Atlantic Richfield Company 0977	BORING DIAMETER: 8"
LOCATION: 155 Northwest 85th Street	BORING DEPTH: 28'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling	SAND PACK: 10-28' (2X12)

CASING ELEVATION	99.77
SURVEY DATE:	3/24/04
DTW:	17.43 (3/24/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

Well/boring completion: Concrete (0–3'), Bentonite (3–10'), Sand (10–22'+); screen from 13'. Water levels: First ▽ at about 20'; Stabilized ▼ at about 17.4'.

DEPTH (FEET)	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	USCS SYMBOL	DESCRIPTION
0					Asphalt 4"
0–2	DRY			SP	POORLY GRADED SAND : olive gray; 95% medium grained sand; 5% gravel.
2–3					GRAVELLY SAND : olive gray; 70% fine to medium grained sand; 30% fine to coarse gravel.
4					NOTE : Boring was cleared to five feet below ground surface using air-knife technology.
5–6.5	DRY	0	20 25 30	SP	POORLY GRADED SAND : olive gray; fine to medium grained sand; very dense.
10–11.5	DRY	0	25 27 31	SP	SAME AS ABOVE :
15–16.5	MST	0	15 19 21	SP	SAME AS ABOVE :
20–21.5	WET	0	23 25 25	SP	POORLY GRADED SAND : olive gray; medium to coarse grained sand; very dense.

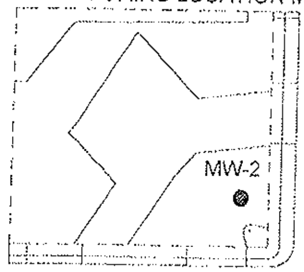
WELL/BORING LOCATION MAP	Delta Environmental Consultants, Inc.	WELL/BORING: MW-1
	INSTALLATION DATE: 3/22/04	DRILLING METHOD: Hollow Stem Auger
	PROJECT: AM04-600-T/WR 67226	SAMPLING METHOD: DM Split Spoon
	CLIENT: Atlantic Richfield Company 0977	BORING DIAMETER: 8"
	LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
	CITY: Seattle	WELL CASING: SCH 40 PVC 2"
	STATE: WA	WELL SCREEN: 13-28' (0.010")
	DRILLER: Cascade Drilling	SAND PACK: 10-28' (2X12)

CASING ELEVATION	99.77
SURVEY DATE:	3/24/04
DTW:	17.43 (3/24/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
						24					
			WET	7	22 23 24	25			SP		POORLY GRADED SAND ; olive gray; fine to medium grained sand; dense.
						26					
						27					
						28					
						29					
						30					
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP



Delta Environmental Consultants, Inc.

WELL/BORING: MW-2

INSTALLATION DATE: 3/22/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-T/WR 67226	SAMPLING METHOD: DM Split Spoon
CLIENT: Atlantic Richfield Company 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling	SAND PACK: 10-28' (2X12)

CASING ELEVATION	99.36
SURVEY DATE:	3/24/04
DTW:	17.24 (3/24/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION: Concrete; Bentonite; Sand

FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	USCS SYMBOL	DESCRIPTION
					0		Asphalt 6"
		DRY			1	SP	GRAVELLY SAND : olive gray; 70% fine to medium grained sand; 30% fine to coarse subrounded gravel.
					4		NOTE : Boring was cleared to five feet below ground surface using air-knife technology.
		DRY	4	2 2 3	5	SP	POORLY GRADED SAND : olive gray; fine to medium grained sand; loose.
		DRY	4	25 28 30	10	SP	SAME AS ABOVE : trace amounts of coarse grained gravel; very dense.
		DRY	388	29 30 35	15	SP	SAME AS ABOVE : no gravel.
	▼				17		
▽		WET	415	27 30 31	20	SP	POORLY GRADED SAND : olive gray; medium to coarse grained sand; very dense.
					22		

WELL/BORING LOCATION MAP	**Delta Environmental Consultants, Inc.**	WELL/BORING: MW-2
	INSTALLATION DATE: 3/22/04	DRILLING METHOD: Hollow Stem Auger
	PROJECT: AM04-600-T/WR 67226	SAMPLING METHOD: DM Split Spoon
	CLIENT: Atlantic Richfield Company 0977	BORING DIAMETER: 8"
	LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
	CITY: Seattle	WELL CASING: SCH 40 PVC 2"
	STATE: WA	WELL SCREEN: 13-28' (0.010")
	DRILLER: Cascade Drilling	SAND PACK: 10-28' (2X12)

CASING ELEVATION	99.36
SURVEY DATE:	3/24/04
DTW:	17.24 (3/24/04)

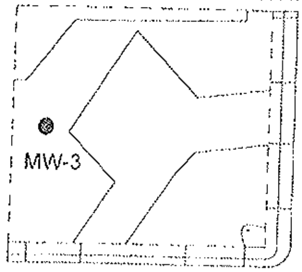
DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
						24					
			WET	258	28 30 30	25			SP		POORLY GRADED SAND : olive gray; medium to coarse grained sand; very dense.
						26					
						27					
						28					
						29					
						30					
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

Delta Environmental Consultants, Inc.

WELL/BORING: MW-3

WELL/BORING LOCATION MAP



INSTALLATION DATE: 3/22/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-T/WR 67226	SAMPLING METHOD: DM Split Spoon
CLIENT: Atlantic Richfield Company 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling	SAND PACK: 10-28' (2X12)

CASING ELEVATION	100.83
SURVEY DATE:	3/24/04
DTW:	18.45 (3/24/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Concrete						0					Asphalt 6"
			DRY			1–2			SP		GRAVELLY SAND : olive gray; 70% fine to medium grained sand; 30% fine to coarse subrounded gravel.
Bentonite						4					NOTE : Boring was cleared to five feet below ground surface using air-knife technology.
			DRY	0	27 30 32	5			SW		WELL GRADED SAND WITH GRAVEL : olive gray; 85% fine to coarse grained sand; 15% fine grained subrounded gravel; very dense.
Sand			DRY	0	25 31 36	10			SP		POORLY GRADED SAND : olive gray; fine to medium grained sand; very dense.
			MST	0	29 33 35	15			SP		SAME AS ABOVE :
		▼				18					
	▽		WET	0	28 33 35	20			SP		SAME AS ABOVE :
						22					

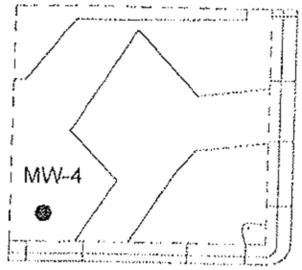
WELL/BORING LOCATION MAP	Delta Environmental Consultants, Inc.	WELL/BORING: MW-3
	INSTALLATION DATE: 3/22/04	DRILLING METHOD: Hollow Stem Auger
	PROJECT: AM04-600-T/WR 67226	SAMPLING METHOD: DM Split Spoon
	CLIENT: Atlantic Richfield Company 0977	BORING DIAMETER: 8"
	LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
	CITY: Seattle	WELL CASING: SCH 40 PVC 2"
	STATE: WA	WELL SCREEN: 13-28' (0.010")
	DRILLER: Cascade Drilling	SAND PACK: 10-28' (2X12)

CASING ELEVATION	100.83
SURVEY DATE:	3/24/04
DTW:	18.45 (3/24/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
						24					
			WET	0	38 50/6"	25			SP		POORLY GRADED SAND : olive gray; 95% medium to coarse grained sand; 5% fine grained subrounded gravel; very dense.
						26					
						27					
						28					
						29					
						30					
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP



Delta Environmental Consultants, Inc.

WELL/BORING: MW-4

INSTALLATION DATE: 3/22/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-T/WR 67226	SAMPLING METHOD: DM Split Spoon
CLIENT: Atlantic Richfield Company 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling	SAND PACK: 10-28' (2X12)

CASING ELEVATION	98.73
SURVEY DATE:	3/24/04
DTW:	16.35 (3/24/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

Well/Boring Completion: Concrete (0–3'); Bentonite (3–10'); Sand (10–22'+); screen from 13'. First water ▽ at approx. 20'; stabilized water ▼ at approx. 16'.

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Concrete						0					Asphalt 4"
						1			SP		GRAVELLY SAND : olive gray; 70% fine to medium grained sand; 30% fine to coarse subrounded gravel.
Bentonite						4					NOTE : Boring was cleared to five feet below ground surface using air-knife technology.
			DRY	0	23 25 28	5			SP		POORLY GRADED SAND : olive gray; fine to medium grained sand; very dense.
Sand			DRY	0	28 30 36	10			SP		SAME AS ABOVE :
		▼	MST	0	30 33 39	15			SP		SAME AS ABOVE :
	▽		WET	5	18 20 26	20			SP		SAME AS ABOVE :
						22					

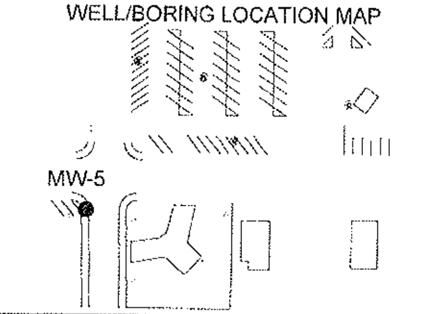
WELL/BORING LOCATION MAP	Delta Environmental Consultants, Inc.	WELL/BORING: MW-4
	INSTALLATION DATE: 3/22/04	DRILLING METHOD: Hollow Stem Auger
	PROJECT: AM04-600-T/WR 67226	SAMPLING METHOD: DM Split Spoon
	CLIENT: Atlantic Richfield Company 0977	BORING DIAMETER: 8"
	LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
	CITY: Seattle	WELL CASING: SCH 40 PVC 2"
	STATE: WA	WELL SCREEN: 13-28' (0.010")
	DRILLER: Cascade Drilling	SAND PACK: 10-28' (2X12)

CASING ELEVATION	98.73
SURVEY DATE:	3/24/04
DTW:	16.35 (3/24/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
						23					
						24					
			WET	4	23 26 28	25			SP		POORLY GRADED SAND : olive gray; fine to medium grained sand; very dense.
						26					
						27					
						28					
						29					
						30					
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP



Delta Environmental Consultants, Inc.

WELL/BORING: MW-5

INSTALLATION DATE: 10/22/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling, Inc. / Andy	SAND PACK: 10-28' (2X12)

CASING ELEVATION	99.13
SURVEY DATE:	12/17/04
DTW:	17.67 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION: Morrison Dubuque Well Box; Concrete; Bentonite; Sand

FIRST ▽ (approx. 20'); STABILIZED ▼ (approx. 17.5')

DEPTH (FEET)	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	USCS SYMBOL	DESCRIPTION
0					Concrete (one foot)
1				SP	POORLY GRADED SAND: light gray; 95% medium grained sand; 5% fine to coarse gravel.
5	DRY	2	50/6"	SP	POORLY GRADED SAND: light gray; fine to medium grained sand; very dense.
10	DRY	2	50/6"	SP	SAME AS ABOVE:
15	MST	18	50/3"	SP	SAME AS ABOVE: dark gray.
20	WET	58	50/5"	SP	SAME AS ABOVE: dark gray.

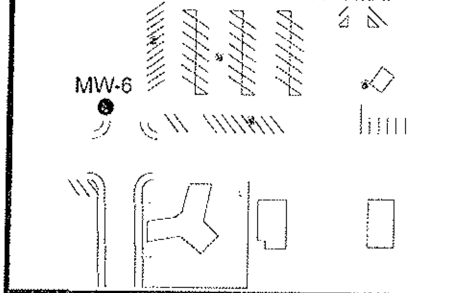
Delta Environmental Consultants, Inc.	WELL/BORING: MW-5
INSTALLATION DATE: 10/22/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling, Inc. / Andy	SAND PACK: 10-28' (2X12)

CASING ELEVATION	99.13
SURVEY DATE:	12/17/04
DTW:	17.67 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
						24					
			WET	188	11 50/6"	25			SP		POORLY GRADED SAND: dark gray; fine to medium grained sand; very dense.
						26					
						27					
						28					
						29					
						30					
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP



Delta Environmental Consultants, Inc.

WELL/BORING: MW-6

INSTALLATION DATE: 10/22/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 25'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 10-25' (0.010")
DRILLER: Cascade Drilling, Inc. / Andy	SAND PACK: 8-25' (2X12)

CASING ELEVATION	98.62
SURVEY DATE:	12/16/04
DTW:	17.32 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION: Morrison Dubuque Well Box; Concrete; Bentonite; Sand

FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	USCS SYMBOL	DESCRIPTION
					0		Asphalt 6"
		DRY	-		1	SP	POORLY GRADED SAND: light gray; fine to medium grained sand; 5% fine to coarse gravel.
		DRY	-	8 12 18	5	SP	Splitspoon sample came up empty. There was no soil sample collected.
		DRY	2	50/6"	10	SP	POORLY GRADED SAND: light brown; fine to medium grained sand.
		MST	10	50/6"	15	SP	SAME AS ABOVE:
	▼				17		
▽		WET	61	50/5"	20	SP	SAME AS ABOVE: dark gray.

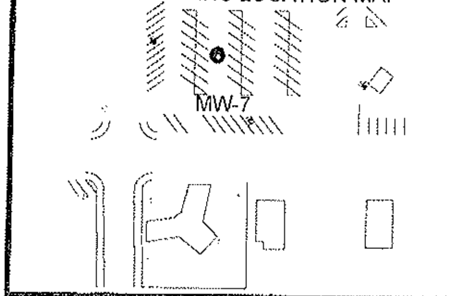
1/25/2005

Delta Environmental Consultants, Inc.		WELL/BORING: MW-5
INSTALLATION DATE: 10/22/04	DRILLING METHOD: Hollow Stem Auger	
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon	
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 8"	
LOCATION: 155 NW 85th Street	BORING DEPTH: 25'	
CITY: Seattle	WELL CASING: SCH 40 PVC 2"	
STATE: WA	WELL SCREEN: 10-25' (0.010")	
DRILLER: Cascade Drilling, Inc. / Andy	SAND PACK: 8-25' (2X12)	

CASING ELEVATION	98.62
SURVEY DATE:	12/16/04
DTW:	17.32 (12/9/04)
DESCRIPTION/LOGGED BY: Brett Bardsley	

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
Sand						24					
						25		■	SP		NOTE: There was no soil sample collected due to heaving sands.
						26		■			
						27					
						28					
						29					
						30					
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP



Delta Environmental Consultants, Inc.

WELL/BORING: MW-7

INSTALLATION DATE: 12/6/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 30.5'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling, Inc. / Steve	SAND PACK: 10-28' (2X12)

CASING ELEVATION	97.17
SURVEY DATE:	12/16/04
DTW:	15.80 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

Well/boring completion: Morrison Dubuque Well Box; Concrete; Bentonite; Sand

MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	USCS SYMBOL	DESCRIPTION
			0		Asphalt 6"
DRY	-		1	SP	POORLY GRADED SAND: light gray; 10% silt; fine to medium grained sand; 5% fine to coarse rounded gravel.
DRY	0	23 25 28	5	SP	POORLY GRADED SAND: light gray; 10% silt; fine to medium grained sand; very dense.
DRY	0	50/6"	10	SP	SAME AS ABOVE:
MST	0	33 50/6"	15	SP	SAME AS ABOVE:
WET	0	35 50/5"	20	SP	SAME AS ABOVE:

Delta Environmental Consultants, Inc.

WELL/BORING: MW-7

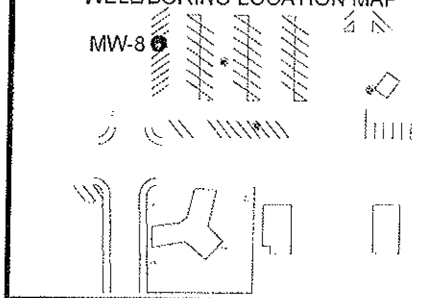
INSTALLATION DATE: 12/6/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 30.5'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
	SAND PACK: 10-28' (2X12)

CASING ELEVATION	97.17
SURVEY DATE:	12/16/04
DTW:	15.80 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
						24					
			WET	0	41 50/6"	25			SP		POORLY GRADED SAND: light gray; 10% silt; fine to medium grained sand; trace amounts of fine rounded gravel; very dense.
						26					
						27					
						28					
						29					
			WET	0	50/6"	30			SP		POORLY GRADED SAND: light gray; 10% silt; fine to medium grained sand; trace amounts of fine rounded gravel; very dense.
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP



Delta Environmental Consultants, Inc.

WELL/BORING: MW-8

INSTALLATION DATE: 12/6/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"
LOCATION: 155 NW 85th Street	BORING DEPTH: 30.5'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling, Inc. / Steve	SAND PACK: 10-28' (2X12)

CASING ELEVATION	97.52
SURVEY DATE:	12/16/04
DTW:	16.05 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

Well/boring completion: Morrison Dubuque Well Box; Concrete; Bentonite; Sand

FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	USCS SYMBOL	DESCRIPTION
					0		Asphalt 6"
		DRY			1	SP	POORLY GRADED SAND: light brown; 10% silt; 80% fine to medium grained sand; 5% fine rounded gravel.
		DRY	0	22 50/6"	5	SP	POORLY GRADED SAND: light brown; 10% silt; fine to medium grained sand.
		DRY	0	22 38 50	10	SP	SAME AS ABOVE: light gray.
	▼	MST	0	20 35 22	15	SP	SAME AS ABOVE:
▽		WET	0	18 21 26	20	SW	WELL GRADED SAND: 10% silt; 90% fine.

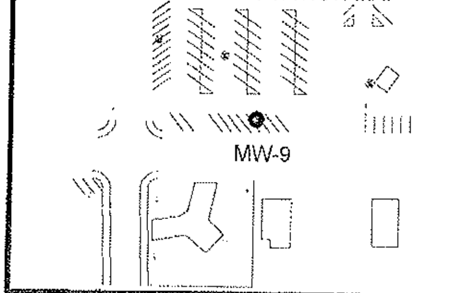
Delta Environmental Consultants, Inc.	WELL/BORING: MW-8
INSTALLATION DATE: 12/6/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"
LOCATION: 155 NW 85th Street	BORING DEPTH: 30.5'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-18' (0.010")
DRILLER: Cascade Drilling, Inc. / Andy	SAND PACK: 10-28' (2X12)

CASING ELEVATION	97.52
SURVEY DATE:	12/16/04
DTW:	16.05 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
						24					
			WET	0	22 50/6"	25			SP		POORLY GRADED SAND: light gray; fine to medium grained sand; trace amounts of fine rounded gravel; very dense.
						26					
						27					
						28					
						29					
				0	50/6"	30					SAME AS ABOVE:
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP	Delta Environmental Consultants, Inc.	WELL/BORING: MW-9



INSTALLATION DATE: 12/6/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"
LOCATION: 155 NW 85th Street	BORING DEPTH: 30.5'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling, Inc. / Steve	SAND PACK: 10-28' (2X12)

CASING ELEVATION	98.24
SURVEY DATE:	12/16/04
DTW:	16.81 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ∇	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Morrison Dubuque Well Box						0					Asphalt 6"
Concrete						1			SP		POORLY GRADED SAND: light brown; 10% silt; 80% fine to medium grained sand.
Bentonite			DRY	2	15 15 17	5			SP		POORLY GRADED SAND: light brown; fine to medium grained sand.
Sand			DRY	0	50/6"	10			SP		SAME AS ABOVE: grayish brown.
			MST	0	32 50/5"	15			SP		SAME AS ABOVE:
		▼				16.8					
	∇		WET	0	18 22 36	20			SP		SAME AS ABOVE: light gray.
						22					

Delta Environmental Consultants, Inc.

