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FEASIBILITY STUDY

ASKO HYDRAULIC PROPERTY

Property:
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

Prepared for:
TOC Holdings Co.
2737 West Commodore Way
Seattle, Washington

Report Date:
June 9, 2014

Feasibility Study

Prepared for:

TOC Holdings Co.
2737 West Commodore Way
Seattle, Washington

ASKO Hydraulic Property
2805 West Commodore Way
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Project No.: 0440-004

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June 9, 2014

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ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
°C	degrees Celsius
1,1-DCE	1,1-dichloroethene
the 2003 BINMIC	the *BINMIC Hydrogeologic and Environmental Settings Report* prepared by The Floyd Snider McCarthy Team in 2003
API	American Petroleum Institute
ASKO Hydraulic Property	located at 2805 West Commodore Way in Seattle, Washington
ARAR	applicable or relevant and appropriate requirement
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
bcy	bank cubic yards
bgs	below ground surface
BINMIC	Ballard Interbay Northend Manufacturing and Industrial Center
BNSF Parcel	Burlington Northern Santa Fe Railway Company King County Tax Parcel Number 423790-0240
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CFR	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-dichloroethene
COPC	chemical of potential concern
CPGV	critical pore gas velocity
CSM	conceptual site model
CVOC	chlorinated volatile organic compound
DNR	Department of Natural Resources
DPD	City of Seattle Department of Planning and Development
DPE	dual-phase extraction
DRPH	diesel-range petroleum hydrocarbon
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERH	electrical resistive heating
ft/day	feet per day
ft^3/min	cubic feet per minute

ACRONYMS AND ABBREVIATIONS (CONTINUED)

ft/min	feet per minute
FMC	FMC Corporation
FS	feasibility study
FS Report	Feasibility Study report prepared by SoundEarth Strategies, Inc.
g/cm^3	grams per cubic centimeter
g/kg	grams per kilogram
GRPH	gasoline-range petroleum hydrocarbon
Hdf	Holocene Depression Fillings
Hf	Holocene fill
iow	inches of water
KDT	Klozur® demand test
lcy	loose cubic yards
LEL	lower explosive limit
LNAPL	light nonaqueous-phase liquid
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	monitored natural attenuation
MTCA	Washington State Model Toxics Control Act
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	No Further Action
O&M	operation and maintenance
OMB	Office of Management and Budget
ORPH	oil-range petroleum hydrocarbon
PCU	Power Control Unit
PNOD	permanganate natural oxidant demand
ppb	parts per billion
PRB	permeable reactive barrier
PSCAA	Puget Sound Clean Air Agency
Qpf	pre-Fraser-age glacial deposits
Qpfc	coarse-grained pre-Fraser-age glacial deposits
Qpff	fine-grained pre-Fraser-age glacial deposits

ACRONYMS AND ABBREVIATIONS (CONTINUED)

RAO	remedial action objective
RCW	Revised Code of Washington
RI	remedial investigation
RI Report	Remedial Investigation Report
ROW	right-of-way
RP	recommended practice
scfm	standard cubic feet per minute
Site 1	encompasses the northern, central, and southern portions of the ASKO Hydraulic Property and the northern portion of the south-adjoining property and the southern portion of the north-adjoining West Commodore Way ROW
Site 2	encompasses the northwest portion of the ASKO Hydraulic Property adjacent to the ASKO Industrial Repair building and the south portion of the north-adjoining West Commodore Way ROW
the Sites	includes Site 1 and Site 2
SoundEarth	SoundEarth Strategies, Inc.
SVE	soil vapor extraction
TCE	trichloroethene
trans-1,2-DCE	trans-1,2-dichloroethene
TPH	total petroleum hydrocarbons
USACE	United States Army Corps of Engineers
USC	United States Code
UST	underground storage tank
VCP	Voluntary Cleanup Program
VOC	volatile organic compound
WAC	Washington Administrative Code
ZOI	zone of vacuum influence
ZVI	zero valent iron

1.0 INTRODUCTION

SoundEarth Strategies, Inc. (SoundEarth; formerly Sound Environmental Strategies Corporation) has prepared this Feasibility Study report (FS Report) on behalf of TOC Holdings Co. (TOC; formerly named Time Oil Co.) for the ASKO Hydraulic Property. The ASKO Hydraulic Property is located at 2805 West Commodore Way in Seattle, Washington (Figure 1). The ASKO Hydraulic Property is part of the Seattle Terminal Properties. The Seattle Terminal Properties include four real properties (King County Tax Parcel Numbers 112503-9050, 112503-9120, 423790-0405 [ASKO Hydraulic Property], and 112503-9081) and one parcel leased from the Washington State Department of Natural Resources (DNR; King County Tax Parcel Number 112503-9113). The Seattle Terminal Properties are identified as the Bulk Terminal Property, East Waterfront Property, ASKO Hydraulic Property, West Waterfront Property, and the Washington State DNR Aquatic Lease Land Property. The Seattle Terminal Properties and West Commodore Way are located in Section 11, Township 25 North, Range 3 East. The latitude and longitude of the Seattle Terminal Properties is approximately 47°39’41−51”North and 122°23’28−41”West. The layout of the Seattle Terminal Properties is shown on Figure 2. The City of Seattle West Commodore Way right-of-way (ROW) runs from east to west and separates the Bulk Terminal Property and ASKO Hydraulic Property from the East Waterfront Property and West Waterfront Property. The Seattle Terminal Properties are bounded to the south by King County Tax Parcel Number 423790-0240, which is owned by Burlington Northern Santa Fe Railway Company (BNSF Parcel). The Seattle Terminal Properties and West Commodore Way are located within the Ballard Interbay North Manufacturing Industrial Center (BINMIC) designated by the City of Seattle in 1994.

SoundEarth conducted a remedial investigation (RI) to address data gaps identified from the data presented in previous subsurface investigations and interim actions conducted by SoundEarth and others that had confirmed releases of the chemicals of potential concern (COPCs) to the environment at the ASKO Hydraulic Property. The releases of COPCs resulted in the migration of contamination in soil and groundwater. The confirmed and suspected sources of COPCs are associated with historical facility operations; however, the release mechanisms are unknown. The previous investigations and interim actions conducted at the ASKO Hydraulic Property are summarized in the Remedial Investigation Report (RI Report), prepared by SoundEarth in 2014.

The feasibility study (FS) was performed as part of an ongoing cleanup action in accordance with Washington State Model Toxics Control Act (MTCA) Cleanup Regulations as established in Chapter 173-340 of the Washington Administrative Code (WAC 173-340). In accordance with WAC 173-340-360(2), the final cleanup action will meet the cleanup standards at the defined points of compliance, protect human health and the environment, comply with applicable state and federal laws, provide for compliance monitoring, and provide a permanent solution to the maximum extent practicable.

1.1 PURPOSE

The objective of this FS is to develop and evaluate cleanup action alternatives to facilitate selection of a final cleanup action for the Sites in accordance with WAC 173-340-350(8). An FS includes the development, screening, and evaluation process for numerous remedial alternatives.

The FS Report has been prepared to develop and evaluate cleanup action alternatives for the Sites and to select the most appropriate alternative based on the evaluation criteria as defined by MTCA WAC

173-340-350 through 173-340-390. According to MTCA, a cleanup action alternative must satisfy all of the following threshold criteria as specified in WAC 173-340-360(2):

- Protect human health and the environment.
- Comply with applicable state and federal laws.
- Comply with cleanup standards.
- Provide for compliance monitoring.

While these criteria represent the minimum standards for an acceptable cleanup action, WAC 173-340-360(2)(b) also recommends that the cleanup action alternative satisfy the following criteria:

- Use permanent solutions to the maximum extent practicable.
- Provide for a reasonable restoration time frame.
- Consider public concerns.

1.2 PRELIMINARY SITE DEFINITION

According to Washington State Department of Ecology (Ecology) *Guidelines for Property Cleanups under the Voluntary Cleanup Program* dated July 2008, "a site is defined by the nature and extent of contamination associated with one or more releases of hazardous substances (such as the release of gasoline from a leaking underground storage tank [UST]) prior to any cleanup of that contamination" (Ecology 2008).

Based on the information gathered to date, there are two distinct and separate areas of COPCs associated with releases of hazardous substances at the ASKO Hydraulic Property and BNSF Parcel. These areas are identified as Site 1 and Site 2 (the Sites). Site 1 encompasses the north, central, and south portions of the ASKO Hydraulic Property and the north portion of the south-adjoining property referred to as the BNSF Parcel and the south portion of the north-adjoining West Commodore Way ROW. Site 2 encompasses the northwest portion of the ASKO Hydraulic Property adjacent to the building occupied by ASKO Industrial Repair and the southwest portion of the north-adjoining West Commodore Way ROW. The general boundaries for Site 1 and Site 2 are shown on Figure 3.

1.3 PRELIMINARY CLEANUP LEVELS

Preliminary cleanup levels were established for individual hazardous substances in each medium during the scoping of the RI based on various phases of investigation performed by others. The preliminary cleanup levels have been refined during the RI. The current land use of the ASKO Hydraulic Property is a mix of industrial and commercial. The final cleanup levels will be defined in the subsequent Cleanup Action Plan as additional information becomes available on the potential future land use.

The ASKO Hydraulic Property is zoned industrial. However, the City of Seattle will permit commercial uses in industrial areas to the extent that they reinforce the industrial character of the region and new residential uses will not be permitted except for special types of dwellings that are related to the industrial area and that would not restrict or disrupt industrial activity.

The preliminary cleanup levels for COPCs confirmed or suspected in environmental media of potential concern are provided in Table 1. These cleanup levels for individual hazardous substances are based on established MTCA Method A cleanup levels in accordance with WAC 173-340-720 through WAC 173-340-760. MTCA Method B cleanup levels are used for hazardous substances that are not considered indicator hazardous substances or where MTCA Method A cleanup levels were not established. For example, a MTCA Method A cleanup level has not been established for cis-1,2-dichloroethene (cis-1,2-DCE), which is not considered an indicator hazardous substance; therefore, the MTCA Method B cleanup level will be used for cis-1,2-DCE.

The final cleanup standards will be determined based on the selected cleanup action(s) and the current and potential future land and resource uses. The final cleanup standards for the Sites including cleanup levels, points of compliance, and remediation levels, if applicable, will be defined in the Cleanup Action Plan presented under separate cover, in accordance with WAC 173-340-700.

1.4 REPORT ORGANIZATION

This FS Report is organized into the following sections:

- **Section 2.0, Background.** This section provides a description of general facility information and conditions for the ASKO Hydraulic Property, a description of current and historical land uses for the ASKO Hydraulic Property, the West Commodore Way ROW, and BNSF Parcel, where portions of Site 1 and/or Site 2 are located. This section also provides a summary of the environmental setting including topography, surface water and sediments, soils and geology, hydrogeology, and air.
- **Section 3.0, Summary of Conceptual Site Model.** This section provides a summary of the conceptual site model (CSM) developed for the Sites based on the completion of the RI conducted by SoundEarth, and previous investigations performed by others.
- **Section 4.0, Field Pilot Tests and Treatability Studies.** This section summarizes field tests and treatability studies that were performed to evaluate the effectiveness of potential candidate remedial technologies and to obtain preliminary design data used to evaluate the cost-effectiveness of the technology.
- **Section 5.0, Remedial Alternatives Assessment.** This section lists the remedial action objectives (RAO) developed for the Sites which were used to define the technical elements for the screening evaluation and to select a cleanup action alternative. The technical elements include applicable or relevant and appropriate requirements (ARAR), COPCs, media of concern, and preliminary cleanup standards. This section provides the comparative evaluation of cleanup action alternatives and disproportionate cost analysis, and presents the recommended cleanup action alternative.
- **Section 6.0, Bibliography.** This section lists references used to develop this document.
- **Section 7.0, Limitations.** This section presents SoundEarth's standard limitations associated with conducting the work reported herein and preparing this FS Report.

2.0 BACKGROUND

This section provides a description of general facility information and site conditions for the ASKO Hydraulic Property; a description of current and historical land uses for the ASKO Hydraulic Property, the BNSF Parcel, and the West Commodore Way ROW; and a summary of the environmental settings, including topography, surface water and sediments, soil and geology, hydrogeology, and air.

2.1 PROPERTY DESCRIPTION

The ASKO Hydraulic Property main address is 2805 West Commodore Way, Seattle, Washington. The ASKO Hydraulic Property is comprised of a single tax parcel (King County Tax Parcel Number 423790-0405) and encompasses a total area of 1.59 acres (69,283 square feet).

The west portion of the ASKO Hydraulic Property is developed with a 1964-vintage, 7,198-square-foot building, which is currently occupied by ASKO Industrial Repair, a hydraulic repair and machine shop. Additional structures include a 1952-vintage, 1,660-square-foot, open-sided building located near the southeast corner of the parcel; a reinforced concrete platform built in 1948; a portion of a 1947-vintage, 7,200-square-foot warehouse building, currently occupied by Marine Service & Supply, located on the southeast portion of the ASKO Hydraulic Property; an office trailer located west of the warehouse and occupied by Marine Service & Supply; and several container boxes and a trailer located west of the 1947-vintage warehouse building. The west portion of the 1947-vintage warehouse building described above extends onto the Bulk Terminal Property. The remainder of the parcel is covered with concrete, asphalt, gravel, or low-growing vegetation and surrounded by a chain-link fence.

The ASKO Hydraulic Property is serviced by overhead electrical, cable, and telephone utilities, and underground natural gas, water, sanitary sewer, and stormwater utilities. According to the City of Seattle Department of Planning and Development (DPD) Side Sewer Cards and Maps, sanitary and stormwater sewer connections enter the ASKO Hydraulic Property from the north. The sanitary sewer connects to the northeast corner of ASKO Industrial Repair, and the stormwater sewer connects to three stormwater catch basins, which are located surrounding ASKO Industrial Repair. In addition, two stormwater catch basins are located west of the 1952-vintage building (DPD 2013).

2.2 PROPERTY LAND USE AND HISTORY

The current and historical use information presented in this FS Report for the ASKO Hydraulic Property, the BNSF Parcel, and the West Commodore Way ROW is compiled from reviewed sources, including City of Seattle, Seattle Public Utilities, DPD, King County Assessor's website, historical assessor records obtained from Puget Sound Regional Archives, Sanborn Fire Insurance Maps; Kroll and Baist Atlases; Polk and Cole City Directories; aerial photographs, historical records provided by Ecology and TOC, and previous reports prepared by others. Historical documentation referenced in this section is provided in the RI Report.

According to the *BINMIC Hydrogeologic and Environmental Settings Report* (the 2003 BINMIC Report) prepared by The Floyd Snider McCarthy Team (Floyd Snider McCarthy 2003), the ASKO Hydraulic Property is located within the BINMIC (Figure 2 of the 2003 BINMIC Report). The current land use of the ASKO Hydraulic Property is a mix of industrial and commercial.

According to the City of Seattle's zoning map, the ASKO Hydraulic Property is located within the BINMIC and is zoned as Industrial General 2 Unlimited/65 and Industrial Buffer Unlimited/45. The Industrial General 2 Unlimited/65 zoning classification allows for a broad range of industrial and commercial uses. Typical land use includes general and heavy manufacturing, commercial, entertainment, transportation and utility services, and salvage and recycling. The intent of the Industrial Buffer Unlimited/45 zoning classification is to provide an appropriate transition between industrial areas and adjacent residential and/or commercial zones. Typical land use includes general and light manufacturing, commercial, limited transportation services, entertainment, and salvage and recycling uses. The City of Seattle will reportedly permit commercial uses in industrial areas to the extent that they reinforce the industrial character of the region (DPD 2013a). New residential uses will not be permitted by the City of Seattle except for special types of dwellings that are related to the industrial area and that would not restrict or disrupt industrial activity. In addition, the City of Seattle has designated portions of ASKO Hydraulic Property as environmentally critical areas for Heron Habitat and Wildlife Preservation Areas (DPD 2013b).

The earliest available records indicated that portions of the ASKO Hydraulic Property were developed with as many as two small structures in 1905. Reportedly, the land use was agricultural. In 1908, the ASKO Hydraulic Property consisted of smaller parcels that were combined after TOC purchased the parcels between 1946 and 1950. TOC operated a petroleum bulk storage facility at the Bulk Terminal Property between 1941 and October 2001, which utilized structures within the ASKO Hydraulic Property, East Waterfront Property, Washington State DNR Aquatic Lease Land Property, BNSF Parcel, and the West Commodore Way ROW.

Operations of the petroleum bulk storage facility included distribution of petroleum products, including gasoline and diesel, between transport ships, railroad tank cars, and trucks. Petroleum products were transported at the Seattle Terminal Properties via drums and distribution pipelines. Piping ran from aboveground storage tanks (AST) on the Bulk Terminal Property to barreling sheds where 5-gallon containers and 55-gallon drums were filled with petroleum products, which were transported beneath the West Commodore Way ROW to the East Waterfront Property via inclined gravity conveyors (Former West and East Barrel Inclines). Historical records indicated that as many as three configurations of barreling sheds were formerly located at the Seattle Terminal Properties. The first configuration was located on the west portion of the Bulk Terminal Property immediately east of the ASKO Hydraulic Property (Former Barreling Shed #1). The second configuration was located on the southwest portion of the Bulk Terminal Property extending onto the ASKO Hydraulic Property (Former Barreling Shed #2) and the third configuration was operated on the southeast portion of the ASKO Hydraulic Property (Former Barreling Shed #3). The structure for Former Barreling Shed #3 is still present. The full extent of operations conducted at the barreling sheds is unknown. In addition, distribution piping ran between the Bulk Terminal Property, East Waterfront Property, and BNSF Parcel where petroleum products were pumped between ASTs, transport ships, and railroad tank cars.

Four rail spurs entered the south portion of the ASKO Hydraulic Property from the BNSF Parcel. One rail spur (Former Rail Spur #1) was located north of the reinforced concrete platform and was used in conjunction with the 1947-vintage warehouse. Three rail spurs (Former Rail Spurs #2 through #4) were located on the parcel boundary between the BNSF Parcel and the ASKO Hydraulic Property. Distribution piping ran from Former Rail Spurs #2, #3, and/or #4 to the barreling sheds and the Bulk Terminal Property. A historical map of the Seattle Terminal Properties indicated that Former Rail Spur #4 was owned by Great Northern Railway Company and that Former Rail Spurs #1, #2, and #3 were owned by TOC; however, a Spur Track Agreement between Great Northern Railway Company and TOC indicated that Great Northern Railway Company owned all the rail spurs. Aerial photographs indicated that the rail spurs were removed by 1985.

Three ASTs, which reportedly stored lube oil and/or used motor oil, were located on the eastern portion of the ASKO Hydraulic Property (Former AST Area). The capacity of each AST was reported to be 14,000 gallons. Piping ran from a blending shed located on the Bulk Terminal Property to the ASTs. Aerial photographs indicated that the ASTs were installed by 1953 and removed before 1978.

In 1960, the ASKO Hydraulic Property was also used as a truck storage area and parking lot for the petroleum bulk storage facility; this appears to have been the use of this parcel from approximately 1960 to 1974. The 1964-vintage warehouse building on the northwest portion of the ASKO Hydraulic Property was used to service TOC vehicles and included a 550-gallon fuel oil UST located directly northeast of the building. A permit application dated 1964 on file with King County Department of Design, Construction, and Land Use indicated there was a permit for two 550-gallon USTs on file. It is unknown if a second UST was installed under this permit; however, historical records provided by TOC showed two 550-gallon USTs used for the storage of waste oil and heating oil.

A summary table, including reference sources and development description based on available current and historical information for the ASKO Hydraulic Property, is provided in the RI Report. Historical property features are also presented on Figure 4.

2.3 LAND USE AND HISTORY OF WEST COMMODORE WAY ROW

The West Commodore Way ROW was completed by 1912. West Commodore Way ROW runs from east to west and is located directly north of the ASKO Hydraulic Property. The West Commodore Way ROW consists of a concrete and asphalt roadway with gravel easement. The North Trunk Sewer, operated by the King County Wastewater Treatment Division, was constructed beneath West Commodore Way by the City of Seattle between 1909 and 1913. The tunneled portions of the North Trunk Sewer located within West Commodore Way were reportedly constructed as brick crown within a timber set and lagging tunnel. The North Trunk Sewer continues to the West Point Treatment Plant. The top of the North Trunk Sewer is at an approximate elevation of 8 to 20 feet above the North American Vertical Datum 1988. The diameter of the North Trunk Sewer section running beneath the West Commodore Way ROW is reportedly 144 inches (12 feet).