WELL/BORING: MW-9

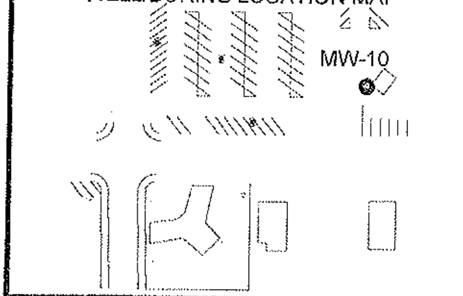
INSTALLATION DATE: 12/6/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"
LOCATION: 155 NW 85th Street	BORING DEPTH: 30.5'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling, Inc. / Steve	SAND PACK: 10-28' (2X12)

CASING ELEVATION	98.24
SURVEY DATE:	12/16/04
DTW:	16.81 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	USCS SYMBOL	DESCRIPTION
Sand						23		
						24		
				0	42 26 32	25	SP	POORLY GRADED SAND: light gray; fine to medium grained sand; trace amounts of fine rounded gravel.
						26		
						27		
						28		
						29		
				0	50/6"	30	SP	SAME AS ABOVE:
						31		
						32		
						33		
						34		
						35		
						36		
						37		
						38		
						39		
						40		
						41		
						42		
						43		
						44		

WELL/BORING LOCATION MAP



Delta Environmental Consultants, Inc.

WELL/BORING: MW-10

INSTALLATION DATE: 12/6/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"
LOCATION: 155 NW 85th Street	BORING DEPTH: 30.5'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling, Inc. / Steve	SAND PACK: 10-28' (2X12)

CASING ELEVATION	98.11
SURVEY DATE:	12/16/04
DTW:	16.71 (12/9/04)

DESCRIPTION/LOGGED BY: Brett Bardsley

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Morrison Dubuque Well Box						0					Asphalt 6"
Concrete			DRY			1			SP		POORLY GRADED SAND: light brown; fine to medium grained sand.
Bentonite			DRY	0	15 15 15	5			SP		POORLY GRADED SAND: light gray; fine to medium grained sand; medium dense.
Sand			DRY	0	32 47 32	10			SP		SAME AS ABOVE: very dense sand.
Sand			MST	0	22 32 14	15			SP		SAME AS ABOVE: dense sand.
Sand			WET	0	33 36 41	20			SP		SAME AS ABOVE: very dense.

Depth scale (feet): 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

Delta Environmental Consultants, Inc.	WELL/BORING: MW-10
INSTALLATION DATE: 12/6/04	DRILLING METHOD: Hollow Stem Auger
PROJECT: AM04-600-V/WR 80133	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"
LOCATION: 155 NW 85th Street	BORING DEPTH: 30.5'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling, Inc. / Steve	SAND PACK: 10-28' (2X12)

CASING ELEVATION	98.11
SURVEY DATE:	12/16/04
DTW:	16.71 (12/9/04)
DESCRIPTION/LOGGED BY: Brett Bardsley	

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
						24					
			WET	0	36 50/6"	25			SP		POORLY GRADED SAND: light gray; fine to medium grained sand.
						26					
						27					
						28					
						29					
			WET	0	50/6"	30			SP		SAME AS ABOVE:
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP

Delta Environmental Consultants, Inc.

WELL/BORING: MW-11

INSTALLATION DATE: 6/21/05	DRILLING METHOD: Hollow Stem Auger
PROJECT: G0CKB	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"
LOCATION: 155 NW 85th Street	BORING DEPTH: 25'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 10-25' (0.010")
DRILLER: Cascade Drilling, Inc.	SAND PACK: 8-25' (2X12)

CASING ELEVATION	100.06
SURVEY DATE:	7/8/05
DTW:	18.79 (6/30/05)

DESCRIPTION/LOGGED BY: Matthew Miller

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Concrete						0					Concrete Surface
Concrete						1			CL		CLAY: olive brown; moderate to high plasticity; trace very fine to fine sand; iron oxide staining; trace roots; very stiff.
Bentonite			DP	2	8 11 13	5			CL		
Sand			MST	1	27 56	10			SC		CLAYEY SAND: olive brown; 30 to 40% fines; very fine to fine sand; very dense.
Sand	▽		WET	2	50/2"	15			SC		@15' AS ABOVE: 10 to 20% fines; very dense; minimal sample recovery.
Sand		▼				18					
Sand			WET	1	50/4"	20			SC		@20' AS ABOVE: dark olive gray; decreasing fines.
Sand						22					

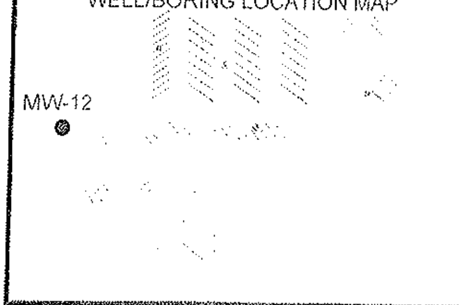
8/25/2005

Delta Environmental Consultants, Inc.	WELL/BORING: MW-11
INSTALLATION DATE: 6/21/05	DRILLING METHOD: Hollow Stem Auger
PROJECT: G0CKB	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"
LOCATION: 155 NW 85th Street	BORING DEPTH: 25'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 10-25' (0.010")
DRILLER: Cascade Drilling, Inc.	SAND PACK: 8-25' (2X12)

CASING ELEVATION	100.06
SURVEY DATE:	7/8/05
DTW:	18.79 (6/30/05)

DESCRIPTION/LOGGED BY: Matthew Miller

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
						24					
			WET	1	50/6"	25			SC		@25" CLAYEY SAND: decreasing fines; 5 to 10% fines; very dense.
						26					
						27					
						28					
						29					PID background levels = 1-2 ppm
						30					
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP	Delta Environmental Consultants, Inc.		WELL/BORING: MW-12
	INSTALLATION DATE: 6/21/05	DRILLING METHOD: Hollow Stem Auger	
	PROJECT: G0CKB	SAMPLING METHOD: DM Split Spoon	
	CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"	
	LOCATION: 155 NW 85th Street	BORING DEPTH: 28'	
	CITY: Seattle	WELL CASING: SCH 40 PVC 2"	
	STATE: WA	WELL SCREEN: 13-28' (0.010")	
	DRILLER: Cascade Drilling, Inc.	SAND PACK: 11-28' (2X12)	

CASING ELEVATION	100.01
SURVEY DATE:	7/8/05
DTW:	18.50 (6/30/05)

DESCRIPTION/LOGGED BY: Matthew Miller

WELL/BORING COMPLETION	FIRST ∇	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Concrete						0					Asphalt
						1			SP		SAND: light olive brown; trace to 5% fines; very fine to fine sand; trace medium to coarse sand; trace gravel.
Bentonite						5			SP		No recovery at 5'
			DP	0	20 36 35	10			SP		SAND: dark grayish brown; trace to 5% fines; very fine to fine sand; trace medium to coarse sand; very dense.
Sand			DP	0	50/6"	15			SP		@15' AS ABOVE:
		▼				18					
	∇		WET	0	50/5"	20			SP		@20' AS ABOVE:
						22					

Delta Environmental Consultants, Inc.	WELL/BORING: MW-12
INSTALLATION DATE: 6/21/05	DRILLING METHOD: Hollow Stem Auger
PROJECT: G0CKB	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 2"
LOCATION: 155 NW 85th Street	BORING DEPTH: 28'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 13-28' (0.010")
DRILLER: Cascade Drilling, Inc.	SAND PACK: 11-28' (2X12)

CASING ELEVATION	100.01
SURVEY DATE:	7/8/05
DTW:	18.50 (6/30/05)
DESCRIPTION/LOGGED BY: Matthew Miller	

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23					
						24					
			WET	0	50/4"	25			SP		SAND: dark grayish brown; trace fines; very fine to fine sand; 5% medium to coarse sand; trace gravel; very dense.
						26					
						27					
						28					
						29					
						30					
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

WELL/BORING LOCATION MAP

Delta Environmental Consultants, Inc. — WELL/BORING: MW-13

INSTALLATION DATE: 6/21/05	DRILLING METHOD: Hollow Stem Auger
PROJECT: G0CKB	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 25'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 10-25' (0.010")
DRILLER: Cascade Drilling, Inc.	SAND PACK: 8-25' (2X12)

CASING ELEVATION	98.02
SURVEY DATE:	7/8/05
DTW:	16.52 (6/30/05)

DESCRIPTION/LOGGED BY: Matthew Miller

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Concrete						1			SP		
Bentonite			DP	0	12 22 27	5			SP		SAND: dark yellowish brown; trace to 5% fines; very fine to fine sand; 5% medium to coarse sand; 10% gravel; iron oxide staining; very dense.
Sand			-		50/0"	10			SP		No recovery at 10'
Sand	▽	▼	WET	-	50/3"	15			SP		@15' AS ABOVE: very dark grayish brown; 5% fines; very fine to fine sand; 5% medium to coarse sand; trace gravel very dense.
Sand			WET	0	50/6"	20			SP		SAND: dark gray; trace fines; very fine to fine sand; 5 to 10% medium to coarse sand; 10% gravel; very dense.

8/25/2005

Delta Environmental Consultants, Inc.	WELL/BORING: MW-13
INSTALLATION DATE: 6/21/05	DRILLING METHOD: Hollow Stem Auger
PROJECT: G0CKB	SAMPLING METHOD: DM Split Spoon
CLIENT: ARCO Facility No. 0977	BORING DIAMETER: 8"
LOCATION: 155 NW 85th Street	BORING DEPTH: 25'
CITY: Seattle	WELL CASING: SCH 40 PVC 2"
STATE: WA	WELL SCREEN: 10-25' (0.010")
DRILLER: Cascade Drilling, Inc.	SAND PACK: 8-25' (2X12)

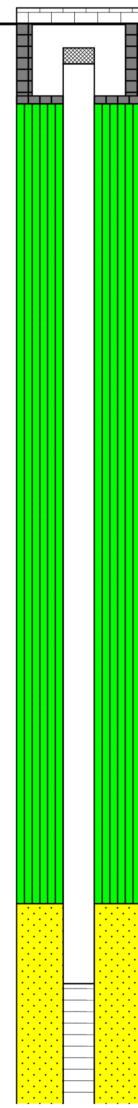
CASING ELEVATION	98.02
SURVEY DATE:	7/8/05
DTW:	16.52 (6/30/05)
DESCRIPTION/LOGGED BY: Matthew Miller	

WELL/BORING COMPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	PID (ppm)	DENSITY BLOWS / 6"	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	USCS SYMBOL	GRAPHIC	DESCRIPTION
Sand						23			SP		GRAVELLY SAND: dark gray; trace fines; very fine to coarse sand; 20 to 30% gravel; very dense.
						24					
			WET	0	50/6"	25					
						26					
						27					
						28					
						29					
						30					
						31					
						32					
						33					
						34					
						35					
						36					
						37					
						38					
						39					
						40					
						41					
						42					
						43					
						44					

Date Start/Finish: 9/23/2010 **Drilling Company:** Cascade Drilling **Driller's Name:** Andy **Drilling Method:** HSA **Auger Size:** 8" **Rig Type:** HSA **Sampling Method:** Split Spoon	**Northing:** -- **Easting:** -- **Casing Elevation:** -- **Borehole Depth:** 24 **Surface Elevation:** -- **Descriptions By:** David Rasar	**Well/Boring ID: MW-16** **Client:** BP West Coast, LLC **Location:** Former ARCO Facility #0977

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (%)	Blow Counts	N - Value	PID Headspace (ppm)	USCS Code	Geologic Column	Stratigraphic Description
0	0									
							0.4	SM		Silty SAND with gravel, fine-medium sand, poorly graded, trace silt, trace gravel, brown, moist.
							80			
5	-5			100	1		2.0			Silty SAND with gravel, very fine-fine sand, poorly graded, trace silt, brown, moist, no odor.
				100	1					
				100	2					
				0	2		2.1			Silty SAND with gravel, very fine-fine sand, poorly graded, trace silt, brown, moist, no odor.
				100	2					
				100	2					
10	-10			100	6		20.0	SM		Silty SAND with gravel, very fine-fine sand, poorly graded, trace silt, brown, moist, no odor.
				100	12					
				100	18					
				100	13		20.0			Silty SAND with gravel, very fine-fine sand, poorly graded, trace silt, brown, moist, no odor.
				100	20					

Well/Boring Construction



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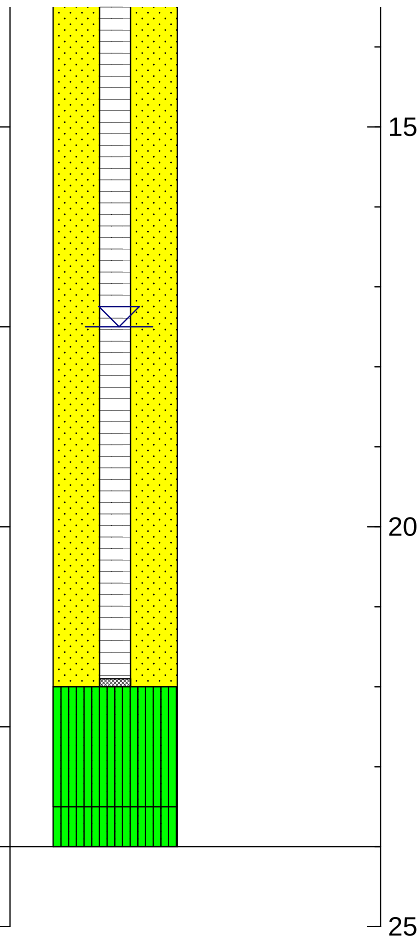
Remarks: bgs: below ground surface
HSA: Hollow Stem Auger

Date Start/Finish: 9/23/2010 **Drilling Company:** Cascade Drilling **Driller's Name:** Andy **Drilling Method:** HSA **Auger Size:** 8" **Rig Type:** HSA **Sampling Method:** Split Spoon	**Northing:** -- **Easting:** -- **Casing Elevation:** -- **Borehole Depth:** 24 **Surface Elevation:** -- **Descriptions By:** David Rasar	**Well/Boring ID: MW-16** **Client:** BP West Coast, LLC **Location:** Former ARCO Facility #0977

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (%)	Blow Counts	N - Value	PID Headspace (ppm)	USCS Code	Geologic Column	Stratigraphic Description
				100	28			SM		
15	-15			100	18		126			Silty SAND with gravel, very fine-fine sand, poorly graded, trace silt, brown, moist, slight HCLO.
				100	20					
				100	28					
				100	12		1029			Silty SAND with gravel, very fine-fine sand, poorly graded, trace silt, grey, moist, slight HCLO, no LNAPL.
		MW-16-18-18.5		100	18					
				100	23					
20	-20			100	23		370			Silty SAND with gravel, very fine-fine sand, poorly graded, trace silt, grey, moist, slight HCLO, no LNAPL.
				100	50/6					
				100	50/6					
		MW-16-22.5-23		100	23			SM		Silty SAND with gravel, very fine-fine sand, poorly graded, trace silt, grey, moist, slight HCLO, no LNAPL.
				100	32					
				100	50/6					
25	-25									

Well/Boring Construction



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Remarks: bgs: below ground surface
HSA: Hollow Stem Auger

Date Start/Finish: 2/1/2011
Drilling Company: Cascade Drilling LLP.
Driller's Name: Frank
Drilling Method: Hollow Stem Auger
Auger Size: 10 inch OD
Rig Type: 75 Limited Access
Sampling Method: 1.5 ft. x 2 inch Split Spoon

Northing: NM
Easting: NM
Casing Elevation: NM

Borehole Depth: 18 ft. bgs
Surface Elevation: NM

Descriptions By: Dave Rasar

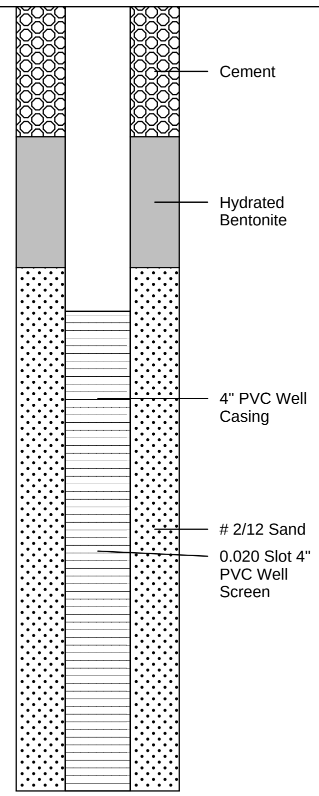
Well/Boring ID: VE-1

Client: BP ARCO

Location: WA-0977
155 NW 85th Street
Seattle, Washington

DEPTH	ELEVATION	Sample Run Number	Sample/Int/Type	Recovery (feet)	Blow Counts	N - Value	PID Headspace (ppm)	Analytical Sample	USCS Code	Geologic Column	Stratigraphic Description
0	0										
		1	0.0 - 7.0				0.0	X	SP		Poorly graded SAND, trace gravel, very fine to fine sand, medium gravel, grey, moist, no HCLO.
5	-5	2					1.1	X	SP		Poorly graded SAND, very fine to fine sand, grey, moist, no HCLO.
			7 - 8.5		50 / 6	>50					No recovery.
10	-10		10 - 11.5		50 50 15	>50	1.3		SP		Poorly graded SAND, very fine to fine sand, trace silt, grey, moist, no HCLO.
			12.5 - 14		25 20 15	35	0.5		SP		SAA.
15	-15		15 - 16.5		28 18 20	38	0.7		SP		SAA, slight HCLO at 15 ft bgs.
			17.5 - 19		28 18 20	38	11.5		SP		SAA, increasing grain size at 18.5 with trace fine gravel.

Well/Boring Construction



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Remarks:
bgs = below ground surface; ft. = feet; OD = outer diameter; NM = Not Measured; SAA = Same As Above; HCLO = hydrocarbon-like odor

Hand cleared to 7.0 ft. bgs using air knife and vac truck. Samples at 2.5 ft. bgs and 5.0 ft. bgs collected with hand auger.

Water Level Data

Date	Depth	Elev.

Depth measured from top of casing

Project: WA-0977 Template:
Data File: Date: 6/30/2011 Created/Edited by: LKW

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Appendix **C**

SVE Pilot Test Results

ARCADIS conducted an SVE system pilot test using newly installed extraction well VE-1 on February 22 and 23, 2011. Data collected from the pilot test was used to determine a radius of influence (ROI) in soils at the site, and to determine if an SVE remedial strategy would be successful in removing residual and sorbed phase hydrocarbon impacts from vadose zone soils.

The pilot test was designed to address measurable LNAPL observed in MW-2, residual petroleum hydrocarbons and potential LNAPL that remain in the sand and silty sand layers in the northwest portion of the site. The pilot test focused on vapor extraction of impacted soils and LNAPL observed between 16 and 19 feet bgs. The scope of work for the SVE pilot test included a flow rate step test and a constant rate test. A short-term step and constant rate SVE pilot test was completed at VE-1. Monitoring wells MW-1, MW-4, MW-5, and MW-16 were used as observation wells during the pilot test (**Figure 2**).

For each test, vacuum pressure was measured at extraction and monitoring well heads using vacuum gauges. Pretreatment effluent concentrations of volatile organic compounds (VOCs) were measured periodically with a photoionization detector (PID) at the extraction well. Air velocity was measured using an anemometer at the extraction well and used to calculate the extraction flow rate.

STEP TEST RESULTS

The SVE step test involved the incremental increase of extraction flow rates to determine the flow capacity of the extraction well. A target extraction rate of approximately 40 standard cubic feet per minute (scfm) was assumed due to subsurface soil conditions encountered during previous soil boring activities. The target extraction rate is calculated based on a pore volume exchange rate of 3 pore volume per day as follows:

$$Q = \pi \times r^2 \times d \times n \times \epsilon$$

Where:
Q = flow rate in cubic feet per minute (cfm)
r = target radius of influence of 50 feet
d = is the screen interval of 10 feet
n = assumed soil porosity of 25% based on sandy soils
ε = pore volume exchange rate in volumes per day, assume 3 pore volume per day.

Flow from the mobile SVE unit started at approximately 50% of the estimated target flow rate, or 20 scfm. Once stable readings were observed (approximately three data points) at extraction and monitoring wells, flow was increased to 75%, 100% and 150% of the target flow rate until the maximum sustainable flow rate and vacuum from the well was achieved.

Step test results are presented on **Table C-1**. Vacuum readings at VE-1 ranged from 8 to 32.5 inches of water column (in. wc) and the extraction flow rate ranged from 20 to 86 standard cubic feet per minute (scfm). Step test data showing the relationship between extraction flow rate and vacuum is presented in **Figure C-1**.

PID readings ranged from 340 to 10,000 parts per million by volume (ppmv). **Figure C-2** presents extraction flow rate and influent VOCs concentrations over time. At the start of the pilot study concentrations of VOCs spiked to 10,000 ppmv, and after the first hour concentrations ranged from approximately 340 ppmv to 1,540 ppmv as the extraction flow rate was increased from approximately 19 to 86 scfm.

Flow rates and PID readings were used to calculate mass removal rates and the total mass removed. Mass removal rates ranged from 8.2 to 46.2 pounds per day (lb/day). The step test lasted approximately three hours and it is estimated that approximately 2.4 lb of petroleum hydrocarbons were removed. **Figure C-3** presents mass removal rates and cumulative mass removed over time.

As mentioned above, vacuum readings were recorded at monitoring wells MW-1, MW-4, MW-5, and MW-16 during the step test. The results are presented on **Table C-1**. At on-site monitoring well MW-16, which is approximately 12 feet away from VE-1, vacuum readings ranged from 0.7 to 2.8 in. wc. At on-site monitoring well MW-1, which is located 71 feet away from VE-1, vacuum readings range from 0 to 0.6 in. wc. At on-site monitoring well MW-4 which is located 85 feet from VE-1, vacuum ranged from 0 to 0.1 in. wc. At off-site monitoring well MW-5, vacuum ranged from 0 to 0.1 in. wc. MW-5 is located 70 feet from VE-1 on the west side of 3rd Avenue NW. Vacuum readings recorded at monitoring wells over time are presented on **Figure C-4**.

CONSTANT RATE TEST RESULTS

Once the maximum sustainable flow rate was achieved, constant rate tests were performed to determine longer term sustainability of the selected vacuum rate. During each constant rate test, vapor extraction flow rates, influent vapor concentrations, and vacuum readings were recorded on a graduated basis. For this site, two constant rate tests were conducted at VE-1.

The first constant rate test was conducted on February 22, 2011 for two hours. The average vacuum at VE-1 was 26 in. wc and the average flow rate was 56 scfm. PID readings ranged from 330 to 821 ppmv. Data from constant rate test is provided in **Table C-2**. **Figure C-5** presents VOCs concentrations and extraction flow rates during the constant rate test. Flow rates and PID readings were used to calculate mass removal rates and the total mass removed. Mass removal rates ranged from 7.4 to 12.4 lb/day. It was calculated that 0.9 lb of petroleum hydrocarbon mass was removed. **Figure C-6** presents the mass removal rate and cumulative mass removed over time.

Vacuum readings were observed and recorded at monitoring wells MW-1, MW-4, MW-5, and MW-16 during the constant rate test. This data was used to determine the SVE pilot test radius of influence (ROI). To do this, the observed vacuum at the extraction and monitoring wells are plotted as a function of distance from extraction well VE-1 on a logarithmic scale for each time interval as shown on **Figure C-7**. Linear equations are developed from this data and the ROI is determined. Based on empirical data, the ROI is equal to the distance where the extraction vacuum is equal to 0.1 in. wc. For this site, linear equations were derived for each time interval and the ROI was determined from these equations. The average ROI determined was 77 feet.

The second constant rate test was conducted on February 23, 2011 over five and a half hours. The average vacuum at VE-1 was 26.4 in. wc and the average flow rate was 60 scfm. PID readings ranged from 200 to 4,882 ppmv. Data from constant rate test is provided in **Table C-2**. **Figure C-8** presents VOCs concentrations and extraction flow rates during the constant rate test. Flow rates and PID readings were used to calculate mass removal rates and the total mass removed. Mass removal rates ranged from 4.0 to

103 lb/day. It was calculated that 2.3 lb of petroleum hydrocarbon mass was removed. **Figure C-9** presents the mass removal rate and cumulative mass removed over time. The ROI was calculated based on the method described above and data is presented on **Figure C-10**. The estimated ROI was 68 feet.

System pre-treatment vapor samples were collected from the manifold sampling point and submitted for lab analysis. Samples were collected using Summa canisters. Two samples, SVE-1 and SVE-2, were collected from extraction well VE-1. SVE-1 was collected at the end of the first constant rate test and sample SVE-2 was collected at the end of the second constant rate test. Samples were submitted to Washington State-certified laboratory, Pace Analytical of Seattle, Washington, for the following chemical analyses:

- Total Hydrocarbon Compounds- Gasoline Range (THC-G) and BTEX by TO-3 Air
- Carbon dioxide, methane, nitrogen, and oxygen by Method 3C Gases

Analytical results are presented on **Table C-3**. Concentrations of gasoline range hydrocarbons and benzene for SVE-1 were 767 ppmv and 7.6 ppmv, respectively. Concentrations of gasoline range hydrocarbons and benzene for SVE-2 were 471 ppmv and 5.4 ppmv, respectively. Laboratory certificates are included at the end of this appendix.

Attachments

Tables

Figures

Pace Analytical Laboratory Certificates

Table C-1
Step Test Results - SVE Pilot Test
WA-0977
155 Northwest 85th Street, Seattle, Washington, 98107

Time	Time Elapsed (h)	VE-1 Vaccuum (in. wc)	Anenometer Reading (ft/min)	Flow rate (scfm)[a]	Influent VOCs - PID (ppmv)	Mass Removal Rate (lb/day)[b]	Cumulative Mass Removed (lb)[b]	Measured Vacuum (in. wc)			
								MW-16	MW-1	MW-4	MW-5
12:09	0	10.18	1150	25.09	1700	15.1	0	0.85	0	0	--
12:24	0.25	9	900	19.63	10000	46.2	0.5	0.8	0	0	--
12:34	0.42	8	940	20.51	1530	40.9	0.8	0.7	10	0	--
12:44	0.58	9	880	19.20	1535	10.8	0.8	0.85	0.125	0	0
12:54	0.75	18	1990	43.42	818	13.0	0.9	1.6	0.35	0.05	0.07
13:04	0.92	19	1950	42.54	850	12.7	1.0	1.65	0.1	0.05	0.05
13:14	1.08	19	1910	41.67	710	11.6	1.1	1.75	0.38	0	0.01
13:24	1.25	19	1970	42.98	830	11.5	1.2	1.75	0.32	0.02	0.01
13:48	1.65	24	2660	58.03	1306	19.1	1.5	2.1	0.4	0	0
14:00	1.85	24.2	2770	60.43	1190	26.1	1.7	2.2	0.45	0	0.05
14:15	2.10	25	2720	59.34	1129	24.5	2.0	2.1	0.45	0.05	0.05
14:25	2.27	26	2610	56.94	470	16.4	2.1	2.2	0.5	0.05	0.03
14:35	2.43	22	2470	53.89	370	8.2	2.1	2.18	0.45	0	0
14:45	2.60	32.5	3940	85.96	440	10.0	2.2	2.8	0.6	0.11	0.05
14:55	2.77	32.5	3620	78.98	421	12.5	2.3	2.8	0.6	0.05	0.04
15:05	2.93	32.5	3510	76.58	399	11.3	2.4	2.8	0.6	0.05	0.02

Notes:
(a) Flow rate calculated based on anenometer and cross sectional area of mainfold piping (2 in. pipe).

(b) Assumptions and Calculations for mass removal
- When concentrations are less than laboratory reporting limits, one-half the detection limit is used for mass removal calculations.
- Net Removed (lb) = EFFL GRO Concentration (ppmv) * Hours of Operation (hr) * Flow (scfm) * 1.33E-5 ((lb-min)/(ft3*hr))
- Mass Removal Rate (lb/day) = Net Mass Removed (lb) / (Hours of Operation (hr))/24)
- Molecular weight of GRO (hexane) is approximately 95 grams per mol (g/mol).
- Period percent operational calculation based on total hours between first day and last monitoring event in current quarter.
in. wc = inches of water column

Table C-2
Constant Rate Test Results - SVE Pilot Test
WA-0977
155 Northwest 85th Street, Seattle, Washington, 98107

Constant Rate Test Conducted on February 22, 2011

Time	Time Elapsed	VE-1 Vacuum (in. wc)	Anenometer Reading	Flow rate (scfm)[a]	Influent VOCs	Mass Removal Rate (lb/day)[b]	Cumulative Mass Removed (lb)[b]	Measured Vaccuum (in. wc)				
								VE-1	MW-16	MW-1	MW-4	MW-5 [c]
							distance from VE-1 →	*0*	*12*	*71*	*85*	*70*
15:15	0.0	26.0	2530	55.2	480	9.4	0	26	2.15	0.55	0.05	0.03
15:45	0.5	25.0	2520	55.0	432	8.9	0.2	25	2.1	0.45	0.00[d]	0.05
16:15	1.0	26.0	2600	56.7	821	12.4	0.4	26	2.05	0.5	0.06	0.00[d]
16:45	1.5	26.0	2520	55.0	425	12.3	0.7	26	2.1	0.45	0.00[d]	0.00[d]
17:15	2.0	27.0	2570	56.1	330	7.4	0.9	27	2.1	0.4	0.00[d]	0.00[d]

Constant Rate Test Conducted on February 23, 2011

Time	Time Elapsed	VE-1 Vacuum (in. wc)	Anenometer Reading	Flow rate (scfm)[a]	Influent VOCs	Mass Removal Rate (lb/day)[b]	Cumulative Mass Removed (lb)[b]	Measured Vaccuum (in. wc)				
								VE-1	MW-16	MW-1	MW-4	MW-5 [c]
							distance from VE-1 →	*0*	*12*	*71*	*85*	*70*
8:53	0.1	26.5	2750	60.0	4882	103.5	0	26.5	2	0.32	0	0.05
9:23	0.6	25.5	3000	65.4	233	56.7	1.2	25.5	2	0.39	0	0
9:53	1.1	26.5	2980	65.0	253	5.8	1.3	26.5	1.96	0.41	0	0.05
10:53	1.6	26.5	2740	59.8	298	6.1	1.4	26.5	1.9	0.36	0	0.02
11:53	2.6	27.0	2570	56.1	310	6.1	1.7	27.0	1.6	0.35	0	0.01
12:53	3.6	26.0	2630	57.4	320	6.3	1.9	26.0	1.7	0.35	0	0
13:53	4.6	27.0	2570	56.1	200	4.0	2.2	27.0	1.7	0.2	0	0
14:53	5.6	26.0	2700	58.9	214	4.2	2.3	26.0	1.8	0.35	0	0.03

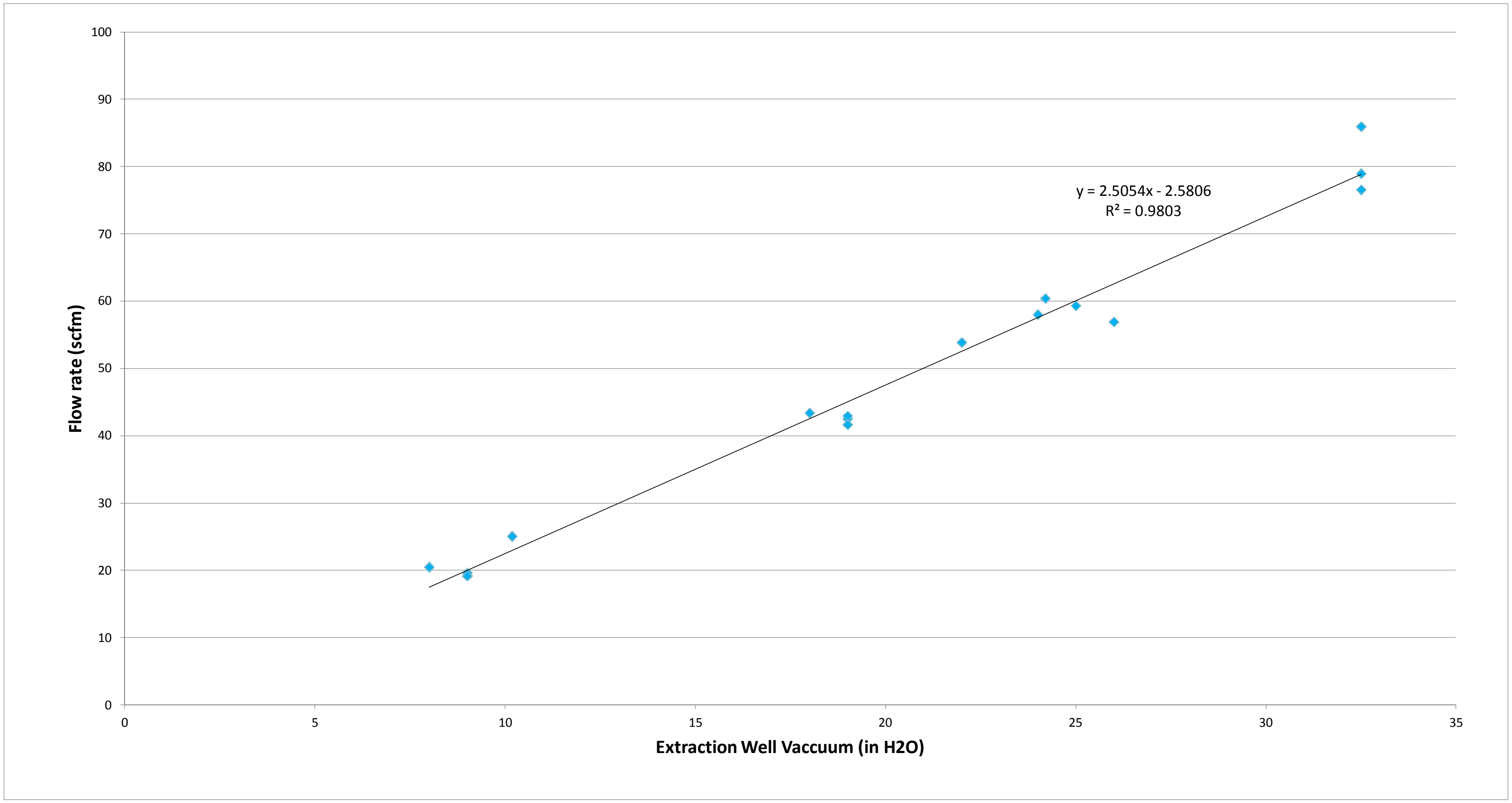
Notes
(a) Flow rate calculated based on anenometer and cross sectional area of mainfold piping (2 in. pipe).

(b) Assumptions and Calculations for mass removal
- When concentrations are less than laboratory reporting limits, one-half the detection limit is used for mass removal calculations.
- Net Removed (lb) = EFFL GRO Concentration (ppmv) * Hours of Operation (hr) * Flow (scfm) * 1.33E-5 ((lb-min)/(ft3*hr))
- Mass Removal Rate (lb/day) = Net Mass Removed (lb) / (Hours of Operation (hr))/24)
- Molecular weight of GRO (hexane) is approximately 95 grams per mol (g/mol).
- Period percent operational calculation based on total hours between first day and last monitoring event in current quarter.