Sanitary sewer and stormwater lines servicing ASKO Industrial Repair connect to the North Trunk Sewer beneath West Commodore Way. Additional utilities located within the West Commodore Way ROW that service the ASKO Hydraulic Property include a natural gas main beneath the south shoulder of West Commodore Way, which approaches from the west and terminates with a service connection to the ASKO Hydraulic Property. A water main located beneath the north shoulder of West Commodore Way supplies potable water to the ASKO Hydraulic Property. TOC records identified a tunnel beneath the West Commodore Way ROW in 1944 used to deliver drums from the Bulk Terminal Property and the ASKO Hydraulic Property to the East Waterfront Property.

A summary table, including reference sources and development description based on available current and historical information for the West Commodore Way ROW, is provided in the RI Report. The West Waterfront Property is located northwest of the West Commodore Way ROW and the East Waterfront Property is located northeast of the West Commodore Way ROW, relative to the ASKO Hydraulic Property. Additional information regarding the northwest and northeast adjoining properties is provided in the RI report.

2.4 LAND USE AND HISTORY OF THE BNSF PARCEL

The BNSF Parcel bounds the ASKO Hydraulic Property to the south. The BNSF Parcel is listed as King County Tax Parcel Number 423790-0240. The BNSF Parcel includes a grass vegetated area immediately south of the ASKO Hydraulic Property followed by a steep south facing vegetated slope that leads to the main rail lines. The south side of the main rail lines consists of a steep north-facing vegetated slope.

The BNSF Parcel was initially developed by the Great Northern Railway Company as part of the main railroad line between Minnesota and Seattle, Washington. Reportedly, the main railroad line was completed in 1893. The BNSF Parcel originally consisted of two main railroad lines with steep vegetated slopes located north and south of the main railroad lines. By 1944, five rail spurs originated from the main railroad lines. Four of the rail spurs (Former Rail Spurs #1 through #4) continue from the BNSF Parcel to the ASKO Hydraulic Property. The fifth rail spur (Former Rail Spur #5) was located next to the main railroad lines at the bottom of the vegetated slope. By 1985, the rail spurs had been removed from the BNSF Parcel and the ASKO Hydraulic Property. The BNSF Parcel is currently owned by BNSF. Property features discussed below are also presented on Figure 4.

A summary table, including reference sources and development description based on available current and historical information for the BNSF Parcel, is provided in the RI Report. The West Government Way ROW is located south of the BNSF Parcel, which separates the BNSF ROW from residential properties. Additional information regarding the south adjoining properties is provided in the RI report.

2.5 ENVIRONMENTAL SETTING AND REGULATORY CLASSIFICATIONS

A summary of the environmental setting, including topography, surface water, soils and geology, hydrogeology, and air, for the ASKO Hydraulic Property and vicinity are provided below. Further background and references of the environmental setting and regulatory classifications for the ASKO Hydraulic Property are provided in the RI Report.

2.5.1 Regional Topography

The ASKO Hydraulic Property is located within the Puget Trough or Puget Lowland portion of the Pacific Border Physiographic Province. The Puget Lowland is a broad, low-lying region situated between the Cascade Range to the east and the Olympic Mountains and Willapa Hills to the west. In the north, the San Juan Islands form the division between the Puget Lowland and the Strait of Georgia in British Columbia. The province is characterized by roughly north-south-oriented valleys and ridges, with ridges that locally form an upland plain at elevations of up to about 500 feet above sea level. The moderately to steeply sloped ridges are separated by swales, which are often occupied by wetlands, streams, and lakes. The physiographic nature of the Puget Lowland was prominently formed by the last retreat of the Vashon Stade of the Fraser Glaciation, which is estimated to have occurred between 14,000 and 18,000 years before present.

The ASKO Hydraulic Property is situated near the base of the northeast hillside of the Magnolia Bluff neighborhood within Seattle. The general topography of the upland surface slopes gently to the north from the north portion of the BNSF Parcel to the ASKO Hydraulic Property towards the shoreline of Salmon Bay. Portions of the upland surfaces at the ASKO Hydraulic Property were terraced to accommodate buildings and storage yards for the former petroleum bulk storage facility operations. The upland surface of the BNSF Parcel was cut to accommodate the main railroad lines. This resulted in two steep, vegetated slopes on the north and south sides of the main railroad lines. Upland surface elevations range from approximately 44.5 feet above sea level next to West Commodore Way at the ASKO Hydraulic Property to approximately 59 feet above sea level on the north portion of the BNSF Parcel.

2.5.2 Surface Water and Sediments

Salmon Bay is located approximately 110 feet north of the ASKO Hydraulic Property. Salmon Bay is a man-made marine waterway located between the Hiram M. Chittenden Locks, operated by U.S. Army Corps of Engineers, to the west and Lake Union to the east. The Hiram M. Chittenden Locks were constructed to move boats between the freshwater Lake Washington Ship Canal to the east and the saltwater Elliot Bay to the west. Upstream of the Hiram M. Chittenden Locks, a submarine barrier was constructed to minimize the mixing of fresh water and saltwater and to limit the movement of saltwater upstream.

2.5.2.1 Surface Water

Saltwater intrudes into Salmon Bay as a result of the operation of the Hiram M. Chittenden Locks, which connect the Lake Washington Ship Canal with Puget Sound. Depending on the levels of salinity present, sediments in certain areas may be classified as marine, low-salinity, or freshwater. It is unlikely that Salmon Bay would be used as a drinking water source because it is known to be mildly saline as a result of mixing with seawater at the Hiram M. Chittenden Locks.

Groundwater from Salmon Bay and the Lake Washington Ship Canal upland areas moves primarily laterally from topographically higher elevations towards the lower elevations adjacent where it discharges to these surface water bodies. Locally, variations in soil conditions and engineering of shallow soils may cause groundwater to flow for short distances in other directions; however, eventually the groundwater discharges to the main surface water bodies.

The majority of the ASKO Hydraulic Property is paved. During storm events, surface water travels as sheet flow to catch basins on the ASKO Hydraulic Property and in the West Commodore Way ROW. Surface water that does not discharge to catch basins, infiltrates into the unpaved area on the ASKO Hydraulic Property and BNSF Parcel, and/or evaporates to the ambient air. Runoff from the building rooftops is captured in gutters and flows down spouts that discharge to the surface.

2.5.2.2 Sediments

General deposition processes for Salmon Bay include eroded soils and discharged outfall sediments from Salmon Bay and the Lake Washington Ship Canal upland areas and associated sediment transport from the Lake Washington Ship Canal. The rate of sediment deposition for Salmon Bay is unknown.

The ground surface at the ASKO Hydraulic Property is paved, or covered with a thick layer of gravel, or densely vegetated. These control measures prevent the erosion of soil at the ASKO Hydraulic Property and minimize the potential migrations of sediments to Salmon Bay.

2.5.3 Soils and Geology

According to the Geologic Map of Northwestern Seattle, the surficial geology in the vicinity of the ASKO Hydraulic Property consists of deposits corresponding to the Vashon Stade of the Fraser Glaciation and pre-Fraser glacial and interglacial periods. In the immediate vicinity of the ASKO Hydraulic Property, surficial deposits consist of pre-Fraser Olympia beds and of modified land, which is characterized fill and/or graded natural deposits that obscure or alter the original deposit.

The youngest pre-Fraser deposits in the Seattle area, known as the Olympia beds, were deposited during the last interglacial period, approximately 18,000 to 70,000 years ago. The

Olympia beds consist of very dense, fine to medium, clean to silty sands and intermittent gravel channel deposits, interbedded with hard silts and peats (Booth et al. 2005; Galster and Laprade 1991). Organic matter and localized iron-oxide horizons are common. The Olympia beds have known thicknesses of up to 80 feet. Beneath the Olympia beds are various older deposits of glacial and nonglacial origin. In general, deposits from older interglacial and glacial periods are similar to deposits from the most recent glacial cycle, due to similar topographic and climactic conditions (Booth et al. 2005).

The Vashon ice-contact deposits are located on the hillside above the ASKO Hydraulic Property and are generally discontinuous, highly variable in thickness and lateral extent, and consist of loose to very dense, intermixed glacial till and glacial outwash deposits. The till typically consists of sandy silts with gravel. The outwash consists of sands and gravels, with variable amounts of silt (Booth et al. 2005).

The Vashon advance outwash deposits are located on the hillside above the ASKO Hydraulic Property and are generally discontinuous and consist of loose to very dense, layered sands and gravels, which are generally well-sorted (poorly graded). Layers of silty sands and silts are less common. The Vashon recessional lacustrine deposits consist of layered silts and clays, which range in plasticity from low to high, and may contain localized intervals of sand or peat. The recessional lacustrine deposits may grade into recessional outwash deposits (Booth et al. 2005).

The undeveloped portions of the Bulk Terminal are either covered with grasses, small shrubs, or gravel. According to geologic cross sections in the 2003 BINMIC Report, Booth et al (2005), Galster and Laprade (1991), boring logs and cross sections in the Fort Lawton Parallel Tunnel Project, Geotechnical Report (Municipality of Metropolitan Seattle 1989), and subsurface investigations conducted at the Seattle Terminal Properties, the uppermost soil layer in the vicinity of the Seattle Terminal Properties and the West Commodore Way ROW typically consists of fine- to coarse-grained soils classified as the Holocene Fill (Hf) geologic unit. The Hf geologic unit ranges from approximately 5 to greater than 20 feet thick, and consists of very loose to very dense, highly variable engineered and non-engineered fill material. Underlying the Hf geologic unit is the Holocene Depression Fillings (Hdf) geologic unit that consists of very soft to medium stiff, fine-grained sand, silt, and clay, with scattered organic particles and very soft peat deposits. The Hf and Hdf geologic units are not depicted on the BINMIC geologic cross section B-B', which shows the Seattle Terminal Properties and the West Commodore Way ROW underlain by an approximate 35-foot thickness of "Unknown Outwash" that overlies clay or glaciolacustrine deposits; however, based on boring logs from the vicinity of the Seattle Terminal Properties, the "unknown Outwash" could be interpreted as the Hf and Hdf geologic units. Underlying the Hf and Hdf geologic units are the pre-Fraser age glacial deposits (Qpf). The Qpf geologic unit consists of dense and hard, interbedded sand, gravel, and silt layers. These deposits can be further subdivided into fine- (Qpff) and coarse-grained (Qpfc) deposits.

2.5.4 Hydrogeology

The glacial and nonglacial deposits beneath the Seattle area comprise the unconsolidated Puget Sound aquifer system, which can extend from ground surface to depths of more than 3,000 feet. Coarse-grained units within this sequence generally function as aquifers, and alternate at some scale with fine-grained units which function as aquitards (Vaccaro et al. 1998). Above local or regional water table aquifers, discontinuous perched groundwater may be present in coarse-grained intervals seated above fine-grained intervals. Below the regional water table, the alternating pattern of coarse and fine-grained units results in a series of confined aquifers. Regional groundwater flow is generally from topographic highs toward major surface water bodies such as Puget Sound, Lake Union, Lake Washington Ship Canal, and Salmon Bay. Vertical hydraulic gradients are typically upward near the major surface water bodies, and downward inland. Regional groundwater flow typically discharges to the closest major surface water body. Salmon Bay is the nearest surface water body and located north of the ASKO Hydraulic Property.

Perched water and three water-bearing zones are encountered beneath the ASKO Hydraulic Property. Discontinuous perched water is encountered beneath the BNSF Parcel, and the southern and northwestern portions of the ASKO Hydraulic Property in areas where localized surface water infiltration occurs. Perched water is encountered in poorly graded sand and silty sand lenses. The poorly graded sand and silty sand lenses with the perched water are underlain by a sequence of discontinuous clay and silt lenses. The shallow, intermediate, and deep water-bearing zones are encountered in deposits that consist of continuous layers of poorly-graded sand and silty sand. The shallow and intermediate water-bearing zones have been observed across the Seattle Terminal Properties. Beneath both the shallow and intermediate water-bearing zones is a clay and silt layer that is approximately 4 feet thick and act as semiconfining units. Below the second semiconfining unit is the deep water-bearing zone observed in the boring advanced for monitoring well 01MW65. Underlying the deep water-bearing zone is the Qpff geologic unit that is greater than 38 feet thick and acts as a confining unit that restricts the vertical migration of groundwater and COPCs located at the Seattle Terminal Properties. Downward vertical gradients are observed by water level measurements in monitoring wells located in perched water and the shallow and intermediate water-bearing zones. The general groundwater flow direction for the shallow and intermediate water-bearing zones is to the northwest-north.

According to the BINMIC Hydrogeologic and Environmental Settings Report, three water supply wells were located in the BINMIC area. Two of the wells are located north of Salmon Bay and the ASKO Hydraulic Property, and the third was reportedly located 0.85 miles southeast of the ASKO Hydraulic Property. The wells were reportedly all used for industrial or commercial purposes and are thought to be abandoned.

Seattle Public Utilities provides the potable water supply to Seattle. Seattle Public Utilities main source of water is derived from surface water reservoirs located within the Cedar and South Fork Tolt River watersheds. According to King County's Interactive Map for the County's Groundwater Program, there are no designated aquifer recharge or wellhead protection areas within several miles of the ASKO Hydraulic Property.

2.5.5 Air

Climate in the Seattle area is generally mild and experiences moderate seasonal fluctuations in temperature. Average temperatures range from 60s in the summer to 40s in the winter. The warmest month of the year is August, which has an average maximum temperature of 74.9 degrees Fahrenheit (°F). The coldest month of the year is January, which has an average minimum temperature of 36.0 °F. The annual average rainfall in the Seattle area is 38.25 inches. The wettest month of the year is December when the area receives an average rainfall total of 6.06 inches (IDcide 2013). The prevailing wind direction in the Seattle area is from the south with variation to the northwest during July, August, and September. The average wind velocity is less than 10 miles per hour (Western Regional Climate Center 2013).

The main underlying sources for ambient air pollutants in Seattle are motor vehicle traffic and residential wood burning (PSCA 2010). Airborne pollutants can reach the terrestrial surfaces and sediment directly, through the deposition of airborne chemicals, primarily in the form of particulate matter onto the water surface, and indirectly, through the deposition of particulate matter on terrestrial surfaces from which they are conveyed via surface water runoff and stormwater to water bodies (Anchor QEA 2012).

3.0 SUMMARY OF CONCEPTUAL SITE MODEL

A CSM identifies confirmed and suspected source areas of hazardous substances, primary release mechanisms for COPCs, affected media, transport mechanisms, fate of hazardous substances in the environment, environmental media of potential concern, and exposure pathways for potential receptors. The CSM is the basis for developing technically feasible cleanup action alternatives from which a final cleanup action approach is selected. The CSM may be refined when additional information becomes available during the implementation of the cleanup action. A schematic drawing showing the conceptual site model based on the preliminary exposure assessment provided in the RI report is presented in Figure 5. Preliminary exposure assessments for Site 1 and Site 2 are presented on Figures 6 and 7. This section summarizes the CSM developed for Site 1 and Site 2 based on the completion of the RI conducted by SoundEarth and others. A summary of the confirmed and suspected source areas, affected media, contaminant fate and transport and the preliminary exposure assessment presented below. A detailed summary of these technical components of the CSM is provided in the RI report.

3.1 CONFIRMED AND SUSPECTED SOURCE AREAS

A source area is the location of a release of a hazardous substance (i.e., trichloroethene [TCE], total petroleum hydrocarbons [TPH], and arsenic) that has affected environmental media, such as soil, surface water, groundwater, and/or air at a site. The historical mechanical systems used for facility operations and processes and distribution infrastructure are identified as confirmed and suspected sources of releases of hazardous substances. The mechanical systems and distribution infrastructure for Site 1 are listed below:

- Former Rail Spurs #1 through #5
- Former underground distribution pipelines
- Former Barreling Sheds #2 and #3
- Former West and East Barrel Inclines
- Former ASTs

The suspected source areas for Site 2 are listed below:

- Former vehicle maintenance facility
- ASKO Industrial Repair machine shop
- Steam cleaning area
- General waste storage including oils and solvents
- Former heating oil and/or waste oil UST(s)

Confirmed and suspected source areas for the Site 1 and 2 are located in the vicinity of the historical mechanical systems and distribution infrastructure and where the highest concentrations of COPCs are present at the Sites.

3.2 AFFECTED ENVIROMENTAL MEDIA

The affected environmental media consists of soil and groundwater with COPCs that were detected at concentrations exceeding their respective preliminary cleanup levels. Soil vapor and outdoor air has been retained as a medium of potential concern based on the concentrations of TCE and TPH in soil and groundwater. The cleanup of the affected soil and groundwater is expected to result in the elimination of soil vapor and outdoor air as a future medium of concern for the Sites.

3.3 CONTAMINANT FATE AND TRANSPORT

Fate and transport of COPCs in affected environmental media are dependent on the physical and chemical properties of the COPC and the geochemical and hydraulic properties of the subsurface environment. Contaminants may exist in four phases in a subsurface environment from a release of a hazardous substance. The four phases include: free-phase (nonaqueous-phase liquid), sorbed-phase (adsorbed to organics or clay soil particles), aqueous-phase (dissolved in water) and gaseous-phase (volatilization from soil or water to air). Commonly, contaminants exist in multiple phases with some degree of partitioning between phases. The contaminant phase depends not only on the properties of the COPC and the site-specific geological properties, but also on the magnitude and extent of release. The physical and chemical properties that control the fate and transport of COPCs include specific gravity, solubility, vapor pressure, Henry's Law constant, and the octanol-water partition coefficient.

The primary indicator hazardous substances for the affected environmental media at the Sites include TCE and TPH. The source(s) of TCE in environmental media at the Sites is unknown. TCE is a primary indicator hazardous substance because it is pervasive throughout the affected environmental media at the Sites although the sources of TCE are unknown. TCE and its degradation compounds share similar environmental fate and transport characteristics. TPH is a primary indicator hazardous substance based on historical facility operations and processes to distribute TPH and the discovery of TPH in soil and groundwater at the Sites. Therefore, TCE and TPH will be the focus of the discussion of contaminant fate and transport for the Sites. The chemical-specific fate and transport of the primary COPCs at the ASKO Hydraulic Property by site are discussed below.

3.3.1 Trichloroethene and Associated Chlorinated Ethenes

The environmental fate for TCE in groundwater is similar to that of TPH, except that due to its high specific gravity (SG = 1.464), TCE tends to sink while TPH will float. The low water solubility (S=1,312 milligrams per liter [mg/L]) and high vapor pressure (58 mm Hg @ 20 degrees Celsius [°C]) yield a Henry's Law constant of 0.0091 which indicates that TCE will rapidly volatilize from water and exist in soil gas. A log K_{ow} of 2.33 suggests TCE is relatively mobile in the subsurface.

TCE is a highly oxidized compound that undergoes both abiotic and biotic degradation processes. Abiotic processes typically include hydrogenolysis, dihaloelimination, and/or hydrolysis of a contaminant. Biodegradation of TCE proceeds anaerobically through a reductive dechlorination pathway. During reductive dechlorination, bacteria gain energy by transferring electrons from an electron donor (H_2) to an electron acceptor (TCE). The chlorine atoms of TCE are sequentially replaced with hydrogen atoms. This process can often be mediated by indigenous bacterial cultures, but is susceptible to stalling at the cis-1,2-DCE or VC dechlorination step. To date, *Dehalococcoides* is the only species known to be capable of complete reductive dechlorination of chlorinated ethenes to ethene.

The principal fate and transport mechanisms for TCE in affected environmental media are summarized below:

- The lateral distribution of TCE concentrations in soil is likely a result of transport via direct contact from historical surface releases of TCE and transport over time via movement of dissolved-phase TCE in groundwater and sorptive capacity of the soil matrix.
- Dissolved-phase TCE in groundwater will migrate with the horizontal and vertical groundwater gradients. The lateral groundwater flow direction at the ASKO Hydraulic Property is to the northwest. Concentrations of TCE in groundwater are typically highest in the source areas and decrease along the groundwater flow path due to dilution with unaffected groundwater and sorption onto soil particles.
- The transport of vapor-phase TCE in the subsurface is a result of volatilization of TCE released in confirmed and suspected source areas to the subsurface and dispersion through the unsaturated subsurface via natural mechanisms, such as barometric fluctuations.
- Release(s) of TCE from facility operations and processes to the subsurface environment may result in an accumulation of DNAPL and/or the contamination of the environmental media of potential concern via phase partitioning. No DNAPL has been observed in the monitoring well network.