(c) Measured vacuum at MW-5 was not used for radius of influence determination.
(d) To determine radius of influence it was assumed pressure reading at these wells were 0.01 in. wc.
in. wc = inches of water column

Table C-3
Laboratory Analytical Results - SVE Pilot Test
WA-0977
155 Northwest 85th Street, Seattle, Washington 98107

Analyte	Samples			
	SVE-1		SVE-2	
Fixed Gases				
Carbon Dioxide (Acn)	2.7	%	ND < 2	%
Carbon monoxide	ND < 0.4	%	ND < 0.4	%
Methane	ND < 4	%	ND < 4	%
Nitrogen	74.9	%	75.1	%
Oxygen	15.7	%	18.3	%
Volatiles				
1,2,4-Trimethylbenzene	4.8	ppmv	2.7	ppmv
1,3,5-Trimethylbenzene	2.4	ppmv	1.3	ppmv
Benzene	7.9	ppmv	5.4	ppmv
Ethylbenzene	7.6	ppmv	4.3	ppmv
m&p-Xylene	36.5	ppmv	18.3	ppmv
Methyl t-butyl ether	6.4	ppmv	3.6	ppmv
n-Hexane	49.6	ppmv	31.2	ppmv
o-Xylene	10.9	ppmv	5.6	ppmv
THC as Gas	767	ppmv	471	ppmv
Toluene	51.6	ppmv	29.8	ppmv



NOTES:

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155 N W 85th St, Seattle, WA 98107

Flow rate vs. Extraction Vacuum
Step Test VE-1

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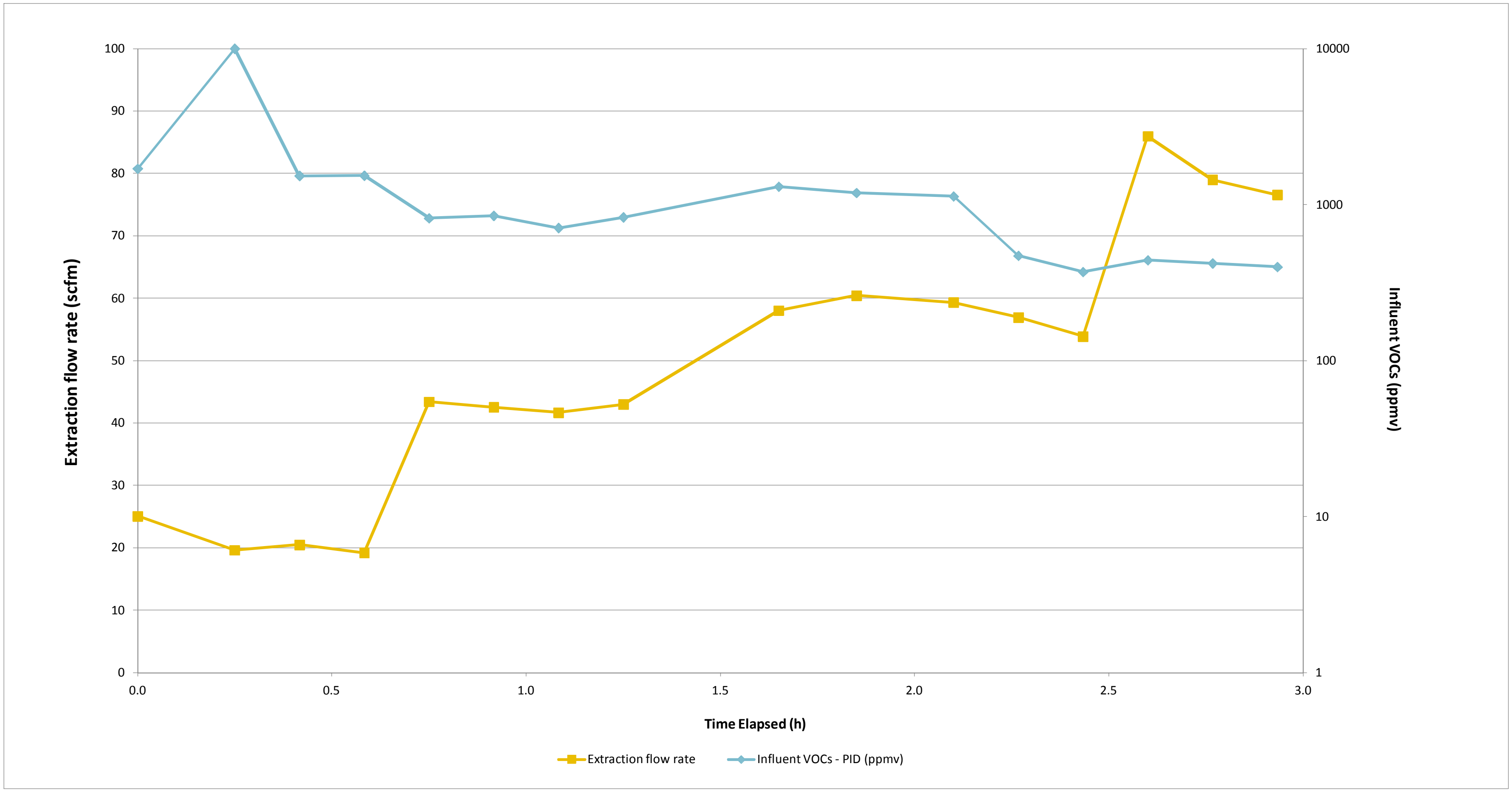
FIGURE
C-1



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Influent VOCs and Q vs. Time
Step Test VE-1

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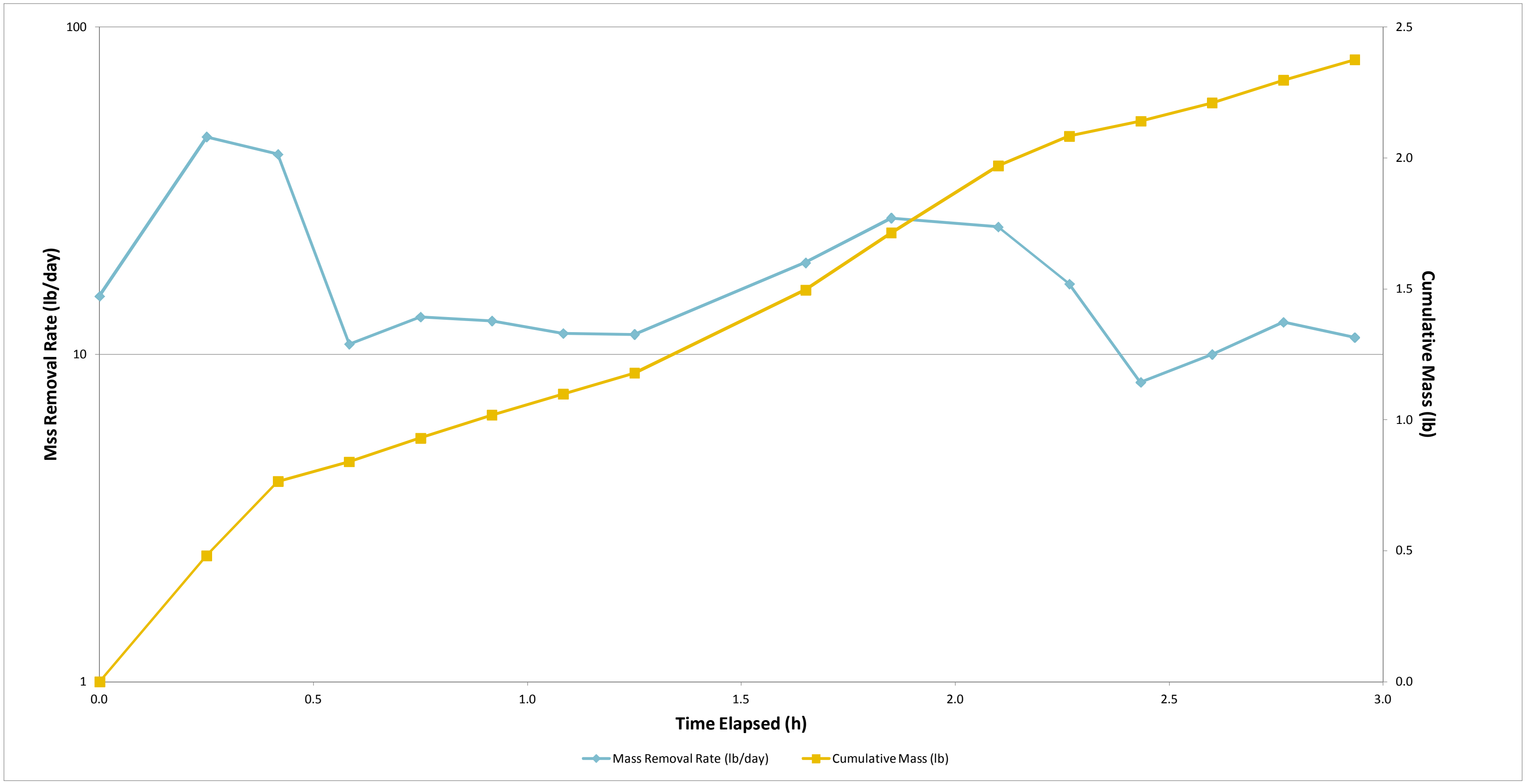
FIGURE
C-2



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GRO Mass Removal - Step Test VE-1

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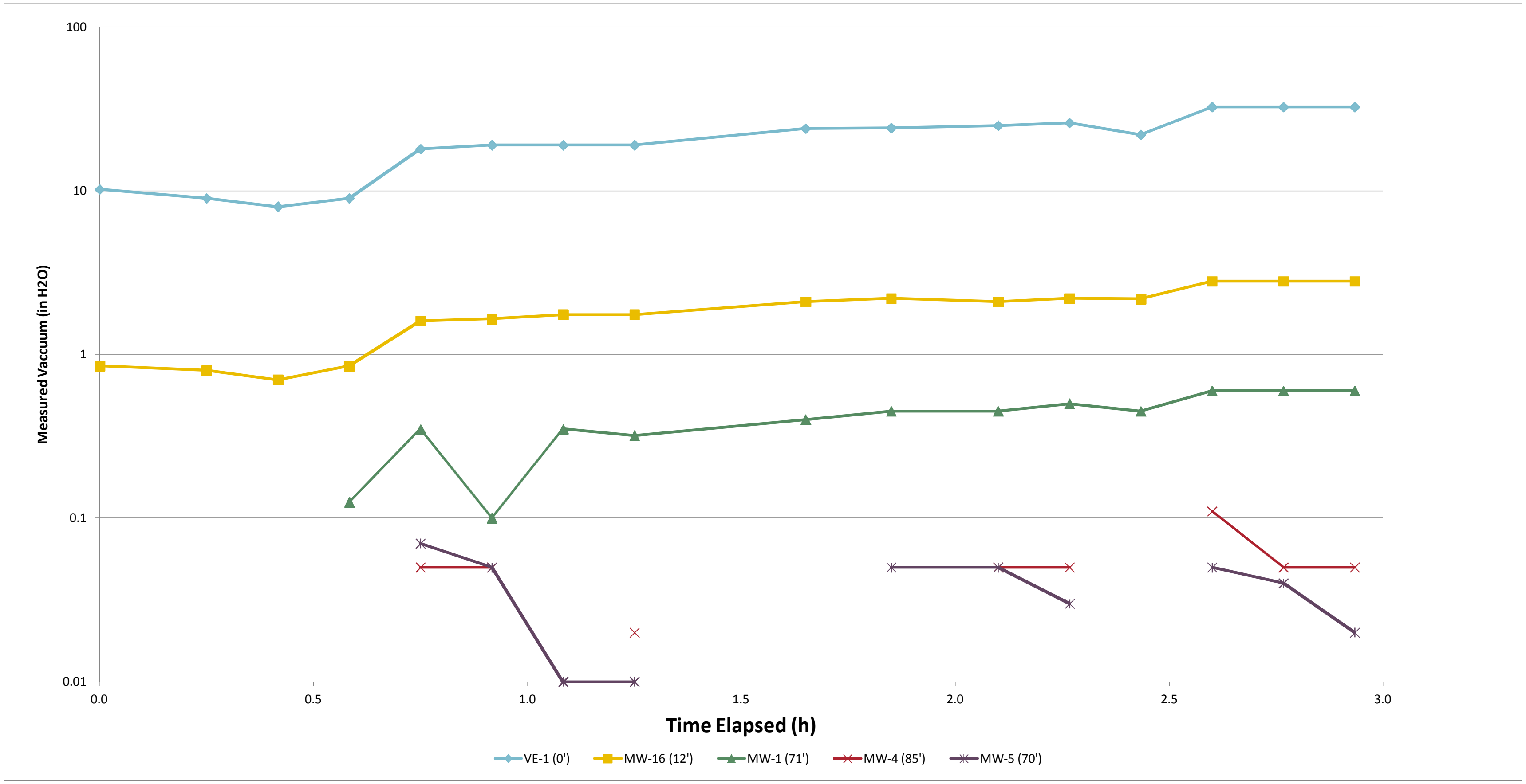
FIGURE
C-3



NOTES:
Values in parentheses denotes distance between extraction well and monitoring well

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Measured Vacuum vs Time Elapsed
Step Test VE-1 (monitoring wells)

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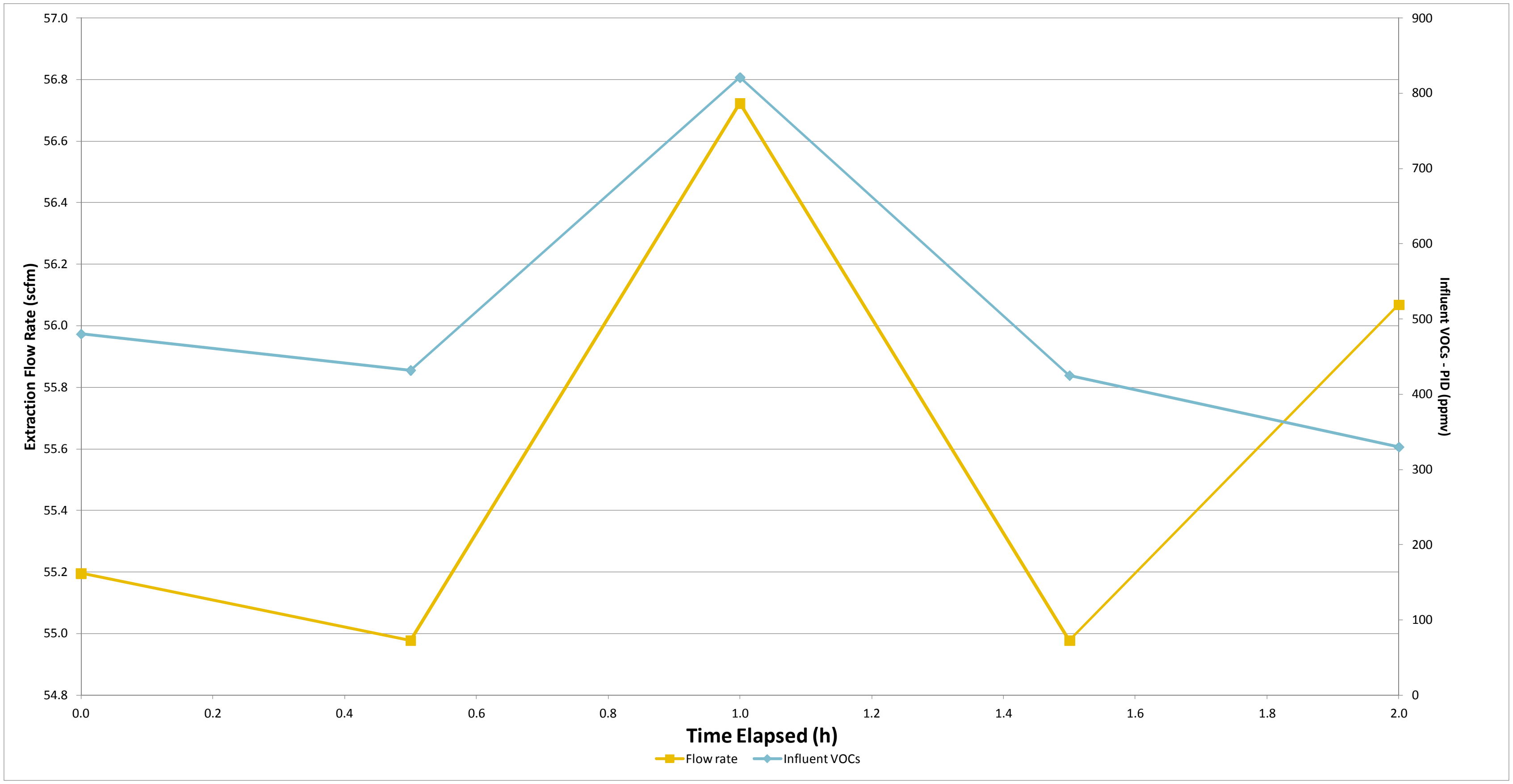
FIGURE
C-4



NOTES:

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Influent VOCs and Flow rate vs. Time Elapsed
Constant Rate VE-1 (#1)

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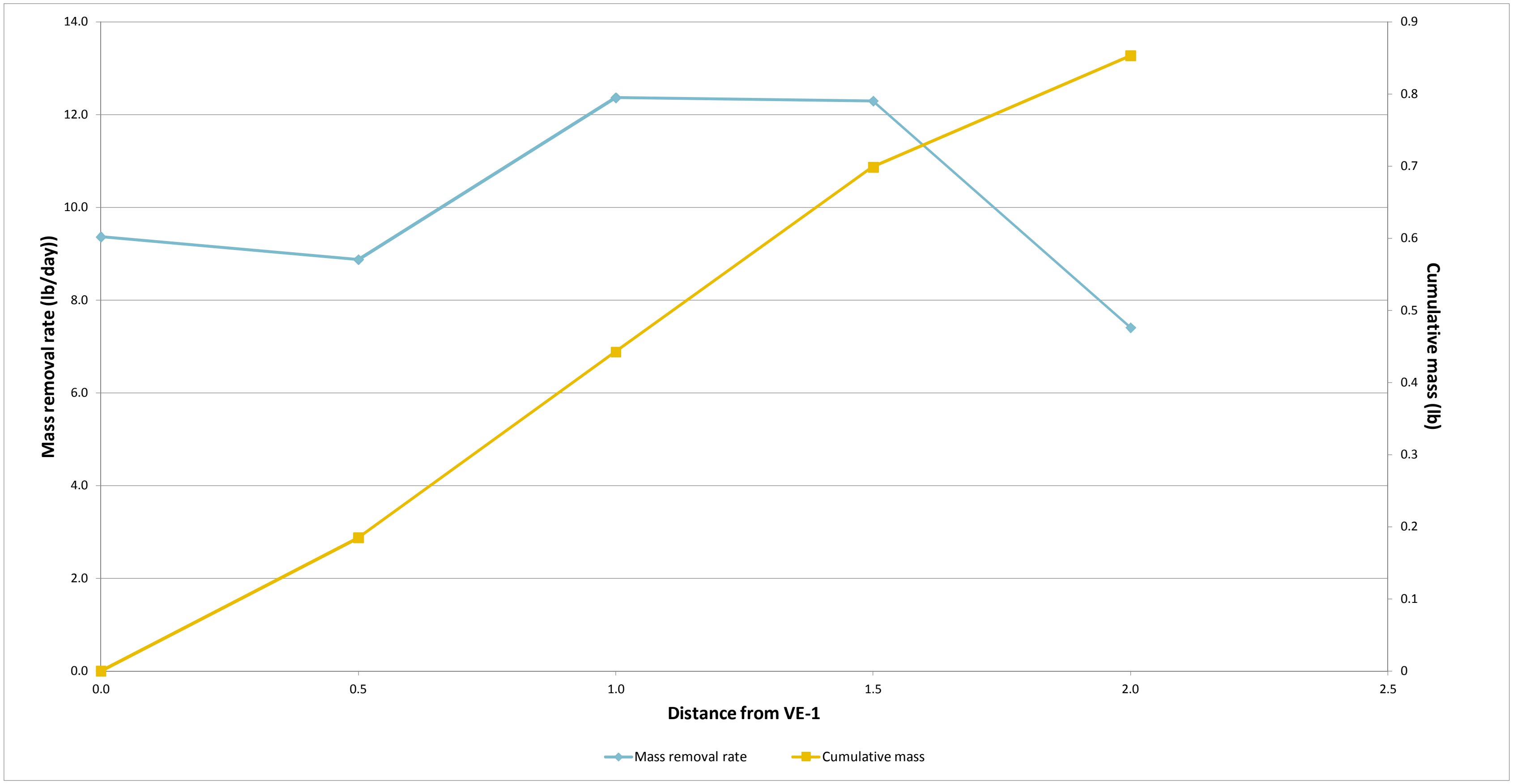
FIGURE
C-5



NOTES:

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GRO Mass Removal - VE-1 Constant RateTest (#1)

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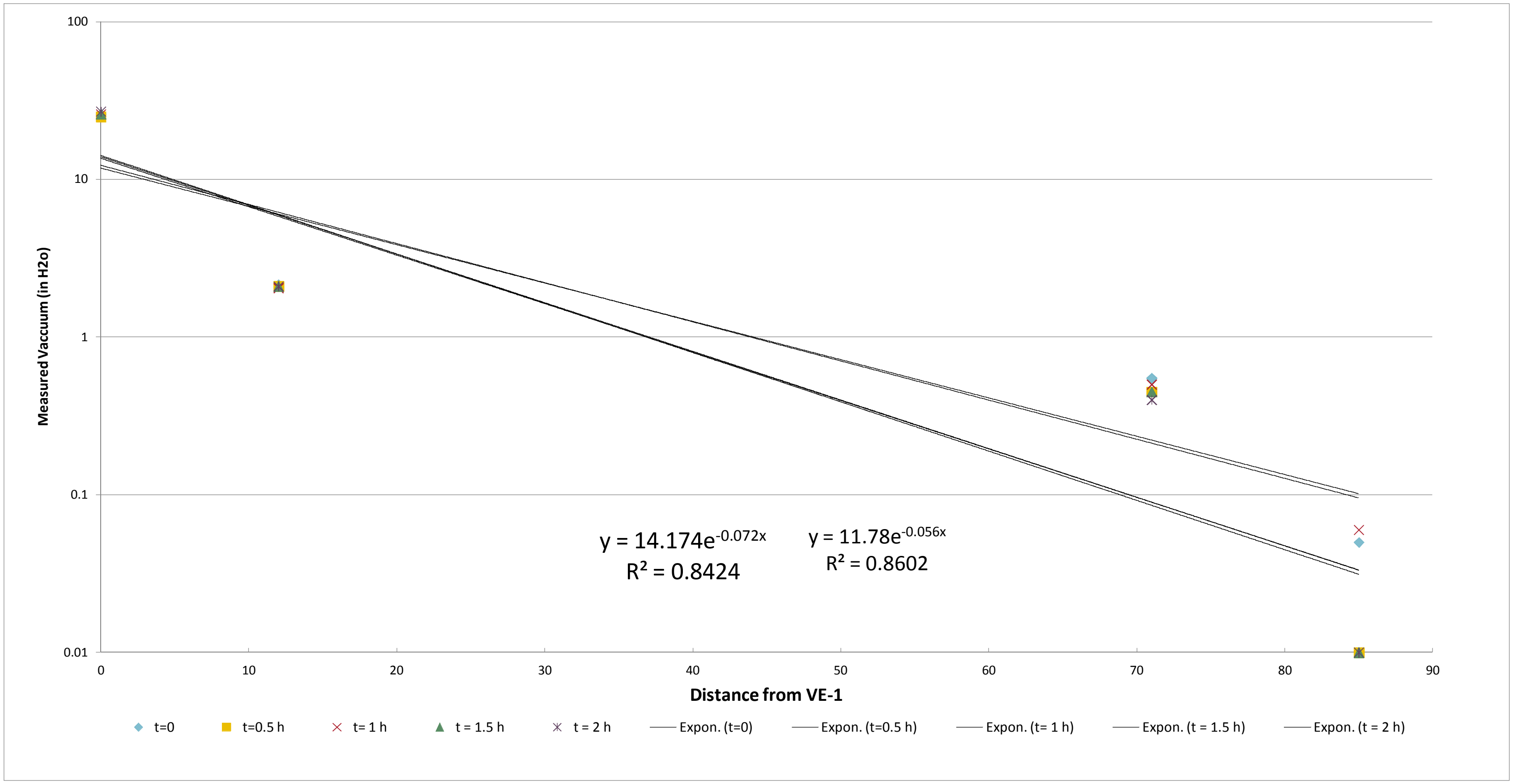
FIGURE
C-6



NOTES:

Data does not include readings from MW-5. Pressure readings were close to zero. MW-1 which is located at a similar distance from VE-1as MW-5 had pressure readings greater than 0. The screen interval of VE-1 is 8 to 18 feet btoc. The screen interval for MW-1 and MW-5 is 13 to 28 feet btoc.