The results from this RI indicate the presence of TCE at concentrations that exceed the preliminary cleanup levels in soil and groundwater beneath the Sites (Figures 8 through 18).

3.3.1.1 Site 1

The site-specific results for Site 1 are summarized below:

- The highest concentrations of TCE were in soil samples collected in the vicinity of the Former Rail Spurs #1 through #4 and Former Barreling Shed #2. These confirmed and suspected source areas are located on the south portion of the ASKO Hydraulic Property and on the north portion of the BNSF Parcel. Concentrations of TCE in soil exceeding the preliminary cleanup levels were present approximately 2 to 30 feet below ground surface (bgs) at Site 1 (Figures 8 through 14).
- The highest concentrations of TCE in groundwater are present in the perched water and shallow water-bearing zone in the vicinity of the Former Rail Spurs #1 through #4 and Former Barreling Shed #2. Additional concentrations of TCE exceeding the preliminary cleanup levels in groundwater have been observed in the shallow water-bearing zone and intermediate water-bearing zone in the vicinity of the Former AST Area. The deep water-bearing zone has not been impacted by TCE (Figures 15 through 18).

3.3.1.2 Site 2

The site-specific results for Site 2 are summarized below:

- The highest concentrations of TCE were in soil samples collected in the vicinity of the general waste storage area. This confirmed and suspected source area is located in the northwest portion of the ASKO Hydraulic Property. Concentrations of TCE in soil exceeding the preliminary cleanup levels were present approximately 10 to 22.5 feet bgs at Site 2 (Figures 12 through 14).
- The highest concentrations of TCE in groundwater are present in the shallow water-bearing zone in the vicinity of the general waste storage area. The intermediate water-bearing zone has not been impacted by TCE (Figures 15 through 18).

3.3.2 Total Petroleum Hydrocarbons and Volatile Petroleum Compounds

In general, petroleum hydrocarbons with lower carbon numbers (e.g., gasoline-range petroleum hydrocarbon [GRPH] and benzene, toluene, ethylbenzene, and total xylenes [BTEX]) are more soluble, and have lower log K_{ow} values and higher vapor pressures than petroleum hydrocarbons with higher carbon numbers (e.g., diesel-range petroleum hydrocarbon [DRPH] and oil-range petroleum hydrocarbon [ORPH]). Therefore, GRPH and BTEX are more mobile, have less affinity to sorb to soil organic matter, are more likely to exist in vapor form, and are more easily biodegraded than heavy fuel fraction. For example, benzene is moderately water soluble (1,770 mg/L), tends to rapidly volatilize from water ($H = 5.48 \times 10^{-3}$), is quite hydrophobic and will sorb to soil (log K_{ow} = 2.05). Dodecane (a 12 carbon compound in DRPH) is nearly insoluble in water (S= 0.008 mg/L), may volatilize from water (H=24.2), but not as free-phase (P_v=0.3 mm Hg), and will strongly sorb to soil (log K_{ow}=6.44).

Biodegradation of TPH in groundwater is dependent on the oxidation-reduction conditions of the groundwater, which is a function of the presence or absence of electron acceptors that support biologically mediated degradation. Biologically mediated oxidation of TPH occurs most effectively under aerobic conditions. Aerobic metabolism occurs when microorganisms transfer electrons from the electron donor (TPH) to an electron acceptor (O_2) in order to gain energy. O_2 is the most energetically favored electron acceptor followed by nitrate (NO_3^-), manganese or ferric oxides (MnO_2), sulfate (SO_4^{2-}) and carbon dioxide (CO_2, methanogenesis). Aerobic metabolism tends to be the quickest form of biodegradation of TPH. Biodegradation occurs when the contaminants are in the dissolved-phase in groundwater or in the capillary fringe. TPH biodegrades at faster rates under aerobic conditions, which are typically found at dissolved-phase plume boundaries. Aerobic biodegradation occurs first in the source area, depleting oxygen levels and creating a predominantly anaerobic environment.

The principal fate and transport mechanisms for TPH and BTEX in affected environmental media are summarized below:

- The lateral distribution of concentrations of TPH and BTEX in soil is a result of transport via adsorption of the soil matrix and direct contact of light nonaqueous-phase liquid (LNAPL).
- Surface erosion may transport contaminated soil to surface water. The direct contact of contaminated soil with surface water and groundwater may result in soil to water partitioning via leaching.

- The lateral distribution of concentrations of TPH and BTEX in groundwater is a result of direct contact with historical releases of LNAPL and associated LNAPL to water partitioning, and leaching of adsorbed-phase petroleum-contaminated soil via soil-to-water partitioning, and the natural attenuation processes, such as advection/dispersion, diffusion, sorption, and biodegradation.
- Natural mechanisms, including temperature, groundwater, and barometric pressure fluctuations, may result in the volatilization of TPH and BTEX in soil and groundwater to soil vapor via soil and/or groundwater to air partitioning. Soil vapor with concentrations of TPH and BTEX may transport to the surface with barometric pressure fluctuations.

The results from this RI indicate the presence of TPH and BTEX at concentrations that exceed the preliminary cleanup levels in soil and groundwater beneath the Sites (Figures 19 through 22).

3.3.2.1 Site 1

The site-specific results for Site 1 are summarized below:

- The highest concentrations of TPH were in soil samples collected in the vicinity of the Former Rail Spurs #1 through #4 and Former Barreling Shed #2. These confirmed and suspected source areas are located on the south portion of the ASKO Hydraulic Property and the north portion of the BNSF Parcel. Concentrations of TPH in soil exceeding the preliminary cleanup levels were present approximately 2 to 13 feet bgs Site 1 (Figures 19 and 20).
- The highest concentrations of TPH in groundwater are present in the perched water and shallow water-bearing zone in the vicinity of the Former Rail Spurs #1 through #4 and Former Barreling Shed #2. Detectable concentrations of TPH in groundwater above the preliminary cleanup levels are not present in the intermediate water-bearing zone and the deep water-bearing zone (Figures 21 and 22).

3.3.2.2 Site 2

The site-specific results for Site 2 are summarized below:

- The highest concentrations of TPH were in soil samples collected in the vicinity of the general waste storage area. These confirmed and suspected source areas are located in the northwest portion of the ASKO Hydraulic Property. Concentrations of TPH in soil exceeding the preliminary cleanup levels were present approximately 1 to 7.5 feet bgs at Site 2 (Figures 19 and 20).
- The highest concentrations of TPH in groundwater are present in the perched water and the shallow water-bearing zone in the vicinity of the general waste storage area. Detectable concentrations of TPH in groundwater above the preliminary cleanup levels are not present in the intermediate water-bearing zone (Figures 21 and 22).

3.4 PRELIMINARY EXPOSURE ASSESSMENT

The preliminary exposure assessment identifies potential receptors for exposure pathways for environmental media of potential concern from contaminant fate and transport mechanisms. Potential receptors at risk from exposure associated with the presence of COPCs at the Sites are human and ecological receptors. The two potential receptors were segregated into subcategories to better identify the potential receptors at risk of exposure from the presence of COPCs in environmental media of potential concern. The subcategories for human health include workers, recreational use, drinking water consumption, and fish and shellfish consumption and for ecological include terrestrial and aquatic biota.

The objective of the preliminary exposure assessment is to assess the completeness of exposure pathways from environmental media of potential concern and associated contaminant fate and transport mechanisms for the potential receptors for the Sites. The results from the preliminary exposure assessment will assist with the evaluation of potential feasible cleanup alternatives that are protective of the potential receptors for the Sites. The results from the preliminary exposure assessment will assist with the evaluation of potential feasible cleanup alternatives that are protective of the potential receptors identified as complete. The preliminary exposure assessment for the Sites is illustrated in flow diagrams (Figures 6 and 7). The preliminary exposure assessment for each exposure pathway and associated environmental media of potential concern is summarized below by affected environmental media.

3.4.1 Soil

Soil with concentrations of COPCs above the preliminary cleanup levels may present a potential exposure pathway to human and/or ecological receptors. The principal contaminant fate and transport mechanisms for soil at the Sites include sorption, erosion, leaching, and volatilization (Figures 6 and 7). Leaching of TCE and TPH from soil by dissolution and desorption to groundwater is discussed below. The exposure pathways identified for soil include the following:

- **Direct Contact (Dermal Contact and Ingestion) with Subsurface Adsorbed-Phase Contaminated Soil.** This exposure pathway is complete for subsurface soil at Site 1 and Site 2 via dermal contact or ingestion. The standard point of compliance for the direct contact exposure pathway for soil is 15 feet bgs for human health and 6 feet bgs for terrestrial receptors, which represents a reasonable depth that could be excavated during normal redevelopment activities and distributed at the ground surface (WAC 173-340-[6][d] and WAC 173-340-7490[4][b]). COPCs above the preliminary cleanup levels are present in shallow subsurface soil within 6 feet bgs at Site 1 and Site 2. Areas where subsurface contaminated soil is present are covered by paved surfaces or with crushed rock or low growing vegetation to prevent the migration of material by erosion transport mechanisms.

  COPCs above the preliminary cleanup levels are present in near surface soil within 2 feet bgs at Site 1. Areas where near surface contaminated soil is present are covered with grass and low growing vegetation, which may not prevent the migration of material by erosion transport mechanisms.

- **Direct Contact of Surface Water Runoff.** Surface water runoff does not come in contact with soil with concentrations of COPCs at Sites 1 or 2, which presents a leaching pathway of COPCs by dissolution or desorption. This exposure pathway is considered incomplete for potential receptors for Site 1 and Site 2.

- **Inhalation of Soil Vapor/Outdoor Air.** This exposure pathway is considered complete for worker and terrestrial receptors by potential inhalation of volatile

COPCs originating in the vadose zone and ambient air for Sites 1 and 2. The air-filled pore space between soil grains in the unsaturated zone or partially saturated zone is referred to as soil gas or soil vapor. TCE and low molecular weight aromatic and aliphatic TPH fractions are highly volatile due to their relative low vapor pressures. The volatilization of TCE from potential DNAPL and TPH fractions from LNAPL, and from adsorbed-phase contaminated soil can accumulate the concentrations of TCE and TPH in soil vapor and migrate to the surface to locally impact outdoor air quality near the unpaved surfaces. Once in the atmosphere, the vapors are unlikely to result in an exposure pathway to the general public due to the vapors being dispersed and/or degraded.

3.4.2 Groundwater

Groundwater is affected by surface and subsurface releases of COPCs and the leaching of potential DNAPL or LNAPL directly into a groundwater-bearing zone and the leaching of TCE and TPH into infiltrating surface water that passes through unsaturated adsorbed-phase soil and migrates to groundwater. Groundwater with concentrations of COPCs above the preliminary cleanup levels may present a potential risk to human and/or ecological receptors. The primary contaminant fate and transport mechanism for groundwater at the Site include sorption, advection/dispersion, diffusion, and volatilization (Figures 5 through 7). Other contaminant fate and transport processes, such as biodegradation and oxidation or reduction, are expected to have minor to no influences in reducing potential exposures of COPCs to receptors. The biodegradation and oxidation or reduction processes appear to be occurring at a naturally slow rate to significantly contribute to the fate and transport processes of COPCs for Site 1 and Site 2. The exposure pathways identified for groundwater include the following:

- **Direct Contact of Surface Water.** This exposure pathway is considered incomplete for potential receptors. The discharge of dissolved-phase TCE and TPH from groundwater hydraulically connected to Salmon Bay sediments is unlikely based on empirical evidence showing that concentrations of TCE and TPH at compliance monitoring wells located downgradient of Site 1 and Site 2 do not contain concentrations of TCE and TPH above laboratory reporting limits and/or the preliminary cleanup levels.
- **Direct Contact and Inhalation of Groundwater.** The perched water and the shallow and intermediate water-bearing zones at Site 1 and the perched water and shallow water-bearing zone at Site 2 have detectable concentrations of COPCs above the preliminary cleanup levels. Current access to the perched water, shallow water-bearing zone, and intermediate water-bearing zone (Site 1) is limited to workers via environmental sampling. There is no drinking water supply wells located in the vicinity of the Sites. A potential receptor at risk from this exposure pathway, if groundwater beneath the Sites is developed for use, is drinking water. It is unlikely that water beneath the Sites would be used for drinking water because of the availability of municipal water supplies and current land use of the Sites; however, there is a potential that future land use could allow for use of groundwater beneath the Sites as a drinking water source with approval from Ecology. Therefore, the exposure pathways for direct contact with dissolved-phase contaminated groundwater and inhalation of vapors from dissolved-phase groundwater is

considered complete for workers and could be complete for drinking water for the perched water (workers only), shallow water-bearing zone, and intermediate water-bearing zone (Site 1 only).

The exposure pathway for the deep water-bearing zone at Site 1 is considered incomplete for potential receptors. Deep zone well 01MW65 is installed next to shallow zone monitoring well 01MW55. Monitoring well 01MW55 has had some of the highest detectable concentrations of TCE and other COPCs in groundwater for Site 1. Monitoring well 01MW65 was installed to assess the potential vertical migration of TCE and its degradation compounds in groundwater for Site 1. Groundwater sample analytical results collected from deep zone monitoring well 01MW55 indicate that concentrations of TCE and other COPCs are below the preliminary cleanup levels. These groundwater analytical results also indicate that the concentrations of TCE and other COPCs in groundwater within the shallow water-bearing and intermediate water-bearing zones are not migrating vertically to the deep water-bearing zone and the semi-confining unit above the deep zone is acting as an attenuation barrier for the dissolved-phase TCE and TPH plumes.

The exposure pathway for the intermediate water-bearing zone at Site 2 is considered incomplete for potential receptors. Intermediate zone well 01MW57 is installed next to shallow zone monitoring well MW05, which has had some of highest detectable concentrations of TCE and other COPCs in groundwater. This monitoring well was installed as a well pair to MW05 to assess the potential vertical migration of TCE and its degradation compounds in groundwater for Site 2. Groundwater sample analytical results collected from intermediate zone monitoring well 01MW57 show that concentrations of COPCs are below the preliminary cleanup levels, and indicate that the concentrations of TCE and other COPCs in groundwater within the shallow water-bearing zone are not migrating vertically to the intermediate water-bearing zone and the semi-confining unit above the intermediate zone is acting as an attenuation barrier for the dissolved-phase TCE and TPH plumes.

- **Inhalation of Soil Vapor/Outdoor Air.** This exposure pathway is considered complete for worker and terrestrial receptors via volatilization of the COPCs in groundwater to the vadose zone and outdoor air with subsequent inhalation by potential receptors. TCE and low-range fuel fraction TPH tend to be highly volatile due to their relative low vapor pressures. The volatilization of TCE from potential DNAPL and TPH from LNAPL, sorbed-phase soil, and dissolved-phase groundwater can accumulate the concentrations of TCE and TPH in soil vapor and migrate to the surface to locally impact outdoor air quality near the unpaved surfaces. Once in the atmosphere, the vapors are unlikely to result in an exposure pathway to the general public due to the vapors being dispersed, diluted, and/or degraded by photolysis.

4.0 FIELD PILOT TESTS AND TREATABILITY STUDIES

This section summarizes field pilot tests and treatability studies performed to evaluate the effectiveness of potential remedial components presented in Table 2 and to obtain preliminary design information to develop and evaluate cleanup action alternatives for the Sites. The tests and studies were performed at the ASKO Hydraulic Property or the east-adjacent Bulk Terminal Property, where the test and study results are relevant to the evaluation and design of candidate remedial components for the ASKO Hydraulic Property. The tests and studies performed included the following:

- Aquifer testing to obtain subsurface soil physical and hydraulic properties. The soil properties were used to support the contaminant fate and transport analysis and the development of the CSM discussed above, and to evaluate the feasibility of in situ remedial components for perched water and shallow water-bearing zone.
- Soil vapor extraction (SVE) pilot test to assess the potential effectiveness of SVE technology to remediate unsaturated soil with concentrations of volatile COPCs.

The following sections summarize the field pilot tests and treatability studies including a description of the testing procedures and methods and a summary of results.

4.1 AQUIFER TESTING

Aquifer testing was conducted at the Seattle Terminal Properties including the ASKO Hydraulic Property between 2009 and 2011 to estimate the hydraulic characteristics of perched water, and the shallow, intermediate, and deep water-bearing zones. The aquifer testing at the ASKO Hydraulic Property included slug testing, a radius of influence tracer study, and laboratory analysis for soil physical properties and organic carbon data. The hydraulic parameters obtained from these tests were used for contaminant fate and transport analysis and development of the CSM. Summary tables and charts of data collected and analyzed and figures from the aquifer testing are provided in Appendix A.

4.1.1 Slug Tests

In March 2009, SoundEarth conducted slug tests in monitoring wells 01MW44, 01MW57, 01MW62, and 01MW65 to estimate the hydraulic conductivities of the shallow, intermediate, and deep water-bearing zones encountered beneath and downgradient of the ASKO Hydraulic Property. Slug tests were also conducted on an additional five monitoring wells installed in the shallow water-bearing zone at the Bulk Terminal Property and the East Waterfront Property.

The slug used for testing was constructed from a piece of PVC pipe filled with clean sand to displace a known volume within the water column. Water levels were monitored during the slug tests using AquiStar PT2X vented pressure transducers that incorporate automatic logging of water level data using AquiStar Aqua4Plus software. The pressure transducer was programmed to record readings at intervals ranging from 1 second to 1 minute during the slug tests. An electronic water level indicator was also used to obtain periodic manual water level measurements during the slug tests.

The test wells were opened and allowed to equilibrate with the atmosphere for at least 30 minutes prior to conducting each test. The pressure transducer was placed at a depth of at least 2 feet below the targeted submergence depth of the slug. Water levels were monitored after placing the pressure transducer in the monitoring well to confirm that the water level had stabilized before inserting the slug. To start the slug test, the slug was lowered into the well until it was fully submerged. Following the introduction of the slug, water levels were allowed to equilibrate. After equilibration was reached, the slug was quickly removed from the monitoring well to test the rising head, and water levels were allowed to re-equilibrate.

Following field testing, the water level data were downloaded from the pressure transducers, compiled, and processed for analysis. Data processing included selecting the time interval of interest, reducing the measurement frequency where appropriate, and converting the water levels to displacements (change versus the initial water level). Time series files of the recorded displacements for each test were then exported to AquiferWin32 (Environmental Solutions, Inc.) for analysis.

The data were analyzed by the Bouwer and Rice (1976) method, using the procedures described by Bouwer (1989), which pertain to wells screened across the water table. Assumptions of the Bouwer and Rice method include the following (Todd and Mays 2005, Bouwer 1989):

- The aquifer is unconfined and has an apparently infinite areal extent.
- The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the slug test.
- Prior to the test, the water table is (nearly) horizontal over the area that will be influence by the test.
- The head in the well is lowered instantaneously at time zero, the drawdown in the water table around the well is negligible, there is no flow above the water table.
- The inertia of the water column in the well and the linear and non-linear well losses are negligible.
- The well either partially or fully penetrates the saturated thickness of the aquifer.
- The flow to the well is in steady state.
- Because the water table in the aquifer is kept constant and is taken as a plane source of water, the Bouwer and Rice method can also be used for a leaky aquifer, provided that its lower boundary is an aquiclude and its upper boundary an aquitard.

The results from the slug tests indicated the following:

- The estimated hydraulic conductivity of the shallow water-bearing zone ranged from 3.4 feet per day (ft/day) in monitoring well 01MW62 to 5.7 ft/day in monitoring well 02MW14.
- The estimated hydraulic conductivity of the intermediate water-bearing zone was 2.8 ft/day in monitoring well 01MW57.
- The estimated hydraulic conductivity of the deep water-bearing zone was 6.2 ft/day in monitoring well 01MW65.
- The arithmetic mean hydraulic conductivity from the slug tests for the shallow bearing-zone conducted at the ASKO Hydraulic Property was 4.3 ft/day.

4.1.2 Tracer Study

On July 12 and 13, 2011, a radius of influence tracer study was conducted on the ASKO Hydraulic Property. The purpose of the tracer study was to evaluate the radial transport of injectate, which could be used to support the selection of a future cleanup action.

A solution consisting of 2,500 gallons of water with a 10,000 parts per billion Rhodamine WT (a fluorescent tracer dye) was mixed in a mixing tank. The solution was injected into monitoring well 01MW81, which was screened within the shallow water-bearing zone. Injection flow rates were estimated by periodic measurement of the water level in the injection tank. Flow was mostly steady during the radius of influence tracer study with an average flow rate of approximately 4 gallons per minute.

The injection was monitored in monitoring wells 01MW82 and MW05, which are screened in the shallow water-bearing zone, and in monitoring well 01MW57, which is screened in the intermediate water-bearing zone. Water levels and temperatures during the test were monitored in monitoring wells 01MW81, 01MW82, and MW05 using AquiStar PT2X vented pressure transducers that incorporate automatic logging of water level data using AquiStar Aqua4Plus software. The pressure transducers were programmed to record readings at intervals ranging from 1 second to 1 minute during the tracer study. An electronic water level indicator was also used to obtain periodic manual water level measurements in monitoring wells 01MW82 and MW05. Fluid conductivity and temperature were monitored in monitoring well 01MW82 using a Hydrolab downhole probe. Water samples were collected from 23 and 25 feet below the top of casing in monitoring wells 01MW82 and MW05, using peristaltic pumps with dedicated tubing. The water samples were analyzed for Rhodamine WT concentrations using an AquaFluor handheld fluorometer. As necessary, the water samples were diluted to achieve concentrations that did not exceed 300 parts per billion (ppb), as recommended by the fluorometer manufacturers. Dilutions were performed with a 10 milliliter handheld pipette.

Concentrations of Rhodamine WT reached a maximum concentration of approximately 5,200 ppb, which was 52 percent of the injectate concentration, in monitoring wells 01MW82 and MW05 between 7 and 8 hours of elapsed time. Fluid conductivity in 01MW82 reached a minimum of 0.154 millisiemens per centimeter, which was 89 percent of the difference between the ambient and injectate values, after 10 hours of elapsed time, which was approximately 19 percent of the ambient value (0.83 millisiemens per centimeters) and approximately 217 percent of injectate conductivity (0.071 millisiemens per centimeter). The fraction of injectate at the minimum measured conductivity value was 89 percent. At the end of the tracer study, fluid conductivity in monitoring well 01MW82 was very close to the injectate value.

The radius of influence parameter as it applies to solute injection describes the distance from the injection well at which a certain goal concentration is observed, after a given time or volume. A 4 to 4.5 foot radius of influence was measured in observation wells 01MW82 and MW05, indicating that with more time and/or a larger volume of injectate, a greater radius of influence may be achieved. No significant changes in water levels or geochemistry conditions were observed in monitoring well 01MW57 during the tracer study indicating the shallow water-bearing zone and intermediate water-bearing zone are separated by a semi-confining to confining layer described above.

4.1.3 Laboratory Analysis of Soil Physical Properties

Soil samples were collected from the shallow water-bearing zone in borings B172 and B193 for laboratory analysis of soil physical properties. The samples were collected during drilling activities for the RI using Dames and Moore samplers lined with 2-inch-long brass rings. The containers were placed in an iced cooler and transported for laboratory analysis to PTS

Laboratories, Inc. of Santa Fe Springs, California, under standard chain-of-custody protocols. The samples were submitted for laboratory analysis of the following:

- Moisture content by American Petroleum Institute (API) Recommended Practice (RP) 40 and American Society for Testing and Materials International (ASTM) D2216.
- Bulk and grain density, total and air filled porosity, and total pore fluid saturation by API RP 40.
- Effective permeability to water and hydraulic conductivity by API RP 40 and U.S. Environmental Protection Agency (EPA) Method 9100.
- Total and effective porosity by Modified ASTM D425.
- Fraction organic carbon and total organic carbon by Walkley-Black.
- Particle size analysis by ASTM D422 and ASTM 4464.

Analytical results for the samples analyzed for soil physical properties indicated the following:

- Moisture content was measured at 20.7 percent by weight in the shallow water-bearing zone at 23.3 feet bgs in boring B172 and 20.5 percent by weight at 26.2 feet bgs.
- Dry bulk grain density was measured ranging from 1.43 to 1.55 grams per cubic centimeter (g/cm^3) in the shallow water-bearing zone. Grain density was measured at 2.72 g/cm^3 in the shallow water-bearing zone.
- The total porosity and air-filled porosity in B172 were measured at 47.5 and 18 percent bulk volume, respectively, in the shallow water-bearing zone at 23.3 feet bgs. The total porosity and air-filled porosity in B193 were measured at 43.1 and 11.2 percent bulk volume, respectively, in the shallow water-bearing zone at 26.2 feet bgs at the ASKO Hydraulic Property.
- Total pore fluid saturation was measured at 62.2 percent pore volume in the shallow water-bearing zone of boring B172 and 73.9 percent pore volume in the shallow water-bearing zone of boring B193 at the ASKO Hydraulic Property.
- Effective permeability to water was measured in the shallow water-bearing zone ranged from 201 to 1,082 millidarcys.
- Effective porosity ranged from 32.8 to 33.8 by percent bulk volume for the soil samples collected from the shallow water-bearing zone at the ASKO Hydraulic Property.
- Hydraulic conductivity was measured at 1.07×10^{-3} centimeters per second (cm/sec) in the sample collected from boring B172 in the shallow water-bearing zone and 1.96×10^{-3} in the sample collected boring B193 in the shallow water-bearing zone, both of which are consistent with values obtained from slug tests.
- Total organic carbon in the shallow water-bearing zone at the ASKO Hydraulic Property was measured at 520 milligrams per kilogram (mg/kg) in boring B172.

- Fraction organic carbon in the shallow water-bearing zone at the ASKO Hydraulic Property was measured at 0.000520 grams per gram in the shallow water-bearing zone in B172.
- The particle size distributions are consistent with the visual estimates recorded in the boring logs (Appendix G of the RI Report), which indicate fine to medium sand with total silt and clay contents ranging from approximately 5 to 20 percent in the shallow water-bearing zone.

The values for the soil physical properties correspond to the range of typical values for soils with similar particle size distributions and densities (Freeze and Cherry 1979).

4.1.4 Aquifer Testing Analysis

SoundEarth conducted aquifer testing in the shallow, intermediate, and deep water-bearing zones to analyze contaminant fate and transport. Aquifer properties of water storage include porosity and water transmission includes hydraulic conductivity, hydraulic gradient, and seepage velocity.

The effective porosity ranged from 32.8 and 33.8 by percent bulk volume for soil samples collected from borings B172 and B193 in the shallow water-bearing zone. The soil observed at these borings is representative from the shallow water-bearing zone. Specific yield was not calculated based on limitations associated with the testing methods.

Hydraulic conductivity is the capacity to transmit water. The shallow water-bearing zone hydraulic conductivity values calculated from the slug test and laboratory testing for most of the locations are relatively consistent. Based on the studies, the hydraulic conductivity in the shallow water-bearing zone at the ASKO Hydraulic Property ranges from about 3.4 to 5.7 ft/day. Hydraulic conductivity in the intermediate zone was 2.8 ft/day and the hydraulic conductivity in the deep water-bearing zone was 6.2 ft/day. The hydraulic conductivity values calculated from the slug test results correspond to the soil characteristics observed in explorations completed in monitoring wells on the ASKO Hydraulic Property.

The hydraulic conductivity values analyzed by laboratory samples collected from the shallow water-bearing zone compare favorably to those obtained from the slug tests. This range of hydraulic conductivity values correspond to the range of published values for similar silty sand materials (Coduto 1999). This supports a conceptualization of the aquifer as mostly homogenous at scales ranging from inches to feet. The values for the soil physical properties correspond to the range of typical values for soils with similar particle size distributions and densities (Freeze and Cherry 1979).

The average hydraulic gradient of the shallow water-bearing zone at the Seattle Terminal Properties is 0.07 feet per foot as presented in RI Report. Seepage velocity is calculated by multiplying hydraulic conductivity by the hydraulic gradient and dividing by the porosity. Based on the results of this aquifer testing analyses, estimated range of groundwater seepage velocity for the shallow water-bearing zone at the ASKO Hydraulic Property is 0.72 to 1.07 ft/day.

4.2 SVE PILOT TEST

SoundEarth conducted an SVE pilot test at the ASKO Hydraulic Property on February 23 and 24, 2010, to evaluate the potential effectiveness of SVE technology to remediate soil with concentrations of TCE and volatile TPH, if present. The pilot test was performed on three test wells: 01SVE01, 01MW44, and

01MW63, using a skid-mounted SVE blower, knock-out tank, and control panel. The locations of the test wells and observation wells are shown in Appendix B. The SVE blower was utilized to apply vacuum to the test wells through a piping assembly equipped with an instrument train and a bleed-air assembly. The instrument train and bleed-air assemblies were equipped to measure vacuum, temperature, and flow rates. Observation wells, 01MW15, 01MW54, 01MW55, and 01MW65, were utilized during each test to measure vacuum at varying distances from the test wells.

Pilot test activities commenced on February 23, 2010, by collecting depth to groundwater measurements prior to applying vacuum to the test wells and to establish the baseline airflow for the blower. Tests were performed by incrementally increasing the vacuum applied to one test well at a time by closing the manual air dilution valve on the instrument train. Flow and vacuum could also be controlled at the discretion of the test operator by varying the speed of the blower motor using a variable frequency drive. The test commenced with the manual air dilution valve fully open resulting in the minimum vacuum applied to the test well. Subsequent vacuum step tests involved closing the air dilution valve incrementally and allowing the flow to stabilize prior to collecting test well and observation well measurements. Samples of recovered soil vapor were collected at the initiation and the end of the test from each of the three test wells and submitted for laboratory analysis for chlorinated volatile organic compounds (CVOC) by EPA Method 8260. Vapor samples were also analyzed on a real-time basis for BTEX using a field gas chromatograph; and for TCE, vinyl chloride, and benzene with colorimetric detector tubes. Vapor samples were also measured at various time intervals during each test for explosive vapor concentrations (expressed as a per cent of the lower explosive limit [LEL]), oxygen, and carbon dioxide concentrations.

Summary figures and tables as well as raw test data and laboratory analytical reports for the SVE pilot tests are provided in Appendix B. The analysis of the SVE pilot test provided below describes air flow as a function of applied vacuum and includes an assessment of the zone of vacuum influence (ZOI) and critical radius. An estimated contaminant mass removal rate in the vapor phase from the Site 1 was determined from analytical results and flow rates collected during the pilot test.

4.2.1 Flow versus Vacuum

Results of the SVE pilot test indicate that the subsurface exhibits a wide range in air flow permeability among the test wells, which is illustrated in the plots of flow versus vacuum for each test well in Appendix B. The slopes for the flow versus vacuum plots in Appendix A illustrate the relationship between applied vacuum and air flow. The greater the slope of the linear regression lines for each data set, the greater the air flow permeability for the test well. The tests wells exhibiting the highest to lowest unit air yields; respectively, were Wells 01SVE01, 01MW63; and 01MW44. The unit air yields for these wells respectively were approximately 0.89, 0.45, and 0.087 standard cubic feet per minute per inch of water (scfm/iow) vacuum applied.

The flow data obtained by the flow-averaging pitot tube connected to each test well is questionable because the velocities measured were below the manufacturer’s recommended minimum levels. An alternative flow estimate for each well involves subtracting the bleed air flow rates (which were within the manufacturer’s recommended range) from the total air flow rates. The total air flow rates were determined as a function of blower speed prior to commencing the tests by producing a blower calibration curve.

4.2.2 Zone of Vacuum Influence

The vacuum responses measured in observation wells during the SVE pilot test are tabulated in Appendix A. Included with the vacuum data are the blower speeds at the time of the vacuum measurements, and the approximate horizontal distance of each observation well from the test well. Data did not follow the expected pattern. Typically, when measuring vacuum in an observation well a certain distance from a pumping well, a fairly uniform vacuum gradient is observed decreasing with distance from the pumping well. In these tests, there was no consistent decreasing vacuum gradient with distance; and, in several wells a positive pressure was measured at the observation well while the test well was subjected to vacuum. Observing positive pressure in an observation well during an SVE test is not uncommon. This phenomenon, known as barometric pumping, may produce a positive pressure in an observation well caused by natural diurnal changes in barometric pressure. In addition, in the case where an observation well and a test well are screened over different depth intervals, there may not be a discernible vacuum in the observation well even though the two wells are in close proximity due to a flow boundary between the two wells.

One should not conclude from these observations that the unsaturated zone exhibits low relative air flow permeability, or that SVE is not an appropriate technology for remediating the unsaturated zone. It would be appropriate to conclude that there are subsurface heterogeneities within the test area that produce non-uniform pressure distributions and therefore non-uniform air flow when vacuum is applied to the subsurface.

These findings also illustrate a common problem of overestimating the ZOI of an extraction well using pressure gradients as the basis for establishing the ZOI for SVE design. Using pressure gradients as a basis for design often results in large areas with very low pore velocities and, therefore, long cleanup times. As a result, a design approach based on critical pore gas velocity (CPGV) has increased in popularity and acceptance (EPA 2001, USACE 2002). The CPGV is used to incorporate the effects of mass transfer limitations into SVE design based on the distinction between "mobile" and "immobile" zones. As described in USACE (2002), soils are often divided into two categories for remediation: low permeability and high permeability, relative to each other. Early models of pump-and-treat referred to the relatively low permeability soil as "immobile" since the water in the soil was practically stagnant. The higher permeability soil is named "mobile" since the majority of flow occurs in these soils. In the vadose zone, the mobile soils are the most permeable and appreciable air flow through these soils is induced when a pressure gradient is applied (e.g., extraction in a well). Immobile soils have relatively low permeability, and air flow through these soils during the application of a pressure gradient is considered negligible. Contaminant transport in immobile soils is dominated by diffusion in the vapor phase or liquid advection and diffusion if moisture contents are high.

USACE (2002) recommends a minimum CPGV between 0.01 and 0.001 centimeters per second (which is equivalent to 0.02 to 0.002 feet per minute [ft/min]) to address mass transfer limitations between immobile and mobile zones in the soil matrix. A CPGV of 0.02 ft/min is recommended because it optimizes the recovery of contaminants in the mobile vapor phase and prevents over-designing the SVE mechanical systems to attempt venting unproductive immobile zones.

An approximate value of the CPGV can be calculated if vapor flow is assumed to be uniformly radial around the extraction well. The velocity is then calculated from the vadose zone thickness, the fraction of soil characterized as mobile (USACE 2002), the porosity, the fraction water saturation, and the extraction rate in accordance with the following equation:

$$CPGV = \frac{Q}{2\pi \times b \times mf \times n \times (1 - Sm) \times r}$$

Where:

CPGV is in units of ft/min

Q = flow rate (ft^3/min)

B = thickness of vadose zone (feet)

m_f = mobile fraction (unitless)

n = porosity (unitless)

S_m = decimal equivalent of water saturation in vadose zone (unitless)

r = critical radius (feet)

Conditions of the SVE pilot test are estimated to be:

Q_{avg} = 29 ft^3/min (90% of 32 ft^3/min average flow rate)

b = 22 feet (average thickness of unsaturated zone)

m_f = 0.38 (estimated)

n = 0.4 (from soil properties testing Table 6 of Appendix B)

S_m = 0.68 (from soil properties testing Table 6 of Appendix B)

$$r = \frac{29}{2\pi \times 22 \times (0.38) \times 0.4 \times (1 - 0.68) \times 0.02}$$

The solution to the above equation for the critical radius (r) for a single extraction well pumping at 29 scfm at the minimum CPGV of 0.02 feet per minute yields a maximum radius of 216 feet. To account for the non-radial flow and unsaturated zone heterogeneities, a more conservative CPGV of 0.2 ft/min results in a radius of 22 feet. As such, 20 feet is selected as a reasonably conservative design critical radius for vertical SVE well spacing.

4.2.3 Vapor Phase Analytical Results

The laboratory analytical results of the air samples collected during the SVE pilot test indicate that a substantial volatile organic compound (VOC) mass could be removed from the subsurface via SVE. The laboratory results indicate a substantial concentration of TCE in the soil vapor recovered from each of the three wells. Other byproducts of reductive dechlorination of TCE, such as cis- and trans-1,2-dichloroethene, 1,1-dichloroethene, and vinyl chloride, were also detected in the samples. The highest concentrations of TCE and reductive dechlorination byproducts were found in well 01MW44. BTEX compounds were generally not detected in the soil vapor except at the end of the test conducted for well 01MW44.

Real time measurements of VOCs, oxygen, LEL, and carbon dioxide concentrations confirmed the presence of VOCs in soil vapor (VOCs and LEL) as well as the fact that hydrocarbons are undergoing aerobic bioremediation as evidenced by the deficit in oxygen and enrichment in carbon dioxide concentrations relative to atmospheric levels for these gases.

4.3 CHEMICAL OXIDANT DEMAND

Chemical oxidant demand tests were conducted to evaluate the feasibility of chemical oxidation for soil and/or groundwater at the Sites. The chemical oxidant demand tests included a permanganate natural oxidant demand (PNOD) test for saturated soil and a Klozur® demand test (KDT) for saturated soil and groundwater.

4.3.1 Permanganate Natural Oxidant Demand

SoundEarth collected a soil sample identified as B171-24 2/28/11 0940 from the ASKO Hydraulic Property and submitted the sample to Carus Remediation Technologies for analysis of PNOD using ASTM D7262-07 Test Method A. The measurement of the PNOD is used to estimate the concentration of permanganate that will be consumed by naturally-occurring reducing agents over a 48-hour time period.

The average 48-hour PNOD based on three replicate tests was 1.6 ± 0.3 grams of permanganate per kilogram (g/kg) of dry soil. According to Carus Remediation Technologies, soil samples that exhibit a 48-hour PNOD of less than 10 g/kg exhibit a low demand relative to other soils. As a result, they recommend permanganate as a suitable remediation technology. Results for the PNOD test are summarized in Appendix C.

4.3.2 Klozur® Demand Tests

An aliquot of the same soil sample collected from B171-24 for the PNOD test and a groundwater sample from monitoring well 01MW45 were also submitted to FMC Corporation (FMC) for a KDT to evaluate oxidant demand for FMC's Klozur activated sodium persulfate product. The KDT measures the loss of persulfate in the presence of soil, groundwater, and activator over a period of 48 and 96 hours. The resulting KDT values can be used to estimate persulfate dosing for subsequent field applications.

The average Klozur Demand for two runs was 1.95 g/kg and 2.05 g/kg at times of 48 and 96 hours, respectively. According to FMC Corporation, the Klozur Demand (using sodium hydroxide as an activating agent) of between 1.9 and 2.1 g/kg represents an average to moderate demand compared to most soils. Based on these results, they recommend an average dose of 2.0 g/kg as a Site-wide design dose. The results show that FMC's Klozur activated sodium persulfate is a viable chemical injectate. The results of the KDT test are presented in Appendix C.

5.0 REMEDIAL ALTERNATIVES ASSESSMENT

The purpose of this FS is to develop and evaluate cleanup action alternatives to facilitate selection of a final cleanup action for the Sites in accordance with WAC 173-340-350(8). An FS includes the development, screening, and evaluation process for numerous remedial alternatives.

The FS is used to screen cleanup action alternatives to eliminate alternatives that are not technically possible, or the costs are disproportionate under WAC 173-340-360(3)(e), or alternatives that will substantially affect the future planned business operations at the site. Based on the screening, the FS presented below evaluates the most advantageous remedial components to recommend a final cleanup action for the Site in conformance with WAC 173-340-360 through WAC 173-340-390.

5.1 CLEANUP STANDARDS

The selected cleanup action alternative must comply with MTCA cleanup regulations specified in WAC 173-340 and with applicable federal and state laws. The preliminary cleanup levels and remedial action objectives for the Site are discussed below.

5.1.1 Applicable or Relevant and Appropriate Requirements

Under WAC 173-340-350 and 173-340-710, applicable requirements include regulatory cleanup standards, standards of control, and other environmental requirements, criteria, or limitations established under state or federal law that specifically address a contaminant, remedial action, location, or other circumstances at a site.