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Measured Vacuum vs. Distance
Constant Rate Test VE-1 (log scale) (#1)

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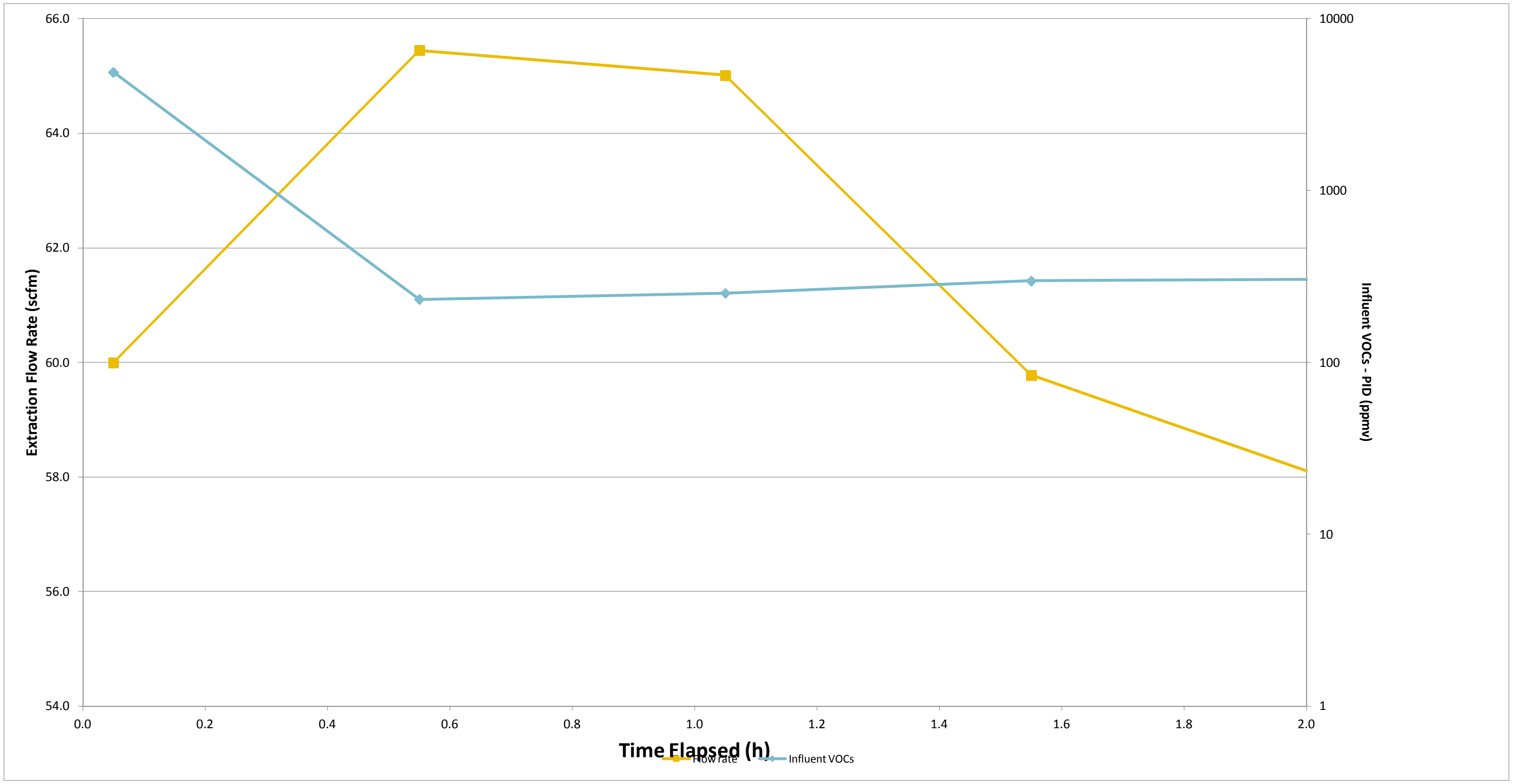
FIGURE
C-7



NOTES:

Former ARCO Facility No. 00977
155 N W 85th St, Seattle, WA 98107

Influent VOCs and Flow rate vs. Time Elapsed
Constant Rate Test VE-1 (#2)

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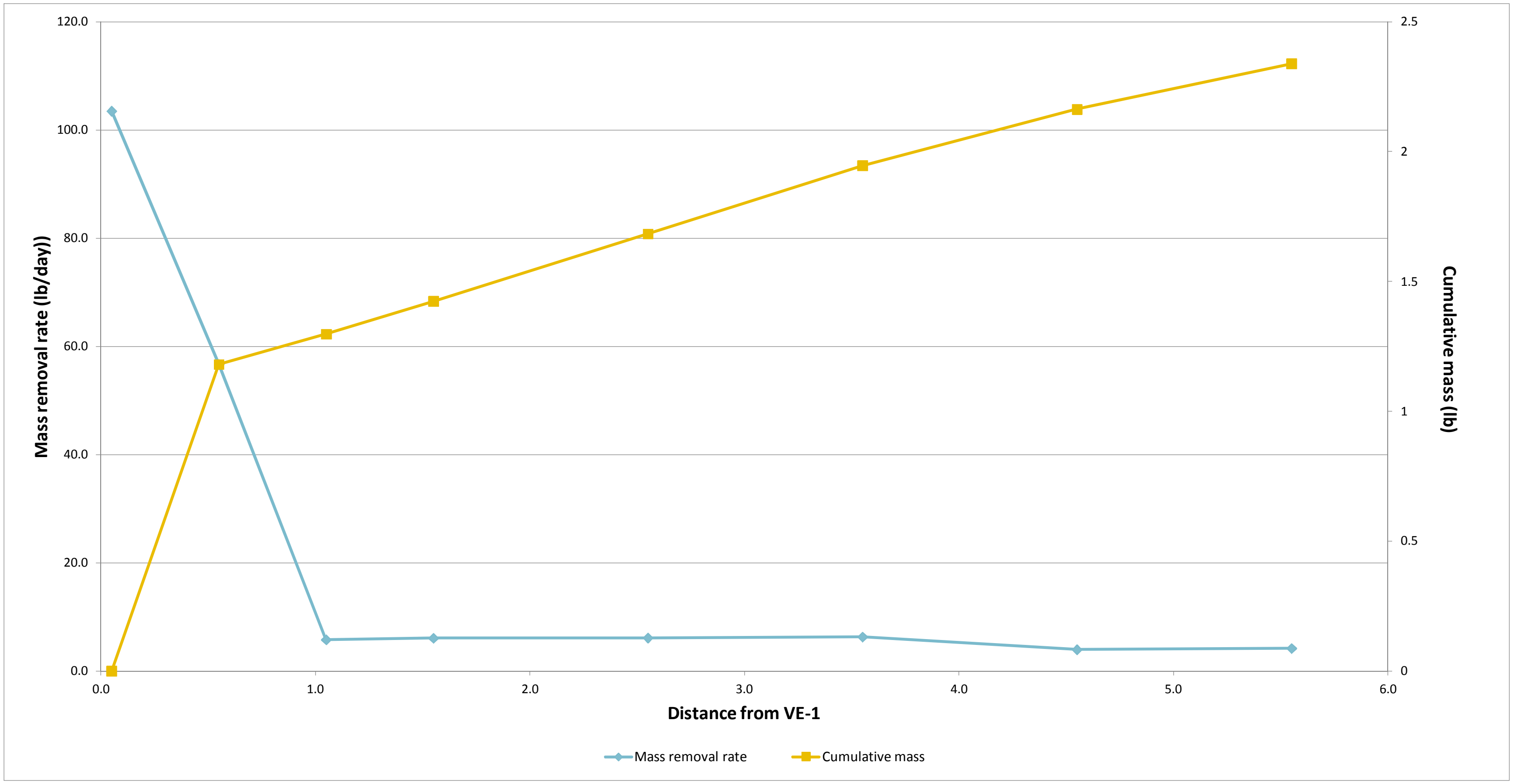
FIGURE
C-8



NOTES:

Former ARCO Facility No. 00977
155 N W 85th St, Seattle, WA 98107

GRO Mass Removal - VE-1 Constant RateTest (#2)

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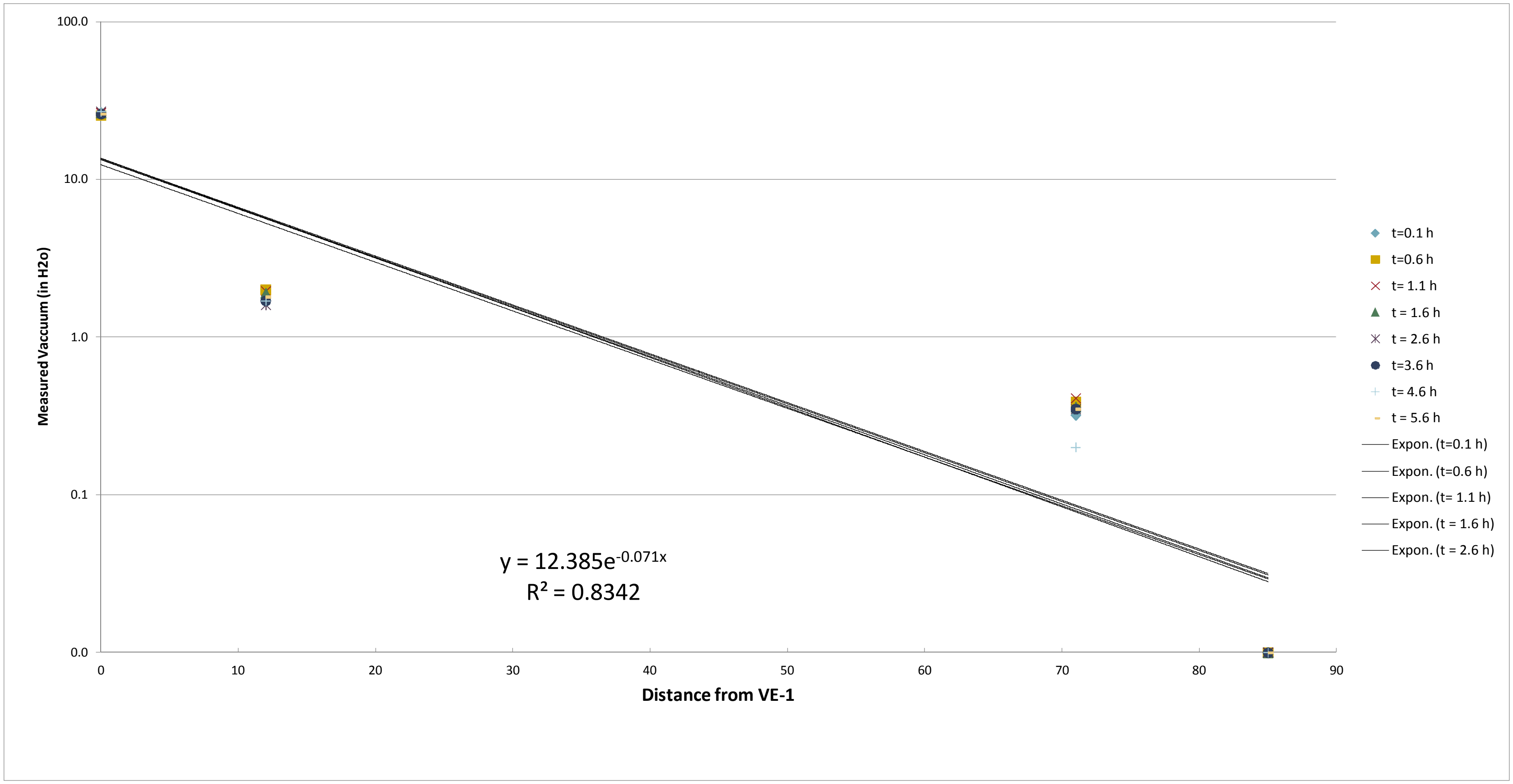
FIGURE
C-9



NOTES:

Data does not include readings from MW-5. Pressure readings were close to zero. MW-1 which is located at a similar distance from VE-1as MW-5 had pressure readings greater than 0. The screen interval of VE-1 is 8 to 18 feet btoc. The screen interval for MW-1 and MW-5 is 13 to 28 feet btoc.

Former ARCO Facility No. 00977
155 N W 85th St, Seattle, WA 98107

Measured Vacuum vs. Distance
Constant Rate Test VE-1 (log scale) (#2)

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FIGURE
C-10

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

March 18, 2011

Scott Zorn
Arcadis U.S., Inc.
2300 Eastlake Ave E. Ste. 200
Seattle, WA 98102

RE: Project: ARCO 977
Pace Project No.: 256787

Dear Scott Zorn:

Enclosed are the analytical results for sample(s) received by the laboratory on February 24, 2011. The results relate only to the samples included in this report. Results reported herein conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Andy Brownfield for
Regina SteMarie
regina.stemarie@pacelabs.com
Project Manager

Enclosures

cc: Alan Kahal, Arcadis U.S., Inc.
Nick Olivier, Arcadis U.S., Inc.
David Rasar, Arcadis U.S., Inc.
Rick Rodriguez, Arcadis U.S., Inc.

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CERTIFICATIONS

Project: ARCO 977
Pace Project No.: 256787

Minnesota Certification IDs
1700 Elm Street SE Suite 200, Minneapolis, MN 55414
A2LA Certification #: 2926.01
Alaska Certification #: UST-078
Alaska Certification #MN00064
Arizona Certification #: AZ-0014
Arkansas Certification #: 88-0680
California Certification #: 01155CA
EPA Region 8 Certification #: Pace
Florida/NELAP Certification #: E87605
Georgia Certification #: 959
Idaho Certification #: MN00064
Illinois Certification #: 200011
Iowa Certification #: 368
Kansas Certification #: E-10167
Louisiana Certification #: 03086
Louisiana Certification #: LA080009
Maine Certification #: 2007029
Maryland Certification #: 322
Michigan DEQ Certification #: 9909
Minnesota Certification #: 027-053-137
Mississippi Certification #: Pace
Montana Certification #: MT CERT0092
Nevada Certification #: MN_00064
Nebraska Certification #: Pace
New Jersey Certification #: MN-002
New Mexico Certification #: Pace
New York Certification #: 11647
North Carolina Certification #: 530
North Dakota Certification #: R-036
North Dakota Certification #: R-036A
Ohio VAP Certification #: CL101
Oklahoma Certification #: D9921
Oklahoma Certification #: 9507
Oregon Certification #: MN200001
Pennsylvania Certification #: 68-00563
Puerto Rico Certification
Tennessee Certification #: 02818
Texas Certification #: T104704192
Washington Certification #: C754
Wisconsin Certification #: 999407970

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SAMPLE ANALYTE COUNT

Project: ARCO 977
Pace Project No.: 256787

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
256787001	**SVE1**	Method 3C Gases	RTP	5	PASI-M
		TO-3 Air	RTP	10	PASI-M
256787002	**SVE2**	Method 3C Gases	RTP	5	PASI-M
		TO-3 Air	RTP	10	PASI-M

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PROJECT NARRATIVE

Project: ARCO 977
Pace Project No.: 256787

Method: **Method 3C Gases**
Description: Method 3C AIR - Fixed Gases
Client: Arcadis U.S., Inc.
Date: March 18, 2011

General Information:
2 samples were analyzed for Method 3C Gases. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Internal Standards:
All internal standards were within QC limits with any exceptions noted below.

Surrogates:
All surrogates were within QC limits with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

QC Batch: AIR/11896

R1: RPD value was outside control limits.
- LCSD (Lab ID: 943148)
  - Oxygen

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

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PROJECT NARRATIVE

Project: ARCO 977
Pace Project No.: 256787

Method: **TO-3 Air**
Description: TO3 GCV AIR BTEX CAN
Client: Arcadis U.S., Inc.
Date: March 18, 2011

General Information:
2 samples were analyzed for TO-3 Air. All samples were received in acceptable condition with any exceptions noted below.

Hold Time:
The samples were analyzed within the method required hold times with any exceptions noted below.

Initial Calibrations (including MS Tune as applicable):
All criteria were within method requirements with any exceptions noted below.

Continuing Calibration:
All criteria were within method requirements with any exceptions noted below.

Internal Standards:
All internal standards were within QC limits with any exceptions noted below.

Surrogates:
All surrogates were within QC limits with any exceptions noted below.

Method Blank:
All analytes were below the report limit in the method blank with any exceptions noted below.

Laboratory Control Spike:
All laboratory control spike compounds were within QC limits with any exceptions noted below.