MTCA defines relevant and appropriate requirements as:

> Those cleanup action standards, standards of control, and other human health and environmental requirements, criteria or limitations established under state and federal law that, while not legally applicable to the hazardous substance, cleanup action, location, or other circumstances at a site, the department determines address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site. The criteria specified in WAC 173-340-710(3) shall be used to determine if a requirement is relevant and appropriate.

Remedial actions conducted under MTCA must comply with the substantive requirements of the ARARs but are exempt from their procedural requirements (WAC 173-340-710[9]). Specifically, this exemption applies to state and local permitting requirements under the Washington State Water Pollution Control Act, Solid Waste Management Act, Hazardous Waste Management Act, Clean Air Act, State Fisheries Code, and Shoreline Management Act.

5.1.1.1 Screening of ARARs

ARARs were screened to assess their applicability to the Sites. Only those that were deemed appropriate and applicable were retained. The following table identifies the ARARs that may be applicable to the Sites:

Preliminary ARARs for the Sites

Preliminary ARAR	Citation or Source
MTCA	Chapter 70.105 of the Revised Code of Washington (RCW)
MTCA Cleanup Regulation	WAC 173-340
Ecology, Toxics Cleanup Program – Guidance To Be Considered	*Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action*, Review DRAFT, October 2009, Publication No. 09-09-047
State Environmental Policy Act	RCW 43.21C

Preliminary ARAR	Citation or Source
Washington State Shoreline Management Act	RCW 90.58; WAC 173-18, 173-22, and 173-27
The Clean Water Act	33 United States Code [USC] 1251 et seq.
Comprehensive Environmental Response, Compensation, and Liability Act of 1980	42 USC 9601 et seq. and Part 300 of Title 40 of the Code of Federal Regulations [40 CFR 300]
The Fish and Wildlife Coordination Act	16 USC 661-667e; the Act of March 10, 1934; Ch. 55; 48 Stat. 401
Endangered Species Act	16 USC 1531 et seq.; 50 CFR 17, 225, and 402
Native American Graves Protection and Repatriation Act	25 USC 3001 through 3013; 43 CFR 10 and Washington's Indian Graves and Records Law (RCW 27.44)
Archaeological Resources Protection Act	16 USC 470aa et seq.; 43 CFR 7
Washington Dangerous Waste Regulations	WAC 173-303
Resource Conservation and Recovery Act (RCRA)	40 CFR Parts 260-280 and 148
Solid Waste Management Act	RCW 70.95; WAC 173-304 and 173-351
Occupational Safety and Health Administration Regulations	29 CFR 1910, 1926
Washington Department of Labor and Industries Regulations	WAC 296
Water Quality Standards for Surface Waters of the State of Washington	RCW 90.48 and 90.54; WAC 173-201A
Water Quality Standards for Ground Water	WAC 173-200
Department of Transportation Hazardous Materials Regulations	40 CFR 100 through 185
Washington State Water Well Construction Act	RCW 18.104; WAC 173-160
City of Seattle regulations, codes, and standards	All applicable or relevant and appropriate regulations, codes, and standards
King County regulations, codes, and standards	All applicable or relevant and appropriate regulations, codes, and standards

5.1.2 Development of Cleanup Standards

The selected cleanup action alternative must comply with the MTCA cleanup regulations specified in WAC 173-340 and with applicable state and federal laws. The preliminary cleanup levels selected for the Sites are consistent with the RAOs, which state that the RAO is to reduce concentrations of COPCs in soil and/or groundwater beneath the Sites to below their preliminary cleanup levels at defined points of compliance. In addition to mitigating risks to human health and the environment, achieving the RAOs will allow Ecology to issue Property- and/or Site-specific determinations of No Further Action (NFA). The preliminary cleanup levels for the media and COPCs are presented in Table 1.

5.2 REMEDIAL ACTION OBJECTIVES

RAOs are administrative goals for a cleanup action that address the overall MTCA cleanup process. The purpose of establishing RAOs for a site is to provide remedial alternatives that protect human health and the environment (WAC 173-340-350). In addition, RAOs are designated to:

- Implement administrative principles for cleanup (WAC 173-340-130).
- Meet the requirements, procedures, and expectations for conducting an FS and developing cleanup action alternatives as discussed in WAC 173-340-350 through 173-340-370.
- Develop cleanup standards (WAC 173-340-700 through 173-340-760) and remedial alternatives that are protective of human health and the environment.

RAOs must include the following threshold requirements from Chapter 173-340 WAC:

- Protect human health and the environment.
- Comply with applicable state and federal laws.
- Comply with cleanup standards.
- Provide for compliance monitoring.

The RAOs for the Sites are to mitigate potential exposure pathways for human and terrestrial receptors; to comply specific hazardous waste ARARs, to remove the RCRA waste designation associated with CVOCs in affected environmental media; and to comply with ARARs and Site-specific cleanup standards to demonstrate compliance and obtain an NFA determination from Ecology. The implementation of the selected cleanup action alternative will address the potential exposure pathways to protect the human health and the environment. The full treatment and/or disposal of affected environmental media (soil and groundwater) with CVOCs (TCE and its degradation compounds) will assist with a petition to remove the RCRA waste designation of F002. Compliance monitoring will demonstrate the cleanup standards have been met at the established points of compliance defined in the cleanup action plan. A request for an NFA determination from Ecology will be made upon completion of the compliance monitoring plan.

5.3 IDENTIFICATION AND EVALUATION OF REMEDIAL COMPONENTS

SoundEarth evaluated remedial components for the Sites with respect to the cleanup requirements set forth in MTCA. According to MTCA, a cleanup action alternative must satisfy the minimum threshold requirements for RAOs, as outlined in Section 5.1.3 above. WAC 173-340-360 (2)(b) also requires that the cleanup action alternative meet the following requirements:

- Use permanent solutions to the maximum extent practicable.
- Provide for a reasonable restoration time frame.
- Consider public concerns.

A comprehensive list of remedial components and the rationale for inclusion or exclusion of specific component options with respect to the MTCA evaluation criteria are summarized in Table 2. The remedial components are separated into nine distinct component groups including passive remediation, in situ physical treatment, in situ thermal, source removal, ex situ source treatment, in situ chemical oxidation, containment/immobilization, phytoremediation, and in situ bioremediation. The nine component groups are further subdivided into component options that are possible controls and technologies to achieve the RAOs. One or a combination of these component options may apply to remediate COPCs for the Sites.

The remedial component options retained after the screening evaluation include the following:

- Monitored natural attenuation (MNA)
- Passive Treatment Wall or Permeable Reactive Barrier (PRB)
- SVE
- Dual-phase extraction (DPE)
- Resistive Thermal with SVE
- Excavation with Shoring (Soldier Pile Wall – Non-Impervious)
- Land Disposal
- Permanganate
- Aerobic Bioremediation
- Anaerobic Bioremedation

A comprehensive list of remedial technologies is presented in Table 2. The remedial alternatives were evaluated using the above criteria. The screening matrix of each cleanup action alternatives is discussed in further detail below.

5.3.1 Monitored Natural Attenuation

MNA is a passive process that depends on intrinsic environmental factors to reduce contaminant concentrations over time in the absence of human effort through natural processes, such as biodegradation, adsorption, dissolution, diffusion, and advection and dispersion.

MNA includes the active process of monitoring and documenting the effectiveness of an otherwise passive technology. It is often used as a polishing technology after an active technology has reduced contaminant concentrations but is unable to achieve cleanup levels. Monitoring is needed to evaluate the effectiveness of natural attenuation and to document the achievement of cleanup levels.

5.3.2 Permeable Reactive Barrier

A PRB is an in situ engineering control designed to passively treat contaminated groundwater. Groundwater flows through a permeable reactive barrier wall containing a mixture of zero-valent iron (ZVI) and sand and gravel. The ZVI acts as a catalyst to dechlorinate the CVOCs dissolved in the groundwater.

This technology was retained for further evaluation for the passive treatment of the dissolved-phase plume migrating onto the ASKO Hydraulic Property from the adjacent upgradient BNSF Parcel.

5.3.3 Soil Vapor Extraction

SVE is a proven technology for recovering volatile chlorinated and non-chlorinated hydrocarbons from unsaturated soil. This technology is implemented by installing vertical and/or horizontal wells within the zone of contamination. Vacuum is applied to recover contaminants in the vapor phase for subsequent treatment and disposal. This technology is not suitable for the treatment or recovery of contaminated groundwater and is not suitable for the remediation of middle- to heavy-range petroleum hydrocarbons. Treatment of recovered soil vapor would likely be required prior to release to the atmosphere.

5.3.4 Dual-Phase Extraction

DPE is a proven technology for the remediation of VOCs in soil and groundwater. A DPE remediation system typically consists of a submersible pump to recover groundwater and the simultaneous application of a vacuum to the exposed soil column for the recovery of VOCs from the soil. The extraction of groundwater reduces the mass of the dissolved-phase contaminants and reduces the mobility of the contaminant plume by hydraulic containment. Groundwater extraction can be effective for low to high permeability soils (EPA 1999). The vapor extraction component removes mass from the semi-saturated and unsaturated soil zones by volatilizing the contaminant and capturing the mass in the vapor phase for ex situ treatment or discharge. The vapor extraction component is best applied when the surface is capped, soils have a low to moderate permeability, and a moderate vacuum is applied (EPA 1999).

5.3.5 Resistive Thermal with SVE—Electrical Resistance Heating (ERH)

ERH consists of applying electric current to the subsurface through an array of electrodes emplaced in the soil to induce soil heating. In this application, heat would be applied to the saturated zone where concentrations of chlorinated and non-chlorinated hydrocarbons exceed cleanup levels. The saturated zone would be heated above the boiling point of the target chlorinated hydrocarbon compound TCE (87.2 degrees Celsius °C) but below the boiling point of water to cause the TCE to evaporate from the groundwater where it would be recovered by soil vapor extraction. Raising the temperature using ERH would also result in the volatilization of benzene in the vapor phase (boiling point 80.1 °C). Other fuel hydrocarbon compounds, such as toluene, ethylbenzene, and xylenes which have boiling points above TCE and benzene, would not be completely removed by heating. However, heating would increase the rate at which these compounds volatilize from the dissolved phase to the vapor phase where the vapors would be recovered more effectively than by SVE only. Recovered soil vapor would either be cooled and treated with vapor-phase granular-activated carbon prior to atmospheric discharge, or treated by catalytic oxidation prior to discharge. The method of treatment for the vapor would ultimately be determined by economic and regulatory factors.

5.3.6 Excavation with Shoring (Soldier Pile Wall—Non-Impervious) and Land Disposal

Excavation with shoring (soldier pile wall) and land disposal are remedial components for the excavation of source material. Excavation of source material is a proven technology for the removal of contaminants from the subsurface. Soldier pile wall shoring would be installed as the excavation advances with depth to protect existing structures and property boundaries.

Soil and groundwater excavated from the source area for non-chlorinated hydrocarbons would be directly land disposal at a permitted facility. Chlorinated hydrocarbon-contaminated soils might require pretreatment prior to land disposal if concentrations of regulated substances exceed levels permissible for land disposal; otherwise, excavated source material would be land disposed directly without pretreatment in accordance with federal, state, and local regulations.

5.3.7 Permanganate—In Situ Chemical Oxidation (ISCO)

Chemical oxidation compounds commonly used for the treatment of chlorinated compounds include permanganate, persulfate, and Fenton's reagent. These compounds effectively break the carbon-to-carbon double bond of chlorinated ethene compounds like TCE and facilitate the full breakdown of chlorinated compounds to nonhazardous compounds when in direct contact.

Permanganate is one of the more commonly used chemical oxidants to treat chlorinated compounds. Permanganate is comparatively more stable in the subsurface due to its relative long half-life and is less costly than persulfate or Fenton's reagent. Persulfate is a strong chemical oxidant, but it has a shorter half-life than permanganate. Fenton's reagent is a rapid chemical reaction compound with a very short half-life that results in limited travel distances when injected. Fenton's reagent also produces a significant amount of gas and heat, which represent a health and safety hazard for workers.

The chemical oxidant can be delivered to the subsurface by batch injections or recirculation systems. The batch injection is common because it involves the use of temporary push borings to deliver the oxidant. The recirculation system involves more aboveground infrastructure and operation and maintenance (O&M) of the system.

Permanganate as a chemical oxidant was retained for further evaluation based on the ability to breakdown chlorinated COPCs in affected media at the Sites.

5.3.8 Aerobic Bioremediation

Bioremediation of non-chlorinated COPCs in soil and groundwater is most effective and sustainable under aerobic conditions (i.e., in the presence of oxygen). Increasing the availability and concentration of oxygen in the subsurface by engineered methods enhances the rate at which the COPCs are degraded. Proven methods to increase oxygen concentrations in the saturated zone include injecting chemical reactants that produce elemental oxygen (peroxides) and sparging compressed air or oxygen gas directly into the water-bearing zone. SVE and DPE are proven technologies for increasing oxygen concentrations in the unsaturated zone. The increased oxygen concentration resulting from these enhancements produces an increased and sustained rate of biodegradation of COPCs.

5.3.9 Anaerobic Bioremediation—Reductive Dechlorination

Anaerobic bioremediation is a process where microorganisms that flourish in the absence of oxygen metabolize chlorinated ethene compounds in soil and groundwater to nonhazardous compounds such as ethene or ethane. The microorganisms that metabolize the target chlorinated hydrocarbons do so most effectively in the absence of oxygen (reductive dechlorination). Edible oil is one nontoxic substrate (vegetable oil) that can be used to produce the anaerobic conditions necessary for reductive dechlorination. Edible oil is injected into a contaminated plume to provide a readily degradable food source for the naturally-occurring microorganisms. Oxygen is consumed along with the edible oil producing the anaerobic environment needed to efficiently reductively dechlorinate the target contaminants.

Anaerobic bioremediation is a potentially effective technology to be implemented at the Sites and was retained for further evaluation based on evidence of current reductive dechlorination of TCE in progress.

5.4 CLEANUP ACTION ALTERNATIVES SELECTED FOR FURTHER EVALUATION

The below-list of cleanup action alternatives were assembled from the remedial components retained from screening:

- **Cleanup Action Alternative 1—**Excavation with Shoring and Off-Site Land Disposal of COPCs
- **Cleanup Action Alternative 2—**Reductive Dechlorination for CVOCs in Groundwater; DPE for CVOCs in Groundwater; SVE for GRPH in Soil; and Excavation for DRPH in Soil
- **Cleanup Action Alternative 3—**ISCO for CVOCs in Groundwater; DPE for TPH in Groundwater; SVE for CVOCs in Soil; Excavation for DRPH in Soil
- **Cleanup Action Alternative 4—**ERH for Chlorinated Hydrocarbons in Groundwater; DPE for Petroleum Hydrocarbons in Groundwater; SVE for Volatile Hydrocarbons in Soil; and Excavation of DRPH in Soil

Remedial components that are common to all alternatives include: MNA, PRB, and aerobic bioremediation. The focused evaluation of these alternatives is presented in Section 5.6.

5.5 ALTERNATIVE EVALUATION CRITERIA

This section presents the criteria used to evaluate the potentially feasible cleanup action alternatives with respect to the RAOs established for the Site. Remedial components were identified in accordance with the requirements set forth in MTCA under WAC 173-340-350(8)(b) and the focused screening of potential remedial components using the requirements and procedures for selecting cleanup actions as set forth in MTCA under WAC 173-340-360(2)(a)(b). The criteria used to evaluate and compare applicable cleanup action alternatives were derived from WAC 173-340-360(3)(f) and include the following:

- **Protectiveness.** The overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, the time required to reduce risk at the facility and attain cleanup standards, the risks resulting from implementing the alternative, and improvement of overall environmental quality of the Sites.
- **Permanence.** The degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated during the treatment process.
- **Effectiveness over the Long Term.** The degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time over which hazardous substances are expected to remain on the Site, and the magnitude of residual risk associated with the contaminated soil and/or groundwater components. The following types of cleanup action components, presented in descending order of preference under MTCA, may be used as a guide when assessing the relative degree of long-term effectiveness of the chosen alternative:
    - Reuse or recycling

- Destruction or detoxification
- Immobilization or solidification
- On-Property or off-Property disposal in an engineered, lined, and monitored facility
- On-Property isolation or containment with attendant engineering controls
- Institutional controls and monitoring

- **Management of Short-Term Risks.** The risk to human health and the environment associated with the alternative during its construction and implementation, and the effectiveness of measures that will be taken to manage such risks.
- **Technical and Administrative Implementability.** The ability to implement the alternative; includes consideration of the technical feasibility of the alternative, administrative and regulatory requirements, permitting, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with the future development plans for the site.
- **Consideration of Public Concerns.** Consideration of public concerns is mandated under the MTCA cleanup regulation for an Ecology-led or potentially liable person-led cleanup action under an Agreed Order or Consent Decree. This is typically implemented by Ecology through a mandatory public review and comment period on a proposed cleanup action plan. Because this public review and comment process is not implemented by the private party responsible for the cleanup under the Voluntary Cleanup Program (VCP) and because this FS Report was prepared within the purview of the VCP, public concerns regarding cleanup actions for the Sites were not evaluated in this document.
- **Cost.** The cost to implement the alternative, including the cost of construction, the net present value of long-term costs, and Ecology oversight costs. Long-term costs that were considered include those associated with O&M, monitoring, equipment replacement, reporting, and maintaining institutional controls. Many of these costs are evaluated as part of the disproportionate cost analysis section presented below.

5.6 FOCUSED EVALUATION OF CLEANUP ACTION ALTERNATIVES

The focused evaluation of cleanup action alternatives considers the practicable remedial components confirmed to be effective at treating COPCs in the affected media of concern. The evaluation also considers whether Site-specific constraints would preclude the application of a remedial component due to the creation of a greater risk to human health and/or the environment, if such constraints could result in the component being technically or administratively infeasible to implement, or if the component was disproportionately costly relative to the benefits realized. A detailed description of the four alternatives that were retained for evaluation is provided below.

5.6.1 Cleanup Action Alternative 1—Excavation with Shoring and Off-Site Land Disposal of COPCs

Cleanup Action Alternative 1 involves excavating all soil exhibiting COPC concentrations exceeding the cleanup levels and backfilling with clean fill to the pre-excavation grades. Figures 23A and 23B provide conceptual illustrations of how this alternative would be implemented.

The project would be performed in two phases because the size of the two excavation areas requires a certain amount of space that precludes excavating both areas contemporaneously. Also, based on the depth of the excavations (32 feet bgs) and proximity to the West Commodore Way ROW to the north, the BNSF ROW to the south, and the TOC headquarters building to the east, it would be necessary to shore the excavations, as shown on Figures 23A and 23B. Shoring would likely consist of soldier piles and wood lagging with tie backs and anchors, as needed. The length of the piles and spacing would be as stipulated by the structural engineer. Shoring to the south along the railroad ROW may not be feasible and depends on negotiated access with BNSF. Estimated costs for this alternative assume that BNSF grants access to its property to install shoring protection.

Phase I would consist of shoring and excavating the smaller area (Site 2) as shown in Figure 23A. This area would be accessed from the western edge of the haul road sloping down to the west at a maximum slope of 3H : 1V (Horizontal to Vertical) to a depth of approximately 32 feet bgs. A haul road and turn loop would be situated on the eastern part of the ASKO Hydraulic Property. The total estimated volume of soil to be excavated from Site 2 is 4,467 bank cubic yards (bcy). Bank cubic yards are a measure of in-place volume. Transporters and disposal vendors often charge based on mass rather than volume. The conversion factor used to estimate the soil mass from volume used in this FS is to assume a bulk density of 1.5 tons per bcy. Soil that is excavated from its bank condition will expand usually between 15 to 30 percent in volume (the swell factor), depending on the soil type and moisture content. An excavated soil volume is termed "loose." An estimate of the loose cubic yards (lcy) and mass of soil excavated Site 2 is approximately 5,584 lcy, and 6,701 tons, respectively, assuming a swell factor of 25 percent and density of 1.5 tons per bcy.

A temporary dewatering pump and treat system would be installed to minimize the moisture content of the excavated soils. Recovered water would be pre-treated and discharged to the King County sanitary sewer system under an industrial waste pretreatment permit. The wood lagging from Phase 1 would be pulled and the excavation backfilled and compacted with clean fill to original grade before commencing Phase 2.

Phase 2 would commence with drilling and installing soldier piles to shore the northern, eastern and southern edges of the larger excavation area for Site 1 as shown on Figure 23B. An estimate of the volume for this area for Site 1 is approximately 11,673 bcy, which equates to approximately 17,509 tons (11,673 bcy x 1.5 tons per bcy). Excavated soil from both excavation areas that contained TCE above detectable levels would be managed for land disposal as Resource Conservation and Recovery Act dangerous/hazardous waste, when generated. In accordance with federal and state dangerous waste regulations at 40 CFR Part 268.48 and WAC 173-303-140, respectively, excavated soil that exhibits a TCE concentration greater than 60 mg/kg (i.e., 10 times the universal nonwastewater treatment standard of 6.0 mg/kg for TCE) would be prohibited from land disposal unless treated to a concentration less than 60 mg/kg. Excavated soil that contained petroleum hydrocarbons above cleanup levels, but did not contain

TCE above detectable levels and is not otherwise designated as a dangerous waste would be subjected to thermal desorption treatment and ultimately reused or recycled.

The respective areal extents of TCE and TPH in groundwater were used to estimate the respective proportions of excavated soil volume requiring disposal as dangerous waste (i.e., TCE-contaminated) versus non-dangerous . The TCE in the groundwater plume covers approximately 80 to 90 percent of the total area being excavated. Although TPH (GRPH and DRPH) in soil and groundwater are coincident with the TCE plume, it appears to account for approximately 5 to 10 percent of the surface area covered by the excavation. The balance of the total area (0 to 5 percent) would be uncontaminated overburden soil. These respective proportions were used to approximate the volume and mass of the various categories of soil for ultimate disposition, once excavated. These estimates are listed in the table below for this alternative.

Excavation Phase	Bank Volume (bcy)	Loose Volume (lcy)	Total Mass Estimate (T)	Mass of TCE-Contaminated Soil			Mass of TPH-Contaminated Soil (T)	Mass of Clean Overburden Soil (T)
				Land-Banned (T)	Dangerous Waste	Contained - out		
				5% of total	25% of total	60% of total	5% of total	5% of total
Phase 1	4,467	5,584	6,701	335	1,675	4,021	335	335
Phase2	11,673	14,591	17,509	875	4,377	10,505	875	875
Total	16,140	20,175	24,210	1,210	6,052	14,526	1,210	1,210

NOTES:
bcy = bank cubic yards
lcy = loose cubic yards
TCE = trichloroethene

Additional assumptions for this cleanup action alternative include the following:

- Excavated soil would be transported by truck to treatment/disposal facilities.
- A PRB consisting of a mixture of ZVI, pea gravel, and sand would be installed during the backfilling of Phase 2 for Site 1 along the ASKO Hydraulic Property boundary with the BNSF Parcel in the configuration shown in Figure 23B. The PRB material would be emplaced along the shoring wall by removing the wood lagging as the excavation was backfilled.
- Twenty new monitoring wells would be installed to evaluate groundwater quality following excavation. New wells would be monitored quarterly for five years for COPCs and natural attenuation parameters. Analyses would indicate that concentrations of COPCs are below the MTCA cleanup levels for groundwater.
- The total life cycle for this alternative is 6 years, including 5 years of post-excavation groundwater monitoring for the purpose of estimating the present worth cost. This duration should not be construed as a guaranteed remediation time frame.

The present worth cost estimate to implement Cleanup Action Alternative 1, assuming a real discount rate of negative 0.8 percent and a life cycle for future compliance monitoring and O&M of 5 years, is approximately $7,622,490 (Table 3). This feasibility level cost should not be considered a design cost estimate or guaranteed cost.

5.6.2 Cleanup Action Alternative 2—Reductive Dechlorination for CVOCs in Groundwater; DPE for CVOCs in Groundwater; SVE for GRPH in Soil; and Excavation for DRPH in Soil

Cleanup Action Alternative 2 would involve the injection of edible oil into the subsurface to promote the reductive dechlorination of chlorinated COPCs within the source area plumes. DPE technology would be employed to address petroleum hydrocarbon contamination in saturated soil and groundwater. Soil contamination with volatile chlorinated and petroleum hydrocarbons would be remediated by SVE technology. DRPH-contaminated soil located at shallow depths would be excavated. Figures 24A and 24B provide a conceptual illustration of how this cleanup action alternative might be implemented.

The cleanup action would be implemented in two stages and commence with excavating the three areas with shallow DRPH-contaminated soil. The DRPH-contaminated soil would be excavated, transported off site for land disposal to a permitted facility. The volume of DRPH-contaminated soil to be excavated is estimated at 1,700 bcy and a total mass of approximately 2,550 tons when converted by multiplying the estimated bcy by 1.5 tons per bcy. Clean structural fill would be imported, backfilled, and compacted to bring the excavated areas back to grade.

Following excavation of the DRPH-contaminated soil, the PRB would be installed by large-diameter auger to intercept TCE-impacted groundwater flowing onto the ASKO Hydraulic Property from the BNSF Parcel. Well drilling would then commence for the edible oil injection wells, and the temporary edible oil injection system would be set up.

The introduction of edible oil during the injection process would quickly transform the water-bearing zone into the strong reducing environment necessary to sustain reductive dechlorination of chlorinated COPCs. The available carbon in edible oil is extremely high, which leads the naturally-occurring aerobic bacteria to consume the available oxygen while consuming the edible oil. Once the aerobic bacteria have consumed sufficient oxygen to turn the aquifer sufficiently anaerobic, indigenous bacteria will begin utilizing the chlorinated COPCs as electron acceptors to gain energy. This reaction leads to the successive removal of chlorine atoms (dechlorination) from the chlorinated ethenes. The eventual end product is non-toxic ethane and free chlorine ions.

Edible oil would be injected into the subsurface through permanent injection wells installed by hollow-stem auger drilling. Approximately 61 injection wells would be installed as shown on Figure 24A. The edible oil would be injected under low pressure into the saturated zone. In addition, the thin capillary fringe layer at the soil/groundwater interface would be treated by mounding the edible oil solution into the vadose zone.

Injection would permeate the thickness of the water-bearing zone with the edible oil substrate. Injections would be accomplished using a temporary injection system constructed on the ASKO Hydraulic Property. The first low-pressure injection program would entail one injection event of approximately 40,000 pounds of pure emulsified oil product. At a second injection event, approximately one half of the size of the initial injection program, aquifer pH adjustment, and bioaugmentation would be incorporated under this cleanup action alternative as a contingency. Bioaugmentation with a specific strain of dehalogenating bacteria (*Dehalococcoides*) prevents the dechlorination reactions from stalling at 1,2-dichloroethene and/or vinyl chloride. These intermediates still exhibit toxicity and require further dechlorination to ethene.

Performance groundwater monitoring during and after the injection would provide indicators as to whether or not bioaugmentation and/or additional substrate injections would be necessary. Groundwater monitoring would be conducted for a period of 3 years to confirm the chlorinated COPCs have been effectively remediated by reductive dechlorination.

Once reductive dechlorination has been successfully implemented for chlorinated COPC contamination in groundwater, the SVE and DPE wells, infrastructure and aboveground equipment will be installed. SVE wells would be installed as shown on Figure 24B to remediate volatile chlorinated and petroleum hydrocarbons from areas exhibiting unsaturated soil contamination. DPE wells would also be installed as shown on Figure 24B. Water would be recovered from the DPE wells by down-well pneumatic total fluids pumps. SVE would be applied to the unsaturated and previously saturated soils. A treatment facility would be constructed to house vapor and water treatment equipment. Vapor recovered by the SVE and DPE wells would be treated by either catalytic oxidation or vapor phase carbon under a permit from the Puget Sound Clean Air Agency (PSCAA). The method of vapor treatment would be selected at the design phase based on economic and regulatory considerations. It is assumed for the purpose of estimating the cost of this alternative that water recovered by the DPE wells would be pre-treated by filtration, phase separation in an oil/water separator, and liquid-phase granular-activated carbon prior to a permitted industrial waste discharge to the King County sanitary sewer.

Performance monitoring and operations and maintenance would follow the SVE/DPE system installation and is estimated to continue for 7 years. This monitoring would include groundwater sampling, and monitoring of remediation system mass recovery and discharges.

Key assumptions for this cleanup action alternative include the following:

- The 61 injection points would be adequate to deliver the edible oil solution. The total amount of injection points may vary based on subsurface conditions.
- Performance monitoring will include monitoring groundwater for total organic carbon, mounding, pH, MNA parameters, COPCs and soil gas. A baseline monitoring event will be completed to establish performance monitoring parameters before implementing the edible oil injection. The performance monitoring parameters would be further discussed in the draft Cleanup Action Plan.
- The volume of edible oil required will be calculated using a mass balance model supplied by the vendor and would be further discussed in the draft Cleanup Action Plan.
- One low-pressure injection event and a second smaller-scale injection event would take place. The number of events is relatively unimportant; it is the overall volume of the edible oil to be injected that is the driving force. The injection would be implemented using permanent monitoring points.
- A PRB consisting of a mixture of ZVI, pea gravel, and sand would be installed along the ASKO Hydraulic Property boundary with the BNSF Parcel in the configuration shown in Figures 24A and 24B. The PRB material would be emplaced by drilling with a 4-foot-diameter caisson rig to a total depth of approximately 48 feet bgs. The bottom 13 feet of each hole would form the permeable reactive barrier and contain the ZVI, sand, and pea gravel mixture.

- Post-cleanup action groundwater monitoring data will indicate that concentrations of COPCs are below the MTCA cleanup levels for groundwater.
- The life cycle for this alternative is assumed to be 10 years for the purpose of estimating the present worth cost. This duration should not be construed as a guaranteed remediation time frame.

The present worth cost estimate to implement Cleanup Action Alternative 2, assuming a real discount rate of 0.1 percent and a life cycle of 10 years, is approximately $4,660,000 (Table 4). This feasibility level cost should not be considered a design cost estimate or guaranteed cost.

5.6.3 Cleanup Action Alternative 3—ISCO for CVOCs in Groundwater; DPE for TPH in Groundwater; SVE for CVOCs in Soil; Excavation for DRPH in Soil

Cleanup Action Alternative 3 involves the injection of potassium permanganate solution into the subsurface to oxidize the chlorinated COPCs in groundwater. DPE technology would also be employed to address petroleum hydrocarbon contamination in groundwater. Soil exhibiting volatile chlorinated and petroleum hydrocarbon contamination would be remediated by SVE technology. DRPH-contaminated soils, which are comparatively shallow in depth, would be excavated. Figures 25A and 25B provides an illustration of the conceptual implementation of this cleanup action alternative.

Similar to Cleanup Action Alternative 2, this alternative would be implemented in phases and commence with excavating the three areas of DRPH-contaminated soil. The DRPH-contaminated soil would be excavated, transported off site for land disposal to a permitted facility. The volume of DRPH-contaminated soil to be excavated is estimated at 1,700 bcy (2,550 tons). Clean structural fill would be imported, backfilled, and compacted to bring the excavated areas back to grade. Following excavation of the DRPH-contaminated soils, well drilling would commence for the chemical oxidation injection wells, the SVE wells, and the DPE wells. SVE and DPE wells would be installed first along with trenches and pipe to connect the SVE and DPE wells to the remediation compound. Chemical oxidation injection wells would be drilled after the completion of the SVE and DPE subgrade piping installations.

ISCO with permanganate provides treatment of the chlorinated COPCs in groundwater. ISCO requires direct contact with the contaminant, and a dense injection grid is necessary for adequate contact with the affected media. The effectiveness of the chemical oxidant within the source area and/or plume is highly dependent on the permeability (hydraulic conductivity) of the soil matrix which ensures rapid and efficient distribution of the chemical in the treatment zone. If the hydraulic conductivity of the soil matrix is too low, the oxidant will not be distributed throughout the treatment zone, thereby leaving some areas untreated. The hydraulic conductivity of the soil at the ASKO Hydraulic Property is a comparatively moderate 1.5×10^{-3} centimeters per second, which is suitable for distributing injected chemical oxidants.

The oxidant would be injected into approximately 82 injection points for adequate distribution in the subsurface and contact with the affected media. PNOD tests completed on samples of soil from the treatment zone revealed a 48-hour demand of 1.6 grams of permanganate per kilogram of dry soil, or 0.16 percent, which is a relatively low oxidant demand. To be conservative, however, a dose of 1 percent permanganate per kilogram of dry soil would be used for the treatment area. This equates to approximately 66,000 kilograms or 145,200 pounds (73 tons) of permanganate dosed to 6,600,000 dry kilograms of dry soil. The mass of soil assumes a total area of 18,750 square feet by a 10-foot-thick treatment zone for Sites 1 and 2 and a dry bulk density of soil of 80 pounds per cubic foot. The injections would be accomplished using a portable injection system that would be skid-mounted and transported in a pickup truck. The injection program would entail one injection event over a 50- to 60-day period.

Monitoring during the injection program would be required to prevent the chemical flowing back out of the well due to back pressure developed in the injection well. The distribution of the chemical oxidant would be monitored by the detection of the purple color of the permanganate in monitoring wells, mounding of the groundwater table, and monitoring dissolved oxygen concentrations with a field meter.

SVE wells would be installed as shown on Figure 25B to remediate volatile chlorinated and petroleum hydrocarbons from areas exhibiting unsaturated soil contamination. Wells within the chlorinated solvent plume area, would be constructed with Schedule 40 CPVC pipe and well screen. DPE wells would also be installed as shown on Figure 25B. These wells would be constructed of Schedule 40 PVC pipe and screen. Water would be recovered from the DPE wells by down-well pneumatic total fluids pumps. A treatment facility would be constructed to house vapor and water treatment equipment. Vapor recovered by the SVE and DPE wells would be treated by either catalytic oxidation or vapor phase carbon under a permit from the PSCAA. The method of vapor treatment would be selected at the design phase based on economic and regulatory considerations. It is assumed for the purpose of estimating the cost of this alternative that water recovered by the DPE wells would be pre-treated by filtration, phase separation in an oil/water separator, and liquid-phase granular-activated carbon prior to a permitted industrial waste discharge to the King County sanitary sewer.

Key assumptions for this cleanup action include the following:

- The 82 injection points would be adequate to deliver the chemical oxidant. The total number of injection points may vary based on subsurface conditions and unknown subsurface obstacles.
- The estimated permanganate dose is conservative enough to provide adequate oxidant to oxidize the COPCs.
- One injection event will be performed over a 50- to 60-day period.
- Performance monitoring will include monitoring groundwater for permanganate in monitoring wells, mounding, dissolved oxygen, and visual monitoring for any signs of permanganate. A baseline monitoring event will be completed to establish performance monitoring parameters before implementing the chemical injection.
- A PRB consisting of a mixture of ZVI, pea gravel, and sand would be installed along the ASKO Hydraulic Property boundary with the BNSF Parcel in the configuration shown in Figures 25A and 25B. The PRB material would be emplaced by drilling with a 4-foot-diameter caisson rig to a total depth of approximately 48 feet bgs. The bottom 13 feet of each hole would form the permeable reactive barrier and contain the ZVI, sand and pea gravel mixture.
- Five years of post-injection groundwater monitoring data will indicate that concentrations of COPCs are below the MTCA cleanup levels for groundwater.

- Site restoration activities will include abandoning injection wells in compliance with regulatory requirements.
- The life cycle for this alternative is assumed to be 10 years for the purpose of estimating the present worth cost. This duration should not be construed as a guaranteed remediation time frame.

The present worth cost estimate to implement Cleanup Action Alternative 3, assuming a real discount rate of 0.1 percent and a life cycle of 10 years, is approximately $4,917,440 (Table 5). This feasibility level cost should not be considered a design cost estimate or guaranteed cost.

5.6.4 Cleanup Action Alternative 4—ERH for Chlorinated Hydrocarbons in Groundwater; DPE for Petroleum Hydrocarbons in Groundwater; SVE for Volatile Hydrocarbons in Soil; and Excavation of DRPH in Soil

Cleanup Action Alternative 4 involves ERH to remediate chlorinated and some volatile non-chlorinated COPCs from soil and groundwater within the two areas in the Sites 1 and 2 exhibiting chlorinated hydrocarbon contamination. DPE technology would be employed to address petroleum hydrocarbon contamination in groundwater. Soil exhibiting volatile chlorinated and petroleum hydrocarbon contamination would be remediated by SVE technology. DRPH-contaminated soil, shallow in depth, would be excavated. Figure 26 provides an illustration of the conceptual implementation of this cleanup action alternative.

Similar to Cleanup Action Alternatives 2 and 3, this alternative would also be implemented in stages and commence with excavating the three areas of DRPH-contaminated soil. The DRPH-contaminated soil would be excavated, transported off-site for land disposal at a permitted facility. The volume of DRPH-contaminated soil to be excavated is estimated at 1,700 bcy (2,550 tons). Clean structural fill would be imported, backfilled, and compacted to bring the excavated areas back to starting grade. Following excavation of the DRPH-contaminated soil, well drilling and pipe trench installation would commence for the ERH, the SVE, and the DPE wells.

Previous success with ERH at the adjacent Bulk Terminal Property in 2010 provides a measure of confidence that the technology is feasible to implement at the ASKO Hydraulic Property. The vendor who markets the ERH technology would implement the process by installing combination electrodes and vapor recovery vents made of slotted steel pipe in a systematic triangular grid of boreholes drilled to a depth of approximately 32 feet bgs. A network of boreholes within the electrode grid would also be drilled for thermocouples to measure temperature within the treatment zone. A Power Control Unit (PCU) would be installed to the existing power supply located at the Bulk Terminal Property and the electrodes would be wired to the PCU to control the current and voltage applied to heat the subsurface to the target temperature of 100 °C, which is sufficient to volatilize dissolved-phase TCE. The electrodes/vents would be connected to a network of shallow buried vapor recovery pipes that would be used to convey vaporized contaminants to the treatment facility for further treatment prior to discharge. TCE in vapor concentrations would be monitored at a set frequency during heating to determine when to cease heating the soil.

SVE wells would be installed outside of the zone of heating as shown on Figure 26 to remediate volatile chlorinated and petroleum hydrocarbons from areas exhibiting unsaturated soil contamination. Wells within the chlorinated solvent soil contamination area, would be constructed with Schedule 40 CPVC pipe and well screen. DPE wells would also be installed as shown on Figure 26. These wells would be constructed of Schedule 40 PVC pipe and screen. Water would be recovered from the DPE wells by down-well pneumatic total fluids pumps. A treatment facility would be constructed to house vapor and water treatment equipment. Vapor recovered by the ERH, SVE, and DPE wells would be treated by catalytic oxidation under a permit from the PSCAA. It is assumed for the purpose of estimating the cost of this alternative that water recovered by the ERH, SVE, and DPE wells would be pre-treated by filtration, phase separation in an oil/water separator, and liquid-phase granular-activated carbon prior to a permitted industrial waste discharge to the King County sanitary sewer.

Key assumptions for this cleanup action include the following:

- Heating the treatment zone to a temperature equal to or greater than the boiling point of TCE will result in sufficient recovery of TCE and its reductive dechlorination byproducts in the vapor phase to achieve the respective soil and groundwater cleanup levels without the need for subsequent remediation following the ERH treatment.
- Performance monitoring would involve monitoring COPC concentrations in the recovered soil vapor and groundwater during the heating period to determine when and where within the treatment area to cease heating the media.
- SVE and DPE wells in areas that were not subjected to heating would continue operating for a period of 7 years.
- A PRB consisting of a mixture of ZVI, pea gravel, and sand would be installed along the ASKO Hydraulic Property boundary with the BNSF Parcel in the configuration shown in Figure 26. The PRB material would be emplaced by drilling with a 4-foot-diameter caisson rig to a total depth of approximately 48 feet bgs. The bottom 13 feet of each hole would form the permeable reactive barrier and contain the ZVI, sand, and pea gravel mixture.
- Site restoration activities will include decommissioning wells in compliance with regulatory requirements.
- The life cycle for this alternative is assumed to be 8 years for the purpose of estimating the present worth cost. This duration should not be construed as a guaranteed remediation time frame.

The present worth cost estimate to implement Cleanup Action Alternative 4, assuming a real discount rate of negative 0.2 percent and a life cycle of 8 years, is approximately $6,958,190 (Table 6). This feasibility level cost should not be considered a design cost estimate or guaranteed cost.