Matrix Spikes:
All percent recoveries and relative percent differences (RPDs) were within acceptance criteria with any exceptions noted below.

Duplicate Sample:
All duplicate sample results were within method acceptance criteria with any exceptions noted below.

Additional Comments:

This data package has been reviewed for quality and completeness and is approved for release.

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ANALYTICAL RESULTS

Project: ARCO 977
Pace Project No.: 256787

Sample: SVE1 **Lab ID: 256787001** Collected: 02/22/11 17:30 Received: 02/24/11 12:07 Matrix: Air

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
Method 3C AIR - Fixed Gases	Analytical Method: Method 3C Gases							
Carbon dioxide	**2.7**	%	2.0	1		03/15/11 10:48	124-38-9	
Carbon monoxide	ND	%	0.40	1		03/15/11 10:48	630-08-0	
Methane	ND	%	4.0	1		03/15/11 10:48	74-82-8	
Nitrogen	**74.9**	%	8.0	1		03/15/11 10:48	7727-37-9	
Oxygen	**15.7**	%	2.0	1		03/15/11 10:48	7782-44-7	
TO3 GCV AIR BTEX CAN	Analytical Method: TO-3 Air							
Benzene	**7.9**	ppmv	1.3	13.4		03/17/11 09:14	71-43-2	
Ethylbenzene	**7.6**	ppmv	1.3	13.4		03/17/11 09:14	100-41-4	
n-Hexane	**49.6**	ppmv	1.3	13.4		03/17/11 09:14	110-54-3	
Methyl-tert-butyl ether	**6.4**	ppmv	1.3	13.4		03/17/11 09:14	1634-04-4	
THC as Gas	**767**	ppmv	13.4	13.4		03/17/11 09:14		
Toluene	**51.6**	ppmv	1.3	13.4		03/17/11 09:14	108-88-3	
1,2,4-Trimethylbenzene	**4.8**	ppmv	1.3	13.4		03/17/11 09:14	95-63-6	
1,3,5-Trimethylbenzene	**2.4**	ppmv	1.3	13.4		03/17/11 09:14	108-67-8	
m&p-Xylene	**36.5**	ppmv	2.7	13.4		03/17/11 09:14	179601-23-1	
o-Xylene	**10.9**	ppmv	1.3	13.4		03/17/11 09:14	95-47-6	

Sample: SVE2 **Lab ID: 256787002** Collected: 02/23/11 15:05 Received: 02/24/11 12:07 Matrix: Air

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
Method 3C AIR - Fixed Gases	Analytical Method: Method 3C Gases							
Carbon dioxide	ND	%	2.0	1		03/15/11 11:00	124-38-9	
Carbon monoxide	ND	%	0.40	1		03/15/11 11:00	630-08-0	
Methane	ND	%	4.0	1		03/15/11 11:00	74-82-8	
Nitrogen	**75.1**	%	8.0	1		03/15/11 11:00	7727-37-9	
Oxygen	**18.3**	%	2.0	1		03/15/11 11:00	7782-44-7	
TO3 GCV AIR BTEX CAN	Analytical Method: TO-3 Air							
Benzene	**5.4**	ppmv	0.69	6.9		03/17/11 12:40	71-43-2	
Ethylbenzene	**4.3**	ppmv	0.69	6.9		03/17/11 12:40	100-41-4	
n-Hexane	**31.2**	ppmv	0.69	6.9		03/17/11 12:40	110-54-3	
Methyl-tert-butyl ether	**3.6**	ppmv	0.69	6.9		03/17/11 12:40	1634-04-4	
THC as Gas	**471**	ppmv	6.9	6.9		03/17/11 12:40		
Toluene	**29.8**	ppmv	0.69	6.9		03/17/11 12:40	108-88-3	
1,2,4-Trimethylbenzene	**2.7**	ppmv	0.69	6.9		03/17/11 12:40	95-63-6	
1,3,5-Trimethylbenzene	**1.3**	ppmv	0.69	6.9		03/17/11 12:40	108-67-8	
m&p-Xylene	**18.3**	ppmv	1.4	6.9		03/17/11 12:40	179601-23-1	
o-Xylene	**5.6**	ppmv	0.69	6.9		03/17/11 12:40	95-47-6	

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QUALITY CONTROL DATA

Project: ARCO 977
Pace Project No.: 256787

QC Batch: AIR/11896 — Analysis Method: Method 3C Gases
QC Batch Method: Method 3C Gases — Analysis Description: METHOD 3C AIR - FIXED GASES
Associated Lab Samples: 256787001, 256787002

METHOD BLANK: 943146 — Matrix: Air
Associated Lab Samples: 256787001, 256787002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Carbon dioxide	%	ND	2.0	03/15/11 09:41	
Carbon monoxide	%	ND	0.40	03/15/11 09:41	
Methane	%	ND	4.0	03/15/11 09:41	
Nitrogen	%	ND	8.0	03/15/11 09:41	
Oxygen	%	ND	2.0	03/15/11 09:41	

LABORATORY CONTROL SAMPLE & LCSD: 943147 943148

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
Carbon dioxide	%	10	11.6	9.0	116	90	70-130	26	30	
Carbon monoxide	%	2	2.3	1.8	116	89	70-130	26	30	
Methane	%	20	23.8	17.6	119	88	70-130	30	30	
Nitrogen	%	40	32.0	41.5	80	104	70-130	26	30	
Oxygen	%	10	8.7	11.8	87	118	70-130	31	30	R1

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QUALITY CONTROL DATA

Project: ARCO 977
Pace Project No.: 256787

QC Batch: AIR/11924
Analysis Method: TO-3 Air
QC Batch Method: TO-3 Air
Analysis Description: TO3 GCV AIR BTEX CAN
Associated Lab Samples: 256787001, 256787002

METHOD BLANK: 944427 Matrix: Air
Associated Lab Samples: 256787001, 256787002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
1,2,4-Trimethylbenzene	ppmv	ND	0.10	03/17/11 08:55	
1,3,5-Trimethylbenzene	ppmv	ND	0.10	03/17/11 08:55	
Benzene	ppmv	ND	0.10	03/17/11 08:55	
Ethylbenzene	ppmv	ND	0.10	03/17/11 08:55	
m&p-Xylene	ppmv	ND	0.20	03/17/11 08:55	
Methyl-tert-butyl ether	ppmv	ND	0.10	03/17/11 08:55	
n-Hexane	ppmv	ND	0.10	03/17/11 08:55	
o-Xylene	ppmv	ND	0.10	03/17/11 08:55	
THC as Gas	ppmv	ND	1.0	03/17/11 08:55	
Toluene	ppmv	ND	0.10	03/17/11 08:55	

LABORATORY CONTROL SAMPLE & LCSD: 944428 944429

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
1,2,4-Trimethylbenzene	ppmv	1	0.95	0.92	95	92	70-130	3	30	
1,3,5-Trimethylbenzene	ppmv	1	0.96	0.94	96	94	70-130	2	30	
Benzene	ppmv	1	0.96	0.94	96	94	70-130	2	30	
Ethylbenzene	ppmv	1	0.98	0.98	98	98	70-130	.6	30	
m&p-Xylene	ppmv	2	2.0	2.0	100	99	70-130	2	30	
Methyl-tert-butyl ether	ppmv	1	1.1	1.0	106	104	70-130	2	30	
n-Hexane	ppmv	1	1.0	0.99	100	99	70-130	1	30	
o-Xylene	ppmv	1	0.99	0.98	99	98	70-130	1	30	
THC as Gas	ppmv	10	10.3	10.3	103	103	70-130	.06	30	
Toluene	ppmv	1	1.0	0.99	100	99	70-130	1	30	

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QUALIFIERS

Project:	ARCO 977
Pace Project No.:	256787

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to changes in sample preparation, dilution of the sample aliquot, or moisture content.

ND - Not Detected at or above adjusted reporting limit.

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

S - Surrogate

1,2-Diphenylhydrazine (8270 listed analyte) decomposes to Azobenzene.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel Clean-Up

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is NELAP accredited. Contact your Pace PM for the current list of accredited analytes.

LABORATORIES

PASI-M	Pace Analytical Services - Minneapolis

ANALYTE QUALIFIERS

R1	RPD value was outside control limits.

Pace Analytical Services, Inc.
940 South Harney
Seattle, WA 98108
(206)767-5060

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: ARCO 977
Pace Project No.: 256787

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
256787001	**SVE1**	Method 3C Gases	AIR/11896		
256787002	**SVE2**	Method 3C Gases	AIR/11896		
256787001	**SVE1**	TO-3 Air	AIR/11924		
256787002	**SVE2**	TO-3 Air	AIR/11924		

256787

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AIR: CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page: 1 of 1

Section A Required Client Information:
- Company: ARCADIS
- Address: 2300 Eastlake Ave E. Seattle WA 98102
- Scott.Zorn@Arcadis-us.com
- Phone: 206 726 4709 Fax:
- Requested Due Date/TAT: Standard

Section B Required Project Information:
- Report To: Alan Kahal
- Copy To: Peter Campbell
- Purchase Order No.: GP09BPNA.WA08
- Project Name: ARCO 977
- Project Number:

Section C Invoice Information:
- Attention:
- Company Name:
- Address:
- Pace Quote Reference:
- Pace Project Manager/Sales Rep. Regina SteMarie
- Pace Profile #: 22095/L14

Program: ☐ UST ☐ Suprefund ☐ Emmisions ☐ Clean Air Act ☒ Voluntary Clean Up ☐ Dry Clean ☐ RCRA ☐ Other____

Location of Sampling by State: WA

Reporting Units: ug/m³ X mg/m³ ___ PPBV ___ PPMV ___ Other ___

Report Level II.___ III.___ IV.___ Other___

Section D Required Client Information

Valid Media Codes: Tedlar Bag TB; 1 Liter Summa Can 1LC; 6 Liter Summa Can 6LC; Low Volume Puff LVP; High Volume Puff HVP; PM10 PM10

ITEM #	AIR SAMPLE ID (One Character per box. (A-Z, 0-9 / -) Sample IDs MUST BE UNIQUE)	MEDIA CODE	SAMPLE TYPE G=Grab C=Composite	COLLECTED Composite Start / End-Grab DATE	TIME	Composite End DATE	TIME	Canister Pressure (Initial Field)	Canister Pressure (Final Field)	Summa Can Number	TO-3 BTEX+TPH(ppm)	TO-3M PPMV MEE	3C- Fixed Gas (%)	TO-14 (39 VOCs)	TO-15 (59+VOCs)	TO-15 Low Level	TO-13 (PAH)	TO-4 (PCBs)	PM10	Pace Lab ID
1	SVE1	HVP	G	2/22	1730			-30	-5	1464	X		X							
2	SVE2	HVP	G	2/23	1505			-30	-5	1079	X		X							
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				

Additional Comments:

RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	Temp in °C	Received on Ice Y/N	Custody Sealed Cooler Y/N	Samples Intact Y/N
Nick Olivier/Arcadis	2/24	1207	Regina SteMarie	02/24/11	12:07	21.0	N	N	Y
							Y/N	Y/N	Y/N
							Y/N	Y/N	Y/N
							Y/N	Y/N	Y/N

SAMPLER NAME AND SIGNATURE
- PRINT Name of SAMPLER: Nick Olivier
- SIGNATURE of SAMPLER: [signature]
- DATE Signed (MM / DD / YY): 2/23/2011

Sample Container Count

256787

Pace Analytical™

CLIENT: Arcadis

COC PAGE 1 of 1

COC ID# —

Sample Line Item	VG9H	AG1H	AG1U	BG1H	BP1U	BP2U	BP3U	BP2N	BP2S	WGFU	WGKU	U			Comments
1												1			
2												1			
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															Trip Blank? No

AG1H	1 liter HCL amber glass		BP2S	500mL H2SO4 plastic	JGFU	4oz unpreserved amber wide
AG1U	1liter unpreserved amber glass		BP2U	500mL unpreserved plastic	R	terra core kit
AG2S	500mL H2SO4 amber glass		BP2Z	500mL NaOH, Zn Ac	U	Summa Can
AG2U	500mL unpreserved amber glass		BP3C	250mL NaOH plastic	VG9H	40mL HCL clear vial
AG3S	250mL H2SO4 amber glass		BP3N	250mL HNO3 plastic	VG9T	40mL Na Thio. clear vial
BG1H	1 liter HCL clear glass		BP3S	250mL H2SO4 plastic	VG9U	40mL unpreserved **clear** vial
BG1U	1 liter unpreserved glass		BP3U	250mL unpreserved plastic	VG9W	40mL glass vial preweighted (EPA 5035)
BP1N	1 liter HNO3 plastic		DG9B	40mL Na Bisulfate amber vial	VSG	Headspace septa vial & HCL
BP1S	1 liter H2SO4 plastic		DG9H	40mL HCL amber voa vial	WGFU	4oz clear soil jar
BP1U	1 liter unpreserved plastic		DG9M	40mL MeOH clear vial	WGFX	4oz wide jar w/hexane wipe
BP1Z	1 liter NaOH, Zn, Ac		DG9T	40mL Na Thio amber vial	ZPLC	Ziploc Bag
BP2N	500mL HNO3 plastic		DG9U	40mL unpreserved **amber** vial		
BP2O	500mL NaOH plastic		I	Wipe/Swab		

Pace Analytical

Sample Condition Upon Receipt

Client Name: Arcadis   Project # 256787

Courier: ☐ Fed Ex ☐ UPS ☐ USPS ☑ Client ☐ Commercial ☐ Pace Other ______

Tracking #: ______

Custody Seal on Cooler/Box Present: ☐ Yes ☑ No   Seals intact: ☐ Yes ☐ No

Packing Material: ☐ Bubble Wrap ☐ Bubble Bags ☑ None ☐ Other ______   Temp. Blank Yes (No)

Thermometer Used 132013 or 101731962 or (226099)   Type of Ice: Wet Blue (None)   ☐ Samples on ice, cooling process has begun

Cooler Temperature 21.0   Biological Tissue is Frozen: Yes No   Date and Initials of person examining contents: NJS 2/24/11

Temp should be above freezing ≤ 6°C   Comments:

Chain of Custody Present:	☑Yes ☐No ☐N/A	1.
Chain of Custody Filled Out:	☐Yes ☑No ☐N/A	2. Analysis pending.
Chain of Custody Relinquished:	☑Yes ☐No ☐N/A	3.
Sampler Name & Signature on COC:	☑Yes ☐No ☐N/A	4.
Samples Arrived within Hold Time:	☑Yes ☐No ☐N/A	5.
Short Hold Time Analysis (<72hr):	☐Yes ☑No ☐N/A	6.
Rush Turn Around Time Requested:	☐Yes ☑No ☐N/A	7.
Follow Up / Hold Analysis Requested:	☐Yes ☑No ☐N/A	8.
Sufficient Volume:	☑Yes ☐No ☐N/A	9.
Correct Containers Used: -Pace Containers Used:	☑Yes ☐No ☐N/A ☑Yes ☐No ☐N/A	10. Summa Cans.
Containers Intact:	☑Yes ☐No ☐N/A	11.
Filtered volume received for Dissolved tests	☐Yes ☐No ☑N/A	12.
Sample Labels match COC: -Includes date/time/ID/Analysis Matrix: AIR	☑Yes ☐No ☐N/A	13.
All containers needing preservation have been checked.	☐Yes ☐No ☑N/A	14.
All containers needing preservation are found to be in compliance with EPA recommendation.	☐Yes ☐No ☑N/A	
Exceptions: VOA, coliform, TOC, O&G		Initial when completed / Lot # of added preservative
Samples checked for dechlorination:	☐Yes ☐No ☑N/A	15.
Headspace in VOA Vials (>6mm):	☐Yes ☐No ☑N/A	16.
Trip Blanks Present:	☐Yes ☑No ☐N/A	17.
Trip Blank Custody Seals Present	☐Yes ☐No ☑N/A	
Pace Trip Blank Lot # (if purchased): ______		

Client Notification/ Resolution: Field Data Required? Y / N

Person Contacted: Alan Kahal   Date/Time: @ receipt

Comments/ Resolution:

COC to be delivered w/ next shipment of summa cans.
Hold for shipment until all samples received. RSM 02/25/11

Project Manager Review: RSM   Date: 03/04/11

Note: Whenever there is a discrepancy affecting North Carolina compliance samples, a copy of this form will be sent to the North Carolina DEHNR Certification Office (i.e out of hold, incorrect preservative, out of temp, incorrect containers)

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Appendix **D**

Remediation Design Calculations For Soil Vapor Extraction and Air Sparge System

Remediation Design Calculations
For Soil Vapor Extraction and Air Sparge System

Prepared for:

Remedial Action Plan
Former BP Station No. 0977
155 NW 85th Street, Seattle, WA

Prepared by:

ARCADIS
2300 Eastlake Avenue East, Suite 100
Seattle, Washington

November 10, 2011

AIR SPARGE (AS)

Minimum Injection Pressure
(*Air Sparging Design Paradigm*)

Minimum Injection Pressure = (0.43) * (hydrostatic head) + [air entry pressure for the well annulus packing material + air entry pressure for the formation (sand and gravel - assume 0.2 psig per *Air Sparging Design Paradigm*)]

Low groundwater
Minimum Injection Pressure = (0.43) * (32 feet-2 feet-19.65 feet) + (0.2 psi) = 4.7 psi

High groundwater
Maximum Injection Pressure = (0.43) * (32 feet-2 feet-16.28 feet) + (0.2 psi) = 6.1 psi

Maximum Injection Pressure
(US Army Corps of Engineers *In-Situ Air Sparging*)

$$\text{Pressure}_{\text{soil column}} = (\text{depth}_{\text{top well screen}}) * (G_s) * (1\text{-}n) * (\rho_{H2O})$$

$$\text{Pressure}_{\text{H2O column}} = (\text{depth}_{\text{top well screen}} - \text{DTW})*(n)*(\rho_{H2O})$$

G_s = Specific gravity of soil = 2.7*(specific gravity of water @ 20 degrees Celsius)
n = Porosity = 30 % = 0.30 (silty sand)
depth $_{\text{top well screen}}$ = 30 ft
ρ_{H2O} = density of water
DTW = Depth to water table = 16.28 ft

$$P_{\text{soil column}} = (30\text{ ft})*(2.7)*(1-0.30)*(62.4\ \frac{lb_m}{ft^3}) = 3538\ \frac{lb_m}{ft^2} = 24.6\ \text{psi}$$

$$P_{\text{H2O column}} = (30\text{ ft} - 16.28\text{ ft})*(0.30)*(62.4\ \frac{lb_m}{ft^3}) = 257\ \frac{lb_m}{ft^2} = 1.8\ \text{psi}$$

Total Overburden Pressure = $P_{\text{soil column}} + P_{\text{H2O column}}$ = 24.6 psi + 1.8 psi = 26.4 psi

Air Sparge design paradigm suggests a range of: $\mathbf{P_{Injection}}$ **=** 0.6* (Total Overburden Pressure) to $\mathbf{P}_{\text{Injection}}$ = 0.8* (Total Overburden Pressure)

$\mathbf{P}_{\text{Injection}}$ = 0.6*(Total Overburden Pressure) = 0.6*(26.4 psi) **= 15.6 psi**
$\mathbf{P}_{\text{Injection}}$ = 0.8*(Total Overburden Pressure) = 0.8*(26.4 psi) **= 21.1 psi**

Air Flow

There are 4 proposed AS wells. The AS wells will be divided up into 2 zones with 2 wells each. Therefore, the total required flow = 2 * (15 scfm) = 30 scfm.