5.7 COMPARISON OF ALTERNATIVES

A summary of the comparative evaluation of the cleanup action alternatives using the MTCA evaluation criteria (WAC 173-340-360[3][f]) is presented in Table 7. A summary of each evaluated criteria is provided below:

- **Protectiveness.** All of the cleanup action alternatives provide a high measure of protectiveness for human health and environment. Cleanup Action Alternative 1 exhibits the highest degree of protectiveness due to the permanent removal and disposal of the contaminated media. Cleanup Action Alternatives 2 through 4 use in situ techniques to biodegrade, oxidize, or volatilize the COPCs.
- **Permanence.** All cleanup action alternatives provide a permanent solution to the reduction of toxicity, mobility, and volume of COPCs through either biological, chemical, or physical means. Cleanup Action Alternatives 1 and 4 would achieve the cleanup levels in soil more quickly than Cleanup Action Alternatives 2 and 3. Cleanup Action Alternatives 2 and 3 have lower scores than Cleanup Action Alternatives 1 and 4 because the former rely on in situ processes to mitigate risks whereas the latter provide for the permanent removal and treatment and disposal of the COPCs.
- **Effectiveness over the Long Term.** The long-term effectiveness of Cleanup Action Alternatives 1 and 4 are greater than that of Cleanup Action Alternatives 2 and 3 due to the higher degree of permanence achieved by the Cleanup Action Alternatives 1 and 4. Cleanup Action Alternative 1 is the most effective of the alternatives over the long term because it includes the physical removal of more contaminated source material.
- **Management of Short-Term Risks.** The short-term risks are substantial for all cleanup action alternatives. Significant risks are posed to workers for Cleanup Action Alternative 1 from drilling, shoring, and transportation-related workplace accidents. These risks improve slightly for the remaining alternatives, but are significant inasmuch as there are risks to workers from the repeated drilling of remediation wells. In addition, chemical exposure in Cleanup Action Alternative 3 and electrical hazards in Cleanup Action Alternative 4 pose additional risks. Cleanup Action Alternative 2 presents the least amount of short-term risks and therefore scores the highest.
- **Technical and Administrative Implementability.** Cleanup Action Alternatives 2 and 3 score higher than Cleanup Action Alternatives 1 and 4 because they are more readily implementable. Obtaining approval from the City of Seattle and BNSF to shore the road and railway, respectively, as well as the extensive geotechnical engineering, design, and construction challenges make the latter alternatives more difficult to implement when compared to Cleanup Action Alternatives 2 and 3.

Results of the comparative evaluation indicate Cleanup Action Alternative 1 ranks the highest with a total ranking score of 38 (Table 7). Cleanup Action Alternative 4 ranks second with a total ranking score of 36. Cleanup Action Alternatives 2 and 3 has total ranking scores of 34 and 33, respectively.

5.8 DISPROPORTIONATE COST ANALYSIS

The purpose of the disproportionate cost analysis is to facilitate selection of the cleanup action alternative providing the highest degree of permanence to the maximum extent practicable. The disproportionate cost analysis considers Cleanup Action Alternatives 1 through 4. Costs are considered disproportionate to benefits if the incremental costs of one alternative versus a less expensive alternative exceed the incremental degree of benefit achieved by the more expensive alternative. The following is a description of the factors that were used to estimate the cost of the four alternatives discussed above.

- **Capital Costs.** These costs include expenditures for equipment, labor, and material necessary to install a remedial action. Indirect costs may be incurred for engineering, financial, or other services not directly involved with installation of remedial alternatives but necessary for completion of this activity.
- **Operation and Maintenance Costs.** These costs are post-construction costs necessary to provide effective implementation of the alternative. Such costs may include, but are not limited to, the following: operating labor; maintenance materials and labor; disposal of residues; and administrative, insurance, and licensing costs.
- **Monitoring Costs.** These costs are incurred from monitoring activities associated with remedial activities. Cost items may include sampling labor, laboratory, analyses, and report preparation.
- **Present Worth Analysis.** Present worth analysis provides a method of evaluating and comparing costs that occur over different time periods by discounting all future expenditures to the present year. The present worth cost or value represents the amount of money which, if invested in year 0 and disbursed as needed, would be sufficient to cover all costs associated with a remedial alternative. The assumptions necessary to derive a present worth cost are inflation rate, discount rate, and period of performance. A discount rate, which is similar to an interest rate, is used to account for the time value of money. EPA policy on the use of discount rates for cost analyses is stated in the preamble to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) published at the Federal Register (55 FR 8722) and in Office of Solid Waste and Emergency Response Directive 9355.3-20, titled "Revisions to the Executive Office of the President, Office of Management and Budget (OMB) Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis" (EPA 1993). Based on the NCP and this directive, a discount rate of 7 percent is recommended in developing present value cost estimates for remedial action alternatives during the FS. This recommended rate represents a "real" discount rate in that it approximates the marginal pretax rate of return of a historical average investment in the private sector and has been adjusted to eliminate the effect of expected inflation. For this FS, a more conservative real discount rate was selected based on the December 2013 revisions to Appendix C of the OMB Circular A-94. The real discount rates used to estimate the present worth of annual operating costs are based on the estimated restoration time frame (life cycle) for each alternative and are extrapolated from the referenced OMB Circular, which is published annually in December.

  Because it is assumed that all capital costs are incurred in year 0, the present worth analysis is performed only on annual O&M and groundwater monitoring costs. The total present worth for a given alternative is equal to the sum of the capital costs and the present worth of annual O&M and monitoring costs over the anticipated life cycle of the alternative.

Using these criteria and relying on the assumptions outlined in Section 5.4, the estimated present worth costs of Cleanup Action Alternatives 1 through 4 are as follows:

- Cleanup Action Alternative 1, $7,622,490 (Table 3)
- Cleanup Action Alternative 2, $4,660,000 (Table 4)
- Cleanup Action Alternative 3, $4,917,440 (Table 5)
- Cleanup Action Alternative 4, $6,958,190 (Table 6)

As indicated above, the cost of Cleanup Action Alternatives 2 and 3 are much less than Cleanup Action Alternatives 1 or 4. Chart 1 plots the relative cost and ranking scores and Chart 2 plots the cost–to-benefit ratios for the four alternatives to illustrate the relative cost and benefits afforded by each alternative. The charts clearly demonstrate that Cleanup Action Alternative 2 exhibits the lowest cost-to-benefit ratio.

5.9 RECOMMENDED CLEANUP ACTION ALTERNATIVE

After performing the comparative analysis and ranking of alternatives in accordance with the MTCA evaluation criteria, Cleanup Action Alternative 2 is the recommended alternative for the ASKO Hydraulic Property. Reductive dechlorination with edible oil substrate is a proven technology for the remediation of the chlorinated COPCs. SVE and DPE are also proven technologies for the remediation of the residual petroleum hydrocarbons. Cleanup Action Alternative 2 meets the threshold requirements for cleanup actions set forth in WAC 173-340-360(3) and WAC 173-340-370. Cleanup Action Alternative 2 is protective of human health and the environment, is more easily implemented than competing alternatives, and provides a permanent solution for reducing concentrations of COPCs at the Sites. The cost to implement Cleanup Action Alternative 2 is the lowest and exhibits the lowest cost-to-benefit ratio when compared to competing alternatives.

Details of the implementation of the recommended cleanup action alternative for the ASKO Hydraulic Property and the decision process used to evaluate whether modifications to the selected approach are warranted will be provided in a draft Cleanup Action Plan.

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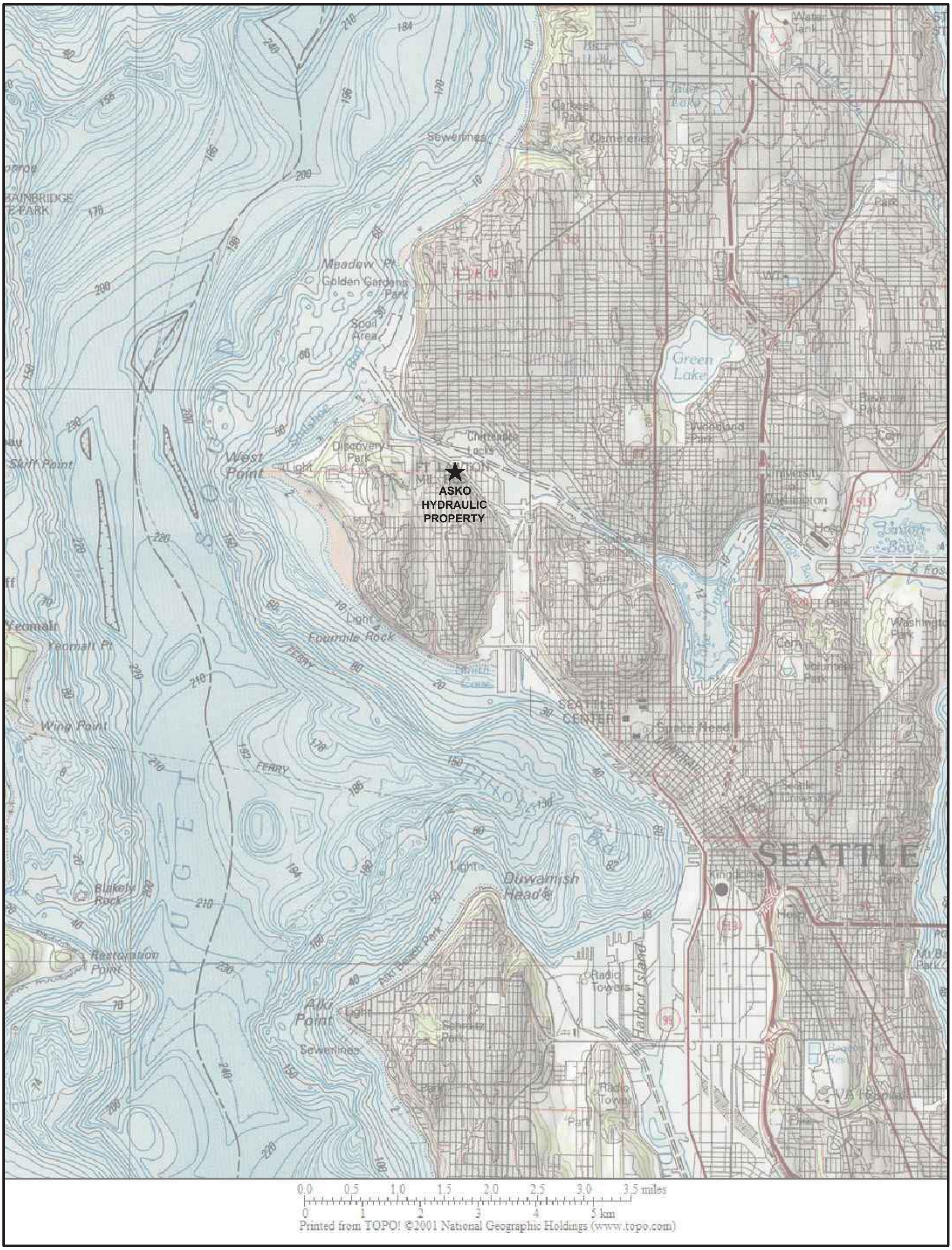
7.0 LIMITATIONS

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, expressed or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of segregated portions of this report.

FIGURES



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CHECKED BY: PJK/TSB
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PROJECT NAME: ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

FIGURE 1
PROPERTY LOCATION MAP

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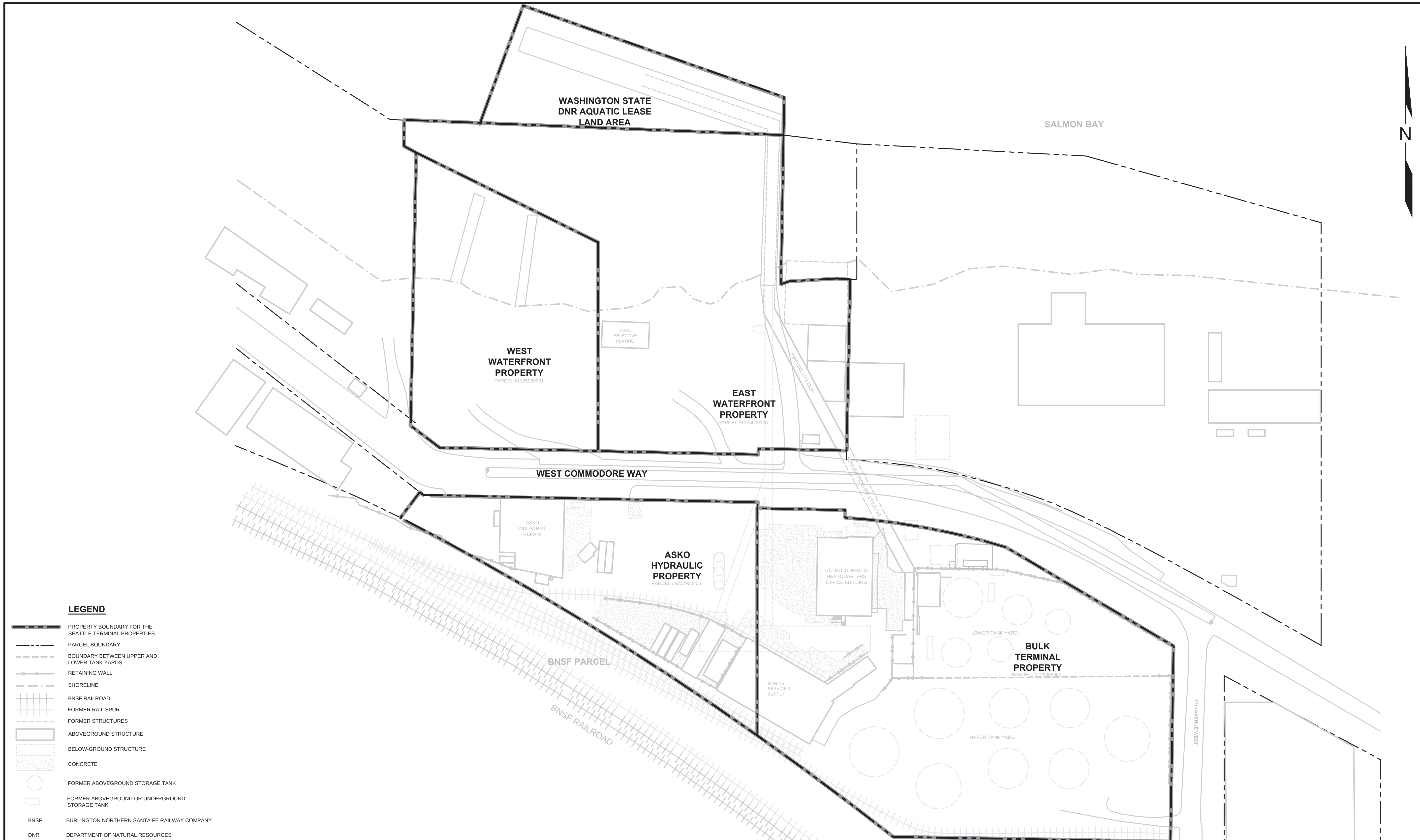

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PROJECT NUMBER: 0440-004
STREET ADDRESS: 2737, 2750, 2800, AND 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

0 30 60 120 240
APPROXIMATE SCALE IN FEET

FIGURE 2
SEATTLE TERMINAL PROPERTIES
PROPERTY PLAN

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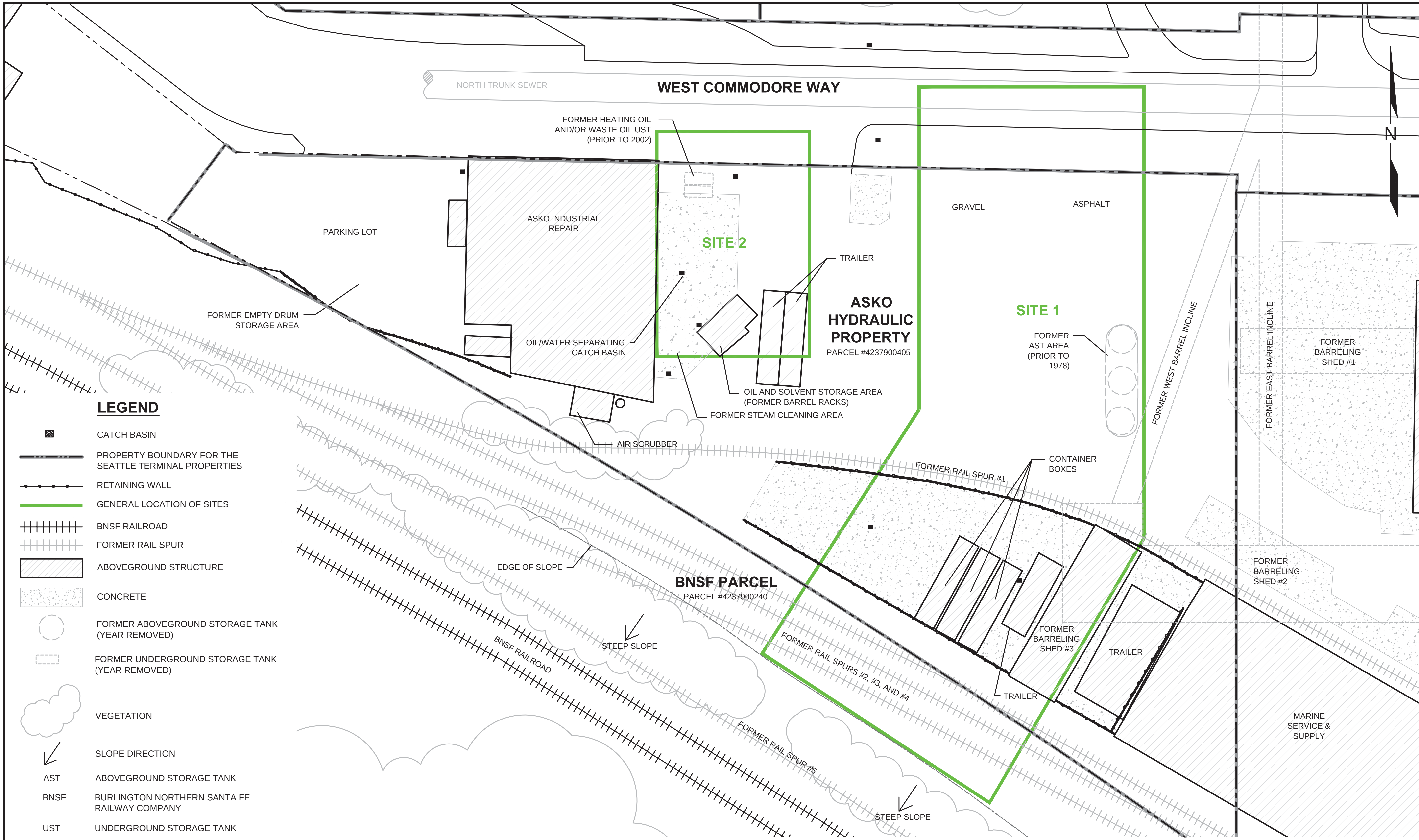