The AS compressor must be capable of producing 30 scfm at a pressure between approximately 4.7 to 21.1 psi at the well head, and designed for three phase electrical service. Air flow will be 15 scfm at each well, with a maximum injection pressure of 21.1 psi.

Frictional Pressure Loss

Based on a maximum flow rate of 30 scfm and a pipe diameter of 2 inches, the pressure loss due to friction is anticipated to be 0.023 inches H_20 (0.0008 psi) per foot of pipe. An extra 5 feet of pipe length per 90 degree elbow was also figured into the pressure loss calculation. An estimated 260 feet of maximum pipe run per zone and 10 elbows results in a maximum pressure loss of 5.98 in H_20. This converts to 0.22 psi.

The friction loss was estimated based on Figure 5-15 in US Army Corps of Engineers Manual EM 1110-1-4001, Engineering and Design - Soil Vapor Extraction and Bioventing (2002).

SOIL VAPOR EXTRACTION

Air Flow

Initially, it is proposed that three extraction wells will be operating (VE-1, VE-2, and VE-3). To ensure that a minimum of one pore volume (V_p) per day of vapor will be extracted from the subsurface to mitigate vapor migration and build up, the blower will operate at approximately 48 cfm per well. The required flow rate (Q_f) in cubic feet per minute was estimated based on the soil porosity (n) of 0.3 (unitless), the measured effective radius of observed induced vacuum (R) of 65 feet and the vadose zone depth (L) of 17.5 feet. The length of the vadose zone is the average of depth-to-water measurements based on historical data for onsite wells.

$$Q_f = (V_p * \pi * R^2 * L * n)$$

$$Q_f = (1 \frac{pore}{day} * \pi * (65 \text{ ft})^2 * 17.5 \text{ ft} * 0.3) / 1440 \frac{\min}{day}$$

$$Q_f = 48 \frac{ft^3}{\min} \text{ per well}$$

During the SVE pilot study, two constant rate tests were conducted. The average flow rate was 58 scfm and observed vacuum ROI was 72.5 feet. The extraction vacuum during the constant rate test was between 25 and 27 in. wc. It is expected that vacuum during normal SVE system operation will be similar to these values.

Frictional Vacuum Loss

Based on a flow rate of 145 scfm and a 2 inch pipe diameter, the pressure loss due to friction is approximately 0.021 inches H_20 (0.0008 psi) per foot of pipe. The maximum total length of piping is approximately 200 feet. An extra 5 feet of pipe length per 90 degree elbow was also figured into the pressure loss calculation. Assuming 10 elbows and 200 feet of pipe the total length used to determine the pressure loss of the system is 250 feet. This results in an overall pressure loss of approximately 4.2 in. H_20 or 0.15 psi.

The friction loss was estimated based on Figure 5-15 in US Army Corps of Engineers Manual EM 1110-1-4001, Engineering and Design - Soil Vapor Extraction and Bioventing (2002).

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Appendix **E**

ARCADIS Standard Operating Procedures (SOPs)

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Monitoring Well Installation

Rev. #: 2

Rev Date: August 22, 2008

Approval Signatures

Prepared by: Sonya A Cadle Date: 8/25/08

Reviewed by: Michael J Gefell Date: 8/25/08
(Technical Expert)

I. Scope and Application

The procedures set out herein are designed to produce standard groundwater monitoring wells suitable for: (1) groundwater sampling, (2) water level measurement, (3) bulk hydraulic conductivity testing of formations adjacent to the open interval of the well.

Monitoring well boreholes in unconsolidated (overburden) materials are typically drilled using the hollow-stem auger drilling method. Other drilling methods that are also suitable for installing overburden monitoring wells, and are sometimes necessary due to site-specific geologic conditions, include: 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 driven well points may also be used in some cases within the overburden. Monitoring wells within consolidated materials such as bedrock are commonly drilled using water-rotary (coring or tri-cone roller bit), air rotary or Rotasonic methods. 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, and cost.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). No coated bentonite pellets will be used in the well drilling or construction process. Specifications of materials to be installed in the well will be obtained prior to mobilizing onsite, including:

- well casing;
- bentonite;
- sand; and
- grout.

Well materials will be inspected and, if needed, cleaned prior to installation.

II. Personnel Qualifications

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. Where field sampling is performed for soil or bedrock characterization, field personnel will have undergone in-field training in soil or bedrock description methods, as described in the appropriate SOP(s) for those activities.

III. Equipment List

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Site Plan with proposed soil boring/well locations;
- Work Plan or Field Sampling Plan (FSP), and site 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 appropriate SOPs;
- appropriate sample containers and labels;
- drum labels as required for investigation derived waste handling;
- chain-of-custody forms;
- 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);

- field notebook.

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 will be necessary to ensure that the materials provided will meet the project objectives. Equipment typically provided by the driller could include:

- drilling equipment required by the American Society of Testing and Materials (ASTM) D 1586, when performing split-spoon sampling;
- disposable plastic liners, when drilling with direct-push equipment;
- drums for investigation derived waste;
- drilling and sampling equipment decontamination materials;
- decontamination pad materials, if required; and
- well construction materials.

IV. 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 separate SOP for utility clearance.

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 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. Determine whether the oversight agency has any such requirements prior to finalizing the drilling and well installation plan.

If dense non-aqueous phase liquids (DNAPL) are known or expected to exist at the site, refer to the DNAPL Contingency Plan SOP for additional details regarding drilling and well installation to reduce the potential for inadvertent DNAPL remobilization.

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

Similarly, consider the material 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.

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. Testing of water supply should be considered.

Specifications of materials used for backfilling bore hole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPLs are likely to be present. In these situations, neat cement grout is preferred.

No coated bentonite pellets will be used in monitoring well construction, as the coating could impact the water quality in the completed well.

Monitoring wells may be installed with Schedule 40 polyvinyl chloride (PVC) to a maximum depth of 200 feet below ground surface (bgs). PVC monitoring wells between 200 and 400 feet total depth will be constructed using Schedule 80 PVC. Monitoring wells deeper than 400 feet will be constructed using steel.

V. 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.

VI. Procedures

The procedures for installing groundwater monitoring wells are presented below:

Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Locate boring/well location, establish work zone, and set up sampling equipment decontamination area.

2. Advance boring to desired depth. Collect soil and/or bedrock samples at appropriate interval as specified in the Work Plan and/or FSP. Collect, document, and store samples for laboratory analysis as specified in the Work Plan and/or FSP. Decontaminate equipment between samples in accordance with the Work Plan and/or FSP. A common sampling method that produces

high-quality soil samples with relatively little soil disturbance is the ASTM D 1586 - Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils. Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary. Rotasonic drilling produces large-diameter soil cores that tend to be more disturbed than split-spoon samples due to the vibratory action of the drill casing. Dual-rotary removes cuttings by compressed air and allows only a general assessment of geology. High-quality bedrock samples can be obtained by coring.

3. Describe each soil or bedrock sample as outlined in the appropriate SOP. Record descriptions in the field notebook and/or personal digital assistant (PDA). It should be noted that PDA logs must be electronically 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 soil boring advancement, document all drilling events in field notebook, 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 Rotasonic, dual-rotary, or direct-push methods are used. When drilling in bedrock, the rate of penetration (minutes per foot) is recorded.

4. If it is necessary to install a monitor well into a permeable zone below a confining layer, 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 should be considered. In this case, the borehole is advanced approximately 3 to 5 feet into the top of the confining layer, and a permanent casing (typically PVC, black steel 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: 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; 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 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. Site-specific criteria and work plans should be created for the completion of non-standard monitoring wells, including telescopic wells.

5. In consolidated formations such as competent bedrock, a monitoring well may be completed with an open borehole interval without a screen and sandpack. In these cases, the borehole is advanced to the targeted depth of the top of the open interval. A permanent casing is then grouted in place following the procedures described in Step 4 above. After the grout sets, the borehole is advanced by drilling through the permanent casing to the targeted bottom depth of the open interval, which then serves as the monitoring interval for the well. If open-borehole interval stability is found to be questionable or if a specific depth interval is later selected for monitoring, a screened monitoring well may later be installed within the open-borehole interval, depending on the annular space and well diameter requirements.

6. Prior to screened well installation or after the completion of an open-bedrock well, the water level or oil/water interface probe should be used to determine the static water level in the borehole in relation to the proposed well screen or open-interval location. If necessary, an open-bedrock well may be drilled deeper to intersect the water table or a permeable water-bearing zone.

7. Upon completing the borehole to the desired depth, if a screened well construction is desired, install the monitoring well by lowering the screen and casing assembly with sump through the augers or casing. Monitoring wells typically will be constructed of 2-inch-diameter, flush-threaded PVC or stainless steel slotted 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. The screen length will be specified in the Work Plan or FSP based on regulatory requirements and specific monitoring objectives. Monitoring well screens are usually 5 to 10 feet long, but may be up to 25 feet long in very low permeability, thick geologic formations. The screen length will depend on the purpose for the well and the objectives of the groundwater investigation. Typically, the slot size will be 0.010 inch and the sand pack will be 20-40, Morie No. 0, or equivalent. In very fine-grained formations where sample turbidity needs to be minimized, it may be preferred to use a 0.006-inch slot size and 30-65, Morie No. 00, or equivalent sand pack. Alternatively, where monitoring wells are installed in coarse-grained deposits and higher well yield is required, a 0.020-inch slot size and 10-20, Morie No. 1, or equivalent sand pack may be preferred. To the extent practicable, the slot size and sand pack gradation may be predetermined in the Work Plan or FSP based on site-specific grain-size analysis or other geologic considerations or monitoring objectives. 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 will be backfilled with neat cement grout to the bottom of the well screen prior to placing the sand pack around the screen. A

blank riser will extend from the top of the screen to approximately 2.5 feet above grade or, if necessary, just below grade where conditions warrant a flush-mounted monitoring well. For wells greater than 50 feet deep, centralizers may be desired to assist in centralizing the monitoring well in the borehole during construction.

8. When the monitoring well assembly has been set in place and the grout has been placed around the sump (if any), place a washed silica sand pack in the annular space from the bottom of the boring to a height of 1 to 2 feet above the top of the well screen. The sand pack is placed and drilling equipment extracted in increments until the top of the sand pack is at the appropriate depth. The sand pack will be consistent with the screen slot size and the soil particle size in the screened interval, as specified in the Work Plan or FSP. A hydrated bentonite seal (a minimum of 2 feet thick) will then be placed in the annular space above the sand pack. If non-hydrated bentonite is used, the bentonite should be permitted to hydrate in place for a minimum of 30 minutes before proceeding. No coated bentonite pellets will be used in monitoring well drilling or construction. Potable water may be added to hydrate the bentonite if the seal is above the water table. Monitor the placement of the sand pack and bentonite with a weighted tape measure. During the extraction of the augers or casing, a cement/bentonite or neat cement grout will be placed in the annular space from the bentonite seal to a depth approximately 2 feet bgs.

9. Place 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 should slope gently away to promote drainage away from the well. Monitoring wells will be labeled with the appropriate designation on both the inner and outer well casings or inside of the curb box lid.

   When an above-grade completion is used, the PVC 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 PVC riser will be sealed using an unvented, expandable locking plug.

10. During well installation, record construction details and actual measurements relayed by the drilling contractor and tabulate materials used (e.g., screen and riser footages; bags of bentonite, cement, and sand) in the field notebook.

11. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section VII below.

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. The hammer provides the force needed to penetrate very stiff/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. The 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 Work Plan. Samples will be collected using dedicated, disposable, plastic liners. Describe samples in accordance with the procedures outlined in Step 3 above. Collect samples for laboratory analysis as specified in the Work Plan and/or FSP.

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 sand pack, bentonite seal, and cement/bentonite grout will be installed as described, where applicable, in Step 7 and 8 above.

4. Install protective steel casing or flush-mount, as appropriate, as described in Step 9 above. During well installation, record construction details and tabulate materials used.

5. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section VII below.

Driven Well Point Installation

Well points will be installed by pushing or driving using a drilling rig or direct-push rig, or hand-driven where possible. The well point construction materials will 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.

VII. Waste Management

Investigation-derived wastes (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, FSP, and/or IDW management SOP.

VIII. Data Recording and Management

Drilling activities will be documented in a field notebook. 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, sand pack type), and quantities of materials used. In addition, the locations of newly-installed wells will be documented photographically or in a site sketch. If appropriate, a measuring wheel or engineer's tape will be used to determine approximate distances between important site features.

The well or piezometer location, ground surface elevation, and inner and outer casing elevations will be surveyed using the method specified in the site 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 of 1929 or 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 National Geodetic Vertical Datum of 1929. A permanent mark will be placed on top of the inner casing to mark the point for water-level measurements.

IX. Quality Assurance

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 SOP. Well materials will also be cleaned prior to well installation.

X. References

American Society of Testing and Materials (ASTM) D 1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*.

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SLUG TEST STANDARD OPERATING PROCEDURES

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PUMPING TEST PROCEDURES

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A. TEST DESIGN

1. Understand What You Are Testing

An instantaneous change in head (slug) test is conducted in order to determine the hydraulic conductivity/transmissivity of a water-bearing zone in a quick and inexpensive manner. It can be conducted in materials of lower hydraulic conductivity than generally considered suitable for pumping tests. A slug test also does not require disposal of large quantities of water.

However, recognize that a slug test's shorter time frame and limited stress on the system provides a measurement of hydraulic conductivity on a smaller scale than a pumping test. Because a slug test affects only the aquifer near the well, its results are more strongly influenced by near-well conditions such as the filter pack, poor well development, and skin effects. Therefore, make sure that the stress on the well (i.e., the amount of change in head) is sufficient to test more than the hydraulic conductivity of the filter pack. Although the results of a slug test are not necessarily representative of the average hydraulic conductivity of the area, this limitation does present an opportunity to test discrete layers within an aquifer. Also understand that the storage coefficient (S) usually cannot be determined from a slug test.

2. Slug Test Theory

An estimate of local hydraulic conductivity of the material surrounding a well is calculated by measuring the time/rate of return to static water levels after an instantaneous change in head. Homogeneity and constant aquifer thickness are general assumptions for the test analysis; these are generally met due to the small radius of influence of the test.

Two classes of solutions are generally used: one that assumes water and soil are incompressible (storage is zero; i.e., Bouwer and Rice, and Hvorslev methods), which is a straight-line solution method similar to Thiem; and one that assumes a non-zero storage coefficient (i.e., Cooper et.al, and Hyder et. al methods), which is a type-curve matching solution method similar to Theis.

3. Determine Well Conditions

Unless installed specifically for the test, sound all wells that are to be tested to verify well depth. (Do not use water level meters for this purpose, because some meters have probes that leak and trap water when subjected to excessive pressure.) Verify that the well has been adequately developed, and is not silted in. If the water-level response in the slug test appears to be too sluggish or no response is apparent, the well may need to be redeveloped.

Measure depth to water, or check historic depths to water, to determine if the screen is below the top of water or straddles the piezometric surface. This will determine the types of slug tests (slug-in, slug-out) and mechanisms (water, mechanical, pneumatic) that are applicable for the particular well to be tested. Note that a fully submerged screen is highly preferable for best test results, otherwise a "double-straight line" effect resulting from filter-pack drainage into the well (initial drainage followed by actual aquifer response) will likely be seen in the test response curve (Bower, 1989).

4. Select the Appropriate Slug-Inducing Equipment

A variety of methods are available for inducing a change in water level. The basic requirements are the change needs to take place rapidly ("instantaneous"), and the change needs to be of sufficient magnitude: at least one foot, preferably two to four feet. (Similar results can be achieved with a wide range of induced head change, so a change greater than four feet is not necessary.) The slug can either be introduced (slug in) or withdrawn (slug out). However, if the well screen is open above the water table, slug out is the only method acceptable.

Methods of introducing a slug are as follows:

a) adding clean (DI or potable) water to the well, preferably from a holding vessel with a ball valve that allows the water to drain into the well quickly;
b) dropping a "blank" (typically capped PVC pipe filled with clean sand) into the well; or
c) after raising the water level within a well by applying a vacuum, releasing the vacuum and observing the drop in water level.

Methods of removing a slug are as follows:

a) pulling a slug of water out of the well quickly with a bailer;
b) pulling a "blank" out of the well; or
c) after pressurizing a well and pushing down the water level, releasing pressure from the well and observing the rise in water level.

5. Select the Appropriate Water-Level Measurement Device

Pressure/head changes are rapid (i.e., "instantaneous"), therefore, the measuring device needs to be able to collect measurements quickly and accurately, especially for fast-responding wells. Pressure transducers with dataloggers are best equipped for slug tests. Pressure transducers are also necessary for closed wells in which water level changes are induced by pressure or vacuum.

(a) Pressure Transducers and Data Logger Combination

Transducers connected to electronic data loggers provide rapid water-level measurements with accuracy and ease. Some electronic data loggers (i.e., Hermit) collect and store data from a number of input channels (downhole pressure transducers plus atmospheric pressure) to provide water-level measurements in multiple within several hundred feet radius of the data logger, while others consist of a single logging transducer (i.e., Troll™, Levelogger™). Typical loggers take readings at preprogrammed linear or logarithmic intervals. If desired, data can be transferred to a personal computer for processing.

Small-diameter transducers (typically 0.5 to 0.75 in) are available that cover a range of pressures. Because they yield readings accurate to a percentage of their pressure range (usually about ±0.1 percent of the range in the center of that range, and ±0.2 percent near the limits) transducers that span a wide pressure range have lower absolute accuracies than those that span a narrow range. For example, a typical transducer with a 5 psi range detects water-level changes over a 11.6 ft with an accuracy of ±0.01 ft, whereas, a transducer with a 15 psi range detects changes over a 34.7 ft with an accuracy of ±0.03 ft. Thus, to ensure the greatest accuracy, select the transducer with the pressure range that most closely encompasses the anticipated drawdown or water-level change. Install the transducer at a depth at least 2 feet from the bottom of the well, but below the targeted drawdown estimated for the well.

Caution: To prevent transducer malfunction, do not submerge transducers in excess of their operating range.

(b) Water Level Meters, Interface Probes

These devices provide quick and easy water-level measurements with reasonable accuracy. They employ a sensor that is lowered into a well on the end of a marked cable (typically imprinted in feet and hundredths of a foot). When the sensor contacts water, a circuit is completed, activating a light, audio signal, ammeter, or digital display in the cable reel or housing. However, because the measurements are manual, the speed of readings cannot match those of a pressure transducer with a data logger. Thus, a water level meter is most useful with slow-responding wells, typically installed in low-permeability formations.

6. Verify Measuring Device Accuracy

Test pressure transducers and data logger readings using a bucket or barrel filled with water. Submerge each transducer, accurately measure the water head above the transducer, and compare the measurement to the data-logger reading. Check transducer response to changing heads by raising the transducer a certain distance, observing the change in the datalogger reading, and then measuring the distance with a standard steel tape. Water level meters should be in good working condition and calibrated, ensuring there are no breaks or splices in the cable.

7. Plan for Test Well Water Disposal

If the water quality is such that direct discharge to the ground is not permitted, arrange for collection and disposal for standard slug-out testing. Discharge water must be disposed according to all applicable laws and regu1ations. Contact the governing agencies to determine which restrictions apply. ARCADIS should not be responsible for signing manifests and should not "take possession" of discharged water.

B. PRETEST ACTIVITIES

1. Establish a Reference Point for Measuring Water Levels

At each test well, establish and clearly mark the position of the selected reference point (often the north side, top of the casing). Determine the elevation of this point, record it, and state how this elevation was determined. This elevation point is important to establish the position of the piezometric surface, so it must be determined accurately.

2. Record Background Water Levels

Measure the groundwater level in the test well before beginning the test for a period of time equal to the length of the slug test response. This will help detect any background water level fluctuations and establish a reference static water level. Be sure to allow time for equilibration with atmospheric pressure for wells with unvented caps. If possible, arrange to have nearby active wells shut down or pumped at a constant rate to ease data interpretation.

3. Set-up: Decontamination

Make sure all equipment that enters the test well (slug, water-level meter, transducer) is decontaminated before use. If testing multiple wells, start with the least contaminated progressing to the most contaminated.

4. Set-up: Remaining Equipment Required for Test

Keep sensitive electronic equipment away from devices that generate significant magnetic fields. For example, do not place data loggers near electric power generators or electric pump motors. Likewise, radio signals may cause dataloggers or computers to malfunction. Secure data logger and transducer cables at the well head to prevent movement that would affect measurements. Mark a reference point on transducer cables and check regularly to detect slippage.

5. Perform a Job Safety Analysis

To ensure that everyone is aware of the hazards associated with the work, and that each person knows his/her responsibilities during the preliminary and full-scale test, run through a JSA of the test before the start of pumping.

C. CONDUCTING THE TEST

1. Record Information

(a) Use appropriate data forms
(b) Record all required background information, including well geometry, on logs before beginning the test
(c) Record time as military (24-hour) time
(d) Record the initial depth to water with a water-level meter. (This can be entered into the datalogger if one is being used.)

2. Start the Test

(a) Introduce or remove the slug quickly, causing a measurable change in water level.
(b) Measure water-level response to the initial change at closely spaced intervals (preferably 0.5 second or less to catch fast response) in order to define the water-level response curve.
(c) Continue measuring and recording depth-time measurements until the

water level has equilibrated or a clear trend on a semi-log plot of time versus depth has been established. Measurements taken manually should continue until the water level has recovered about 80%.

3. Reverse Test

If desired, after a slug-in test has been finished and equilibrium reached, a slug-out test can be performed as a check.

4. Post-test Procedure

Make a preliminary analysis of the data before leaving the test area. Compare volume of slug to actual water displacement in the well. Evaluate the quality of the data, and the method of analysis applicable for the results. If a clear trend was not established, the test may need to be re-run. Ensure that equilibrium has been reached before re-running a test in the same well.

D. ASSESSING TEST RESULTS

1. Have Pertinent Well Construction Details

To evaluate data from the test, it will be necessary to have well construction information, such as the following:

- Lithologic logs
- Well depths
- Screen lengths
- Filter pack thickness and length
- Test well casing radius
- Borehole radius
- Sand pack grain size (affects the size of the practical borehole radius)
- Thickness of saturated zone
- Initial water depth
- Initial head change from slug

2. Determine the Type of Response to the Test

The type of response to the test is as important as the type of permeable zone (confined, unconfined) for picking the type of analysis. As with pumping tests, do not assume that all standard analyses (Bower and Rice; Hvorslev; Cooper, Bredehoeft, Papadopulos) are suitable; pick the type of analysis based on the goodness-of-fit of the response (Herzog and Morse, 1990) to the theoretical curve. Do not force the data; if a clear straight line does not exist then the standard straight-line analytical methods may not be appropriate.

Wells testing confined aquifers with a high transmissivity or long water column (large water mass within the casing) can show an oscillatory recovery (underdamped or critically damped; see ASTM D5785 and ASTM D5881) to initial water level; common response is an exponential decay (overdamped response, frictional forces within the aquifer are dominant over inertial; see ASTM D4104 and ASTM D5912). These oscillatory test results require calculation of the angular frequency and damping factor (Kipp, 1985; van der Kamp, 1976) to account for the inertial effects before solving for transmissivity. The underdamped solution technique is available in the standard aquifer test program, AQTESOLV, and in public domain spreadsheet programs available from the USGS (http://pubs.usgs.gov/of/2002/ofr02197/) and from the Kansas Geological Survey (http:www.kgs.ku.edu/Hydro/Publications/OFR00_40/High_K.zip).

Note: the critically damped well response is a transitional response (showing oscillations) between overdamped and underdamped; its analysis requires the type-curve matching method by Kipp (1985). It is determined by a dimensionless "damping factor":

$$\zeta = \frac{\alpha\left(\sigma + \frac{1}{4} 1n\beta\right)}{2\beta^{\frac{1}{2}}}$$

where ζ >1 is overdamped; ζ =1 is critically damped; and ζ <1 is underdamped.

3. Decontaminate All Equipment Contacting Site Groundwater and Soil

Use appropriate decontamination procedures before proceeding to the next well and/or leaving the site.

E. SPECIAL CONSIDERATIONS

1. Wells Containing Floating Nonaqueous Phase Liquids

It is best to use pressure transducers to measure water levels in wells containing floating product such as gasoline. Contact with floating product, however, may make transducers and cable unsuitable for future use. Thus, protect each transducer and cable assembly by encasing it in plastic tubing or pipe. Be sure that each protected transducer still can respond accurately to any pressure changes.

As an alternative to pressure transducers, make manual measurements (using an interface probe) of both the fuel level and water level individually. Then correct the observed thickness of floating product by its density to arrive at the effective water level. This manual procedure will work, but takes time and is only suitable for slow-responding wells.

2. Karst and Cavernous Aquifers

Recognize that the response of the slug tests within a Karst regime will be as diverse as the stratigraphy. Document the well stratigraphy to understand the range in responses measured within a single groundwater zone.

3. Fractured Aquifers

The upper boundary condition for the Bower-Rice and Hvorslev methods, based on the Thiem analysis, is a no-flow boundary. Often, the residuum above fractured aquifers are at least partially saturated and serve as a leaky upper boundary; this condition cannot generally be confirmed by slug tests.

Fractured-zone aquifers typically meet the assumptions of the analysis by Cooper-Bredehoeft-Papadopulos, although care should be taken in the interpretation in case the screened zone may cross a single fracture or discrete zone

F. REFERENCES

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Well Development – Water Jetting

Standard Operating Procedure

Rev. #: 1

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Approval Signatures

Prepared by: Erin Hauber Date: 7/6/10

Erin Hauber

Reviewed by: Royce Face Date: 7/6/10

Royce Face, PE. PG

Reviewed by: Kevin R. Wilson Date: July 2, 2010

Kevin Wilson, PG

1. Scope and Application

This standard operating procedure (SOP) provides an overview of jetting with water as a method of well development. While the goal of groundwater sampling is to obtain water samples that are representative of natural, undisturbed hydrogeologic conditions, all drilling methods disturb geologic materials around the well bore to some extent. Development of remediation wells (monitoring wells, piezometers, injection wells, extraction wells) is needed to repair (to the extent practicable) damage to the formation caused by drilling, and to remove fine-grained sediments and drilling fluids introduced during the drilling process. Well development enhances the hydraulic connection between the well and the surrounding formation, ensuring that the screen transmits groundwater that is representative of the surrounding formation. Periodic redevelopment may also be necessary to improve the operation of extraction or injection wells.

The ultimate goal of any development technique is to create a filter pack that is coarsest near the well screen and becomes progressively finer until it blends with the native formation. The ideal development would merge the filter pack seamlessly into the formation, without a noticeable change in grain size.

Development through jetting introduces high velocity water into the well screen while simultaneously evacuating water from the well (ideally maintaining an in-well water level that is equal to or below the static water level, but always less than 20 percent of the available head space in the well). Prior to and/or following jetting, the screened interval can be gently surged using a surge block, bailer, or inertia pump with optional surge block fitting to remove fines freed from filter pack during the jetting process.

Design and selection of the appropriate jetting equipment and delivery pressure will be based on site-specific parameters (well construction details), tubing, and pump specifications. The disposal of investigation derived waste (IDW) generated during the jetting process must also be taken into consideration.

In general, jetting involves lowering either single or multiple small diameter pipe(s) or tube(s) equipped with nozzles into the well screen and injecting a high velocity horizontal stream of water through the pipe(s) into the screen openings. The jets are moved vertically along the screened interval and rotated, if needed, to effectively address the entire screen surface area. Typical jetting assemblies include a submersible pump to extract the injected water and maintain the static water level, but alternate removal methods (air lifting, centrifugal pump) are acceptable.

Jetting tools usually have two to four nozzles; however, site conditions and well diameter will ultimately dictate the number of nozzles used at a specific well. Nozzle orifice sizes are selected to produce velocities between approximately 100 and 300 feet per sec (ft/sec). The injected (and extracted) flow into the well and the approximate pressure delivered by the jetting pump to achieve the target jetting velocities can be determined by considering the following:

- screen material and opening configuration
- nozzle specifications
- pressure losses from pump manifold to nozzles
- pump and tubing pressure limitations
- screen exit velocity
- IDW generation and/or recirculation options.

The attached jetting design tool (see Section X. References) can be used to estimate the target manifold pressure and injection/extraction flow rate for a specific remediation well.

II. Personnel Qualifications

Well development activities will be performed by persons who have been trained in proper field procedures. Well development activities will be performed under the guidance of an experienced field geologist, engineer, or technician.

III. Equipment List

General materials for well development include:

- personal protective equipment (PPE) and any other safety equipment required by the site-specific Health and Safety Plan (HASP)
- cleaning equipment
- water level meter and/or oil/water interface probe
- water quality meter that is capable of recording pH, temperature, conductivity, and turbidity (optional)

- photoionization detector (PID) to measure headspace vapors (recommended; may be required by the site-specific HASP)
- plastic sheeting
- graduated pails
- drum(s) or tank(s) to contain purge water, and equipment to move the container(s)
- field notebook
- well construction logs (or summary table) indicating completed well depths and screened intervals
- monitoring well keys.

Materials needed specifically for development by jetting include:

- Down-hole jetting assembly consisting of:
  - Two or three jetting nozzles pointed outward in the horizontal plane.
    - Select jet nozzles rated for velocities between 150 and 300 ft/sec. Higher velocities may damage the well, whereas lower velocities will be less effective at penetrating the filter pack.
    - Nozzles should spray in a wide angle horizontal fan (e.g., 145°). An array of three nozzles with overlapping fans is preferred. If the combined spray arc is not a full 360°, the assembly will need to be rotated throughout the well development process.
    - The nozzles must be equally spaced to hydraulically balance the jetting tool.
    - Since a larger orifice will require a higher injection rate to achieve the same velocity, small-orifice jets (approximately 0.016 inch to 0.065 inch in diameter) are preferred.
  - A rate-controllable submersible pump (or alternate pumping device) attached below the jetting nozzles (or above the jetting nozzles, if jetting at the very bottom of the screen is required).
    - The pump capacity should be greater than the anticipated jetting flow required to jet at the target velocity (for the full array of jets).
  - A flexible rubber flange (or collar) attached between the jetting nozzles and the submersible pump.
    - The flange prevents flow from the jet to the pump from occurring within the well casing, thereby forcing the flow through the screen and filter pack.
    - Flanges should be constructed of flexible rubber and sized appropriately to slide freely up and down inside the well casing, yet provide a partial seal against vertical flow.

  - Associated tubing and control wire bundled together (e.g., with zip ties or heat shrink plastic wrapping). The jetting assembly must be sufficiently rigid and bundled to minimize friction between the well casing and the jetting tool and allow vertical movement and rotation (if necessary). Ease of jetting tool movement within the well can become a concern in small (i.e., 2-inch) diameter wells if the jetting tool is not properly designed.

- Above-grade jetting assembly consisting of:
  - potable water supply (e.g., 250-gallon water tote)
  - above-grade water pump (e.g., booster pump) and recirculation or pressure relief line into supply water tank, if needed
  - injection manifold consisting of the following:
    - poly vinyl chloride (PVC) or steel pipe, with an input connection from the water pump and branches to each jetting line (all piping and tubing must be pressure rated to withstand jetting pressures)
    - pressure gage
    - gate valves on each output line
  - Storage tank for extracted water
  - Filter unit (if recirculation is used)
    - If recirculation is being used, sediment must be removed prior to re-injection.
    - Sediment may erode nozzle orifices (thereby reducing delivered pressure), harm the jetting pump, and abrade screen material,

- Power supplies for jetting pump and submersible pump.

IV. Cautions

- Delivery pressures greater than 150 pounds per square inch (psi) are often required to achieve effective jetting velocities. All tubing/piping, connections, and pumps should be rated for the anticipated delivery pressures, and should be inspected for damage prior to and periodically during use.

- Care should be taken when testing the jetting tool above ground. Similar to a pressure washer, high pressure water exiting the jets may pose a risk if it comes into direct contact with skin.

- The type of screen opening greatly affects what percentage of the jetted water reaches the formation surrounding the filter pack (i.e., v-shaped continuous slot screens transfer the high velocity stream more effectively than louvered screens).

- Water exiting the jetting tool should not exceed the recommended screen exit velocity of 0.05 ft/sec to prevent possible damage to the well screen.

- Continuous movement of the jetting tool is recommended to minimize formation of cavities within the filter pack and to protect the screen.

- Water pressure should not exceed 100 psi when jetting PVC screens.

- Only use sediment-free water with the jetting tool to minimize damage to the well screen from abrasive particles, avoid erosion of the nozzle orifice (which could cause a reduction in nozzle velocity), and protect the jetting pump.

- Avoid using development fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

V. Health and Safety Considerations

Field activities associated with well development by jetting will be performed in accordance with the site-specific HASP, a copy of which will be present onsite during such activities. Note that additional precautions may be required to account for the use of pressurized equipment or handling large storage vessels.

VI. Procedure

The procedures for developing a well using the jetting method are outlined below. These procedures are applicable to wells that are screened primarily in clay and silt formations.

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

2. Using a non-phosphate cleaner (e.g., Alconox) and potable water, clean and double rinse all non-dedicated equipment that will enter the well (refer to separate equipment cleaning procedures where applicable).

3. Breathing zone testing is recommended (to be determined by the project team). If required:

    a. Open the well cover while standing upwind of the well; remove the well cap. Insert the PID probe approximately 4 to 6 inches into the casing or the well headspace; cover with gloved hand.

    b. Record the PID reading in the field notebook.

    c. 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 the well for 5 minutes to allow the volatiles to dissipate, then 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.

4. Measure the depth to water and total well depth. Check for the presence of non-aqueous phase liquid (NAPL). *If NAPL is present do not continue development until consulting with the task manager (or TKI specialist).* Compare the well depth to the as-built construction details. Calculate the volume of water in the well casing.

5. Hydraulic testing is recommended to evaluate the effectiveness of the jetting process (implementation will be determined by the project team). If hydraulic testing is to be performed, the following process can be used:

    a. Lower a pump into the well and begin pumping while monitoring the water level in the well.

    b. Adjust the pumping rate to achieve steady flow from the well, with drawdown in the well at 20 to 30 percent of the original water column.

    c. Record this flow rate and drawdown and calculate the initial specific capacity: $SC = \frac{\text{Flow (Q)}}{\text{drawdown } (\Delta h)}$

6. Determine final jetting/purging parameters and set-up:

    a. Calculate the operational jetting pressure (manifold gage reading) to achieve the target jet velocity (i.e., 150 to 300 ft/sec) based on the jet nozzle manufacturer's specifications (e.g., 200 psi at 0.5 gallons per minute [gpm]), tubing losses, and equipment pressure rating. See attached calculation worksheet.

    b. Water recirculation should not be completed unless approved by the project manager. Recirculation of sediment-laden water may damage the well screen or jetting pump.

    c. Lower the jetting tool into the well. Check that the swabbing flange is loose enough to permit the tool to move up and down inside the well casing without significant effort.

    d. Place a water level meter into the well to monitor the water level during development.

7. To maintain the static water level in the well, the rate of water extraction must equal or exceed the rate of injection. A water level above baseline will drive fines suspended in the water column into the formation and therefore decrease the effectiveness of development. Carefully monitor the water level

to insure that it does not exceed 20 percent of the available head space in the well.

8. Jet and purge the saturated portion of the well screen in 2-foot increments, as follows:

    a. Start jetting in the bottom 2-foot interval of the well screen (or as close to the bottom of the screen as practical, based on the jetting assembly). While jetting:

        i. Pump from beneath (or above) the jetting tool at a rate sufficient to maintain the water-level in the well at or below the static water level.

        ii. Gently swab the well while pumping by slowly moving the jetting tool up and down the well screen at no greater than 0.5 ft/sec. Vigorous surging is not appropriate. Do not reverse the up/down stroke suddenly.

        iii. Hold the jetting tool loosely and away from the body. If jetting/surging rates are imbalanced or a filter pack blockage prevents flow, the tool may push upward or downward. Do not force the tool to remain stationary; adjust jetting/surging rates as needed.

        iv. Do not let the tool remain in one position for longer than a few seconds.

    b. Continue jetting in the 2-foot interval for 10 minutes, rotating the tool (if necessary) and covering the well screen interval multiple times.

    c. Repeat steps 8a through 8b in the next 2-foot interval of screen until the entire length of the saturated screen interval has been developed.

    d. Sediment loading and turbidity of the extracted water should improve throughout the jetting process. Visual observations of the sediment and turbidity should be recorded in the field notes or the well development form (see Section X, References). The project team may opt to record water quality parameters (temperature, conductivity, pH, turbidity) during development.

9. Monitor and record water use (i.e., volume of potable water injected and volume of water purged by pumping) throughout the development process. Increasing the extraction rate or decreasing the injection rate may be necessary to prevent the water level in the well from rising above static conditions or to prevent the well from going dry.

10. After development, measure the depth to water and the total well depth, and check for the presence of non-aqueous phase liquid (NAPL). Confirm that the total depth of the well matches the as-built well depth within a reasonable tolerance. If a discrepancy exists, note it, and evaluate it to the degree feasible. Continue development if necessary.

11. If hydraulic testing was completed prior to development, a test should be completed at the end of development activities to ascertain the level of improvement (see Step 5). Additional development may be needed if the well does not meet design criteria.

12. When complete, re-secure the well cover.

13. Using a non-phosphate cleaner (e.g., Alconox) and potable water, clean and double rinse all non-dedicated equipment that entered the well (refer to separate equipment cleaning procedures where applicable). Place disposable materials in plastic bags for appropriate disposal, and decontaminate reusable, downhole pump components and/or bailer.

VII. Waste Management

IDW generated during well development may include disposable equipment and PPE, purged groundwater, and water associated with equipment cleaning. All disposable and liquid waste should be handled and disposed in accordance with project plans and applicable regulations.

VIII. Data Recording and Management

Well development activities will be documented in a proper field notebook and/or Personal Digital Assistant (PDA). Pertinent information will include:

- General Field Notes:
  - personnel present onsite
  - times of arrival and departure
  - significant weather conditions
  - timing of well development activities

- Jetting Field Notes:
  - observations of NAPL
  - manifold pressure
  - water levels before and during testing
  - observations of purge water color, turbidity, odor, and sheen over time
  - purge rate
  - initial and final total depth of well
  - hydraulic testing parameters (if specified by project technical lead)

IX. References

Jetting Design Tool

Well Development Form