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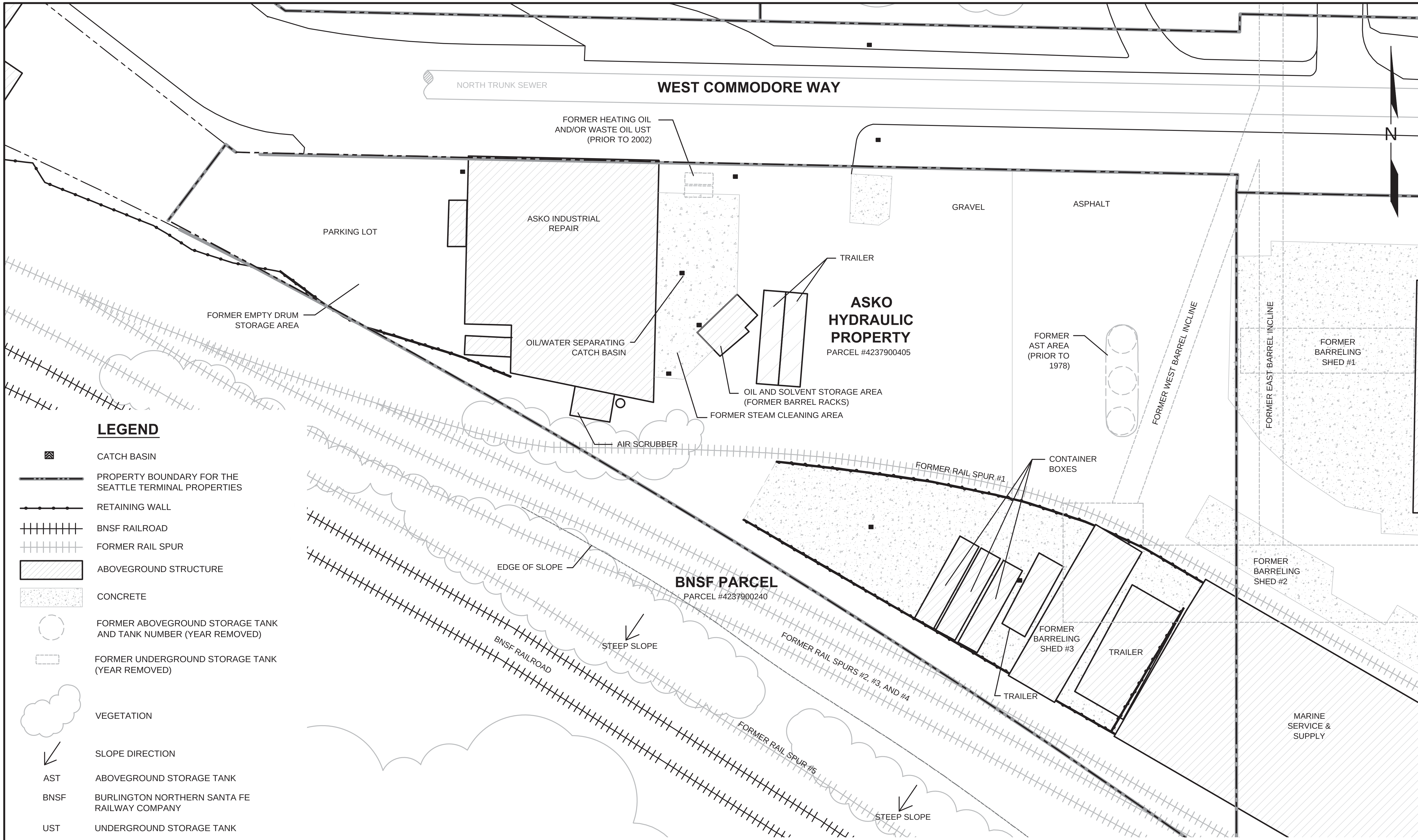
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, SEATTLE: SEATTLE, WASHINGTON

REGION:

0 20 40 80
APPROXIMATE SCALE IN FEET

FIGURE 3
SITE 1 AND SITE 2 LOCATION MAP



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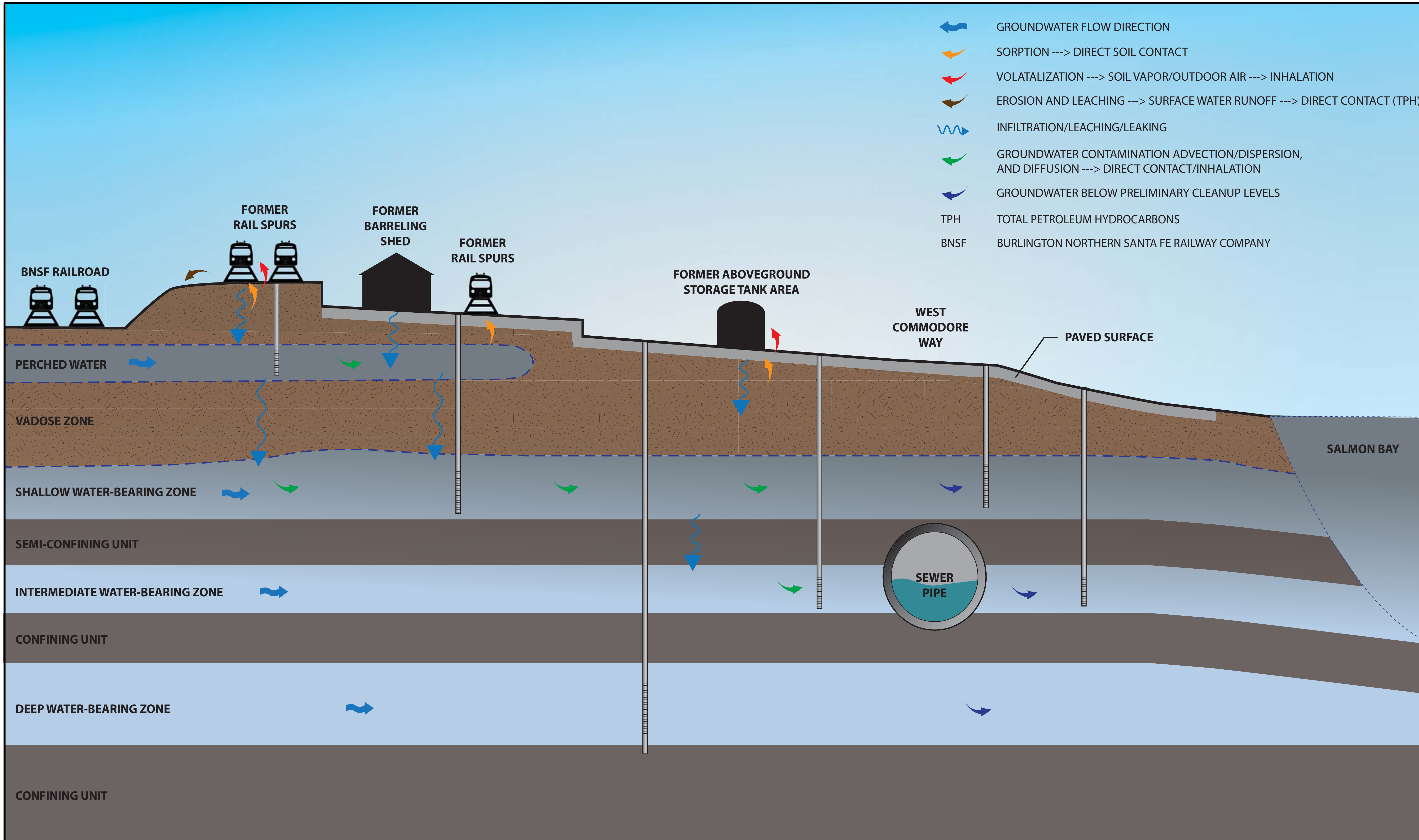
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, SEATTLE: SEATTLE, WASHINGTON

REGION:

0 20 40 80
APPROXIMATE SCALE IN FEET

FIGURE 4
HISTORICAL FEATURES



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CITY, STATE: SEATTLE, WASHINGTON

REGION:

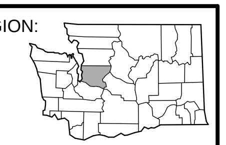

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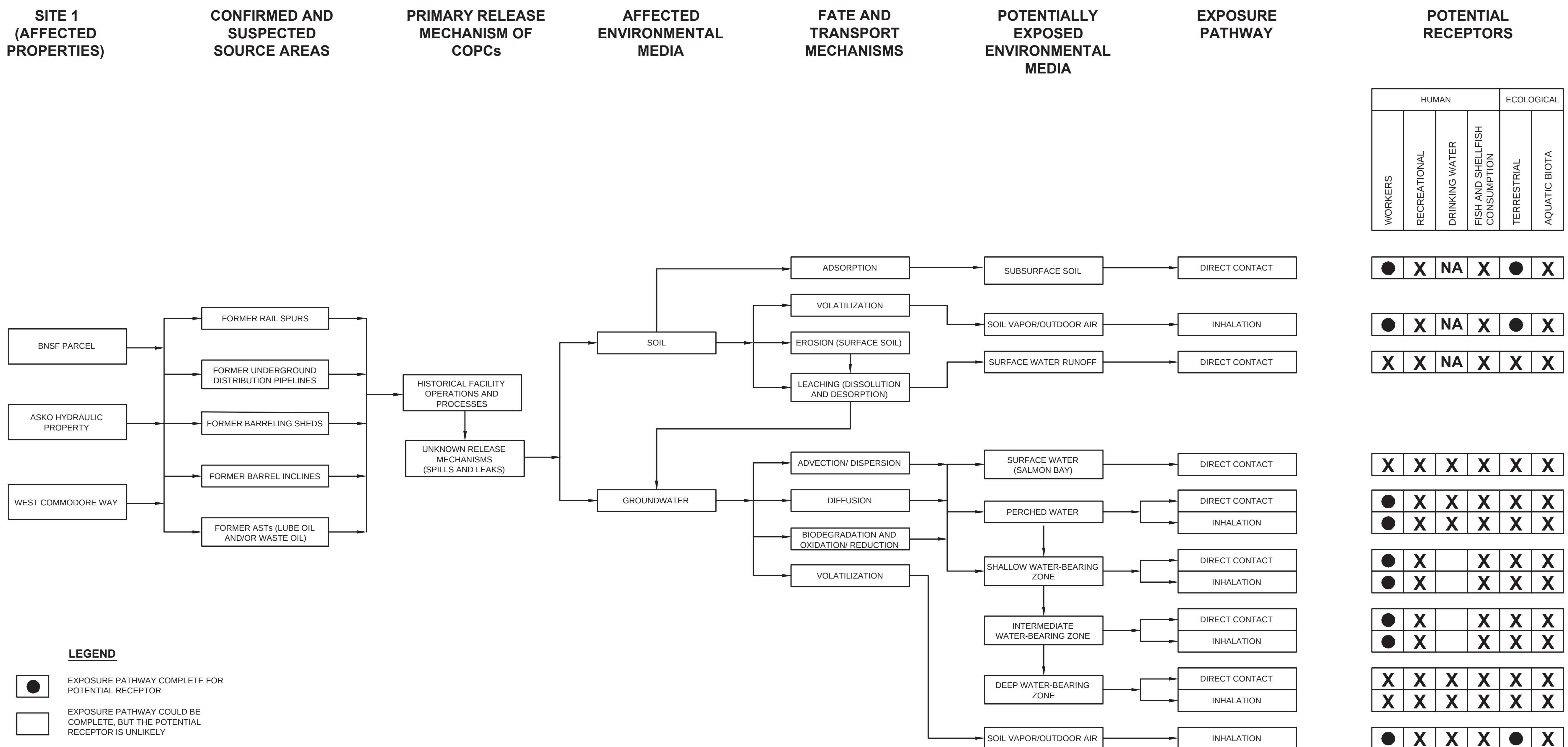
FIGURE 5
CONCEPTUAL SITE MODEL



Exposed Media	Exposure Pathway	Workers	Recreational	Drinking Water	Fish and Shellfish Consumption	Terrestrial	Aquatic Biota
Subsurface Soil	Direct Contact	●	X	NA	X	●	X
Soil Vapor/Outdoor Air	Inhalation	●	X	NA	X	●	X
Surface Water Runoff	Direct Contact	X	X	NA	X	X	X
Surface Water (Salmon Bay)	Direct Contact	X	X	X	X	X	X
Perched Water	Direct Contact	●	X	X	X	X	X
Perched Water	Inhalation	●	X	X	X	X	X
Shallow Water-Bearing Zone	Direct Contact	●	X		X	X	X
Shallow Water-Bearing Zone	Inhalation	●	X		X	X	X
Intermediate Water-Bearing Zone	Direct Contact	●	X		X	X	X
Intermediate Water-Bearing Zone	Inhalation	●	X		X	X	X
Deep Water-Bearing Zone	Direct Contact	X	X	X	X	X	X
Deep Water-Bearing Zone	Inhalation	X	X	X	X	X	X
Soil Vapor/Outdoor Air	Inhalation	●	X	X	X	●	X

LEGEND

- ● EXPOSURE PATHWAY COMPLETE FOR POTENTIAL RECEPTOR
- (blank) EXPOSURE PATHWAY COULD BE COMPLETE, BUT THE POTENTIAL RECEPTOR IS UNLIKELY
- X EXPOSURE PATHWAY INCOMPLETE
- NA NOT APPLICABLE
- AST ABOVEGROUND STORAGE TANK
- COPCs CHEMICALS OF POTENTIAL CONCERN
- BNSF BURLINGTON NORTHERN SANTA FE RAILWAY COMPANY

NOTE: DIRECT CONTACT INCLUDES DERMAL AND INGESTION

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PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

NOT TO SCALE

FIGURE 6
PRELIMINARY EXPOSURE ASSESSMENT
CONCEPTUAL SITE MODEL
SITE 1

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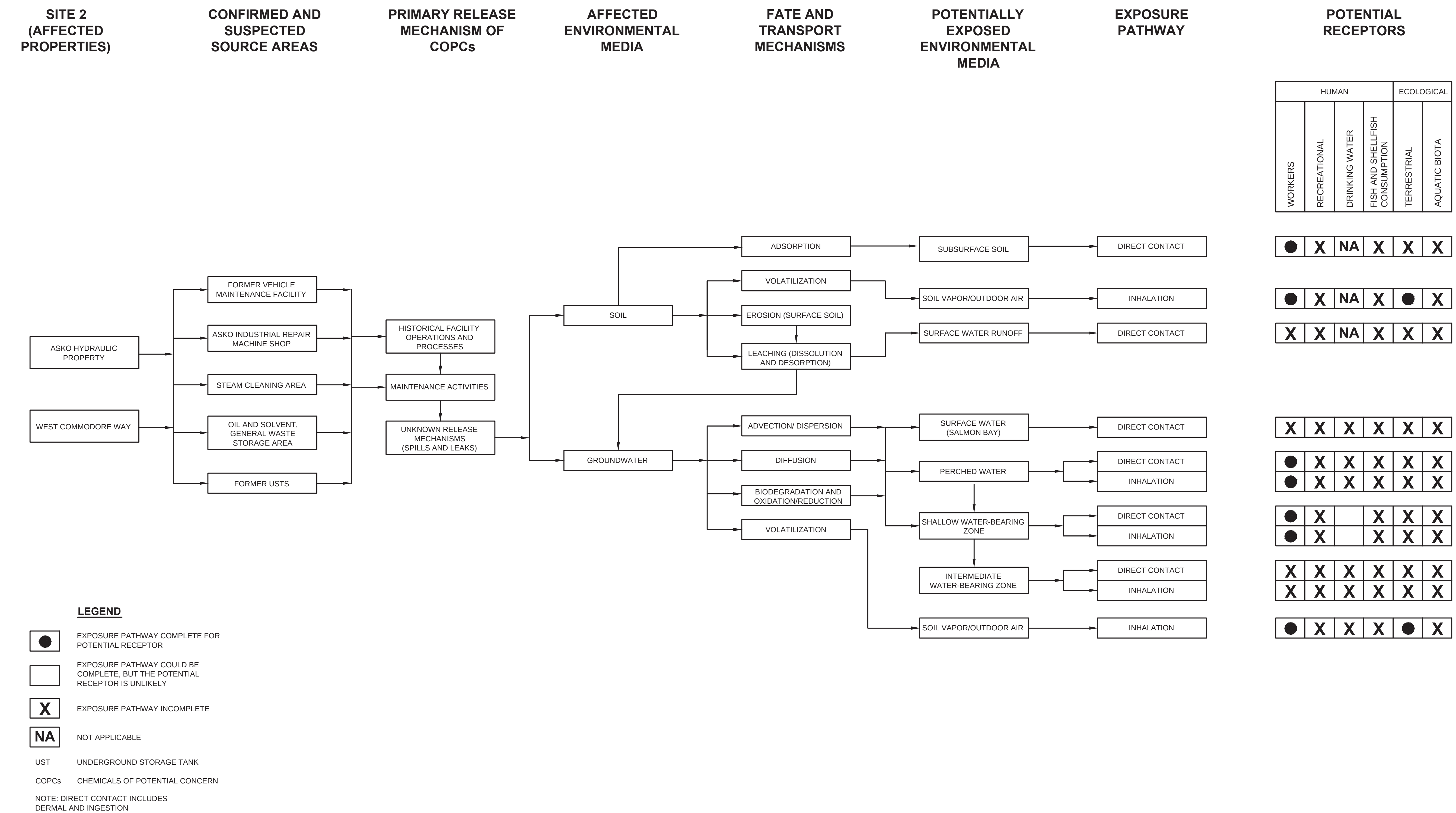

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PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

NOT TO SCALE

FIGURE 7
PRELIMINARY EXPOSURE ASSESSMENT
CONCEPTUAL SITE MODEL
SITE 2

5/14/2014
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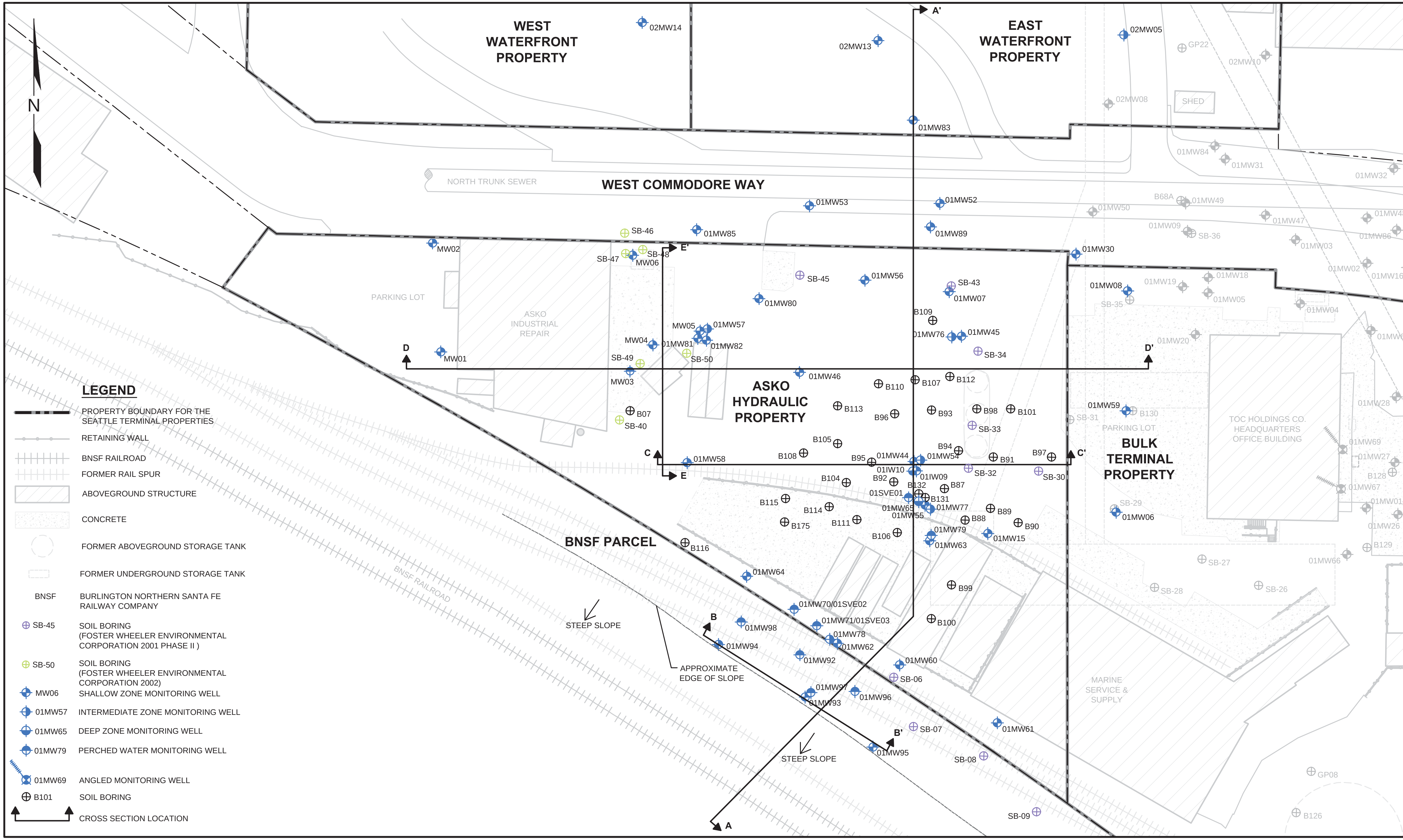

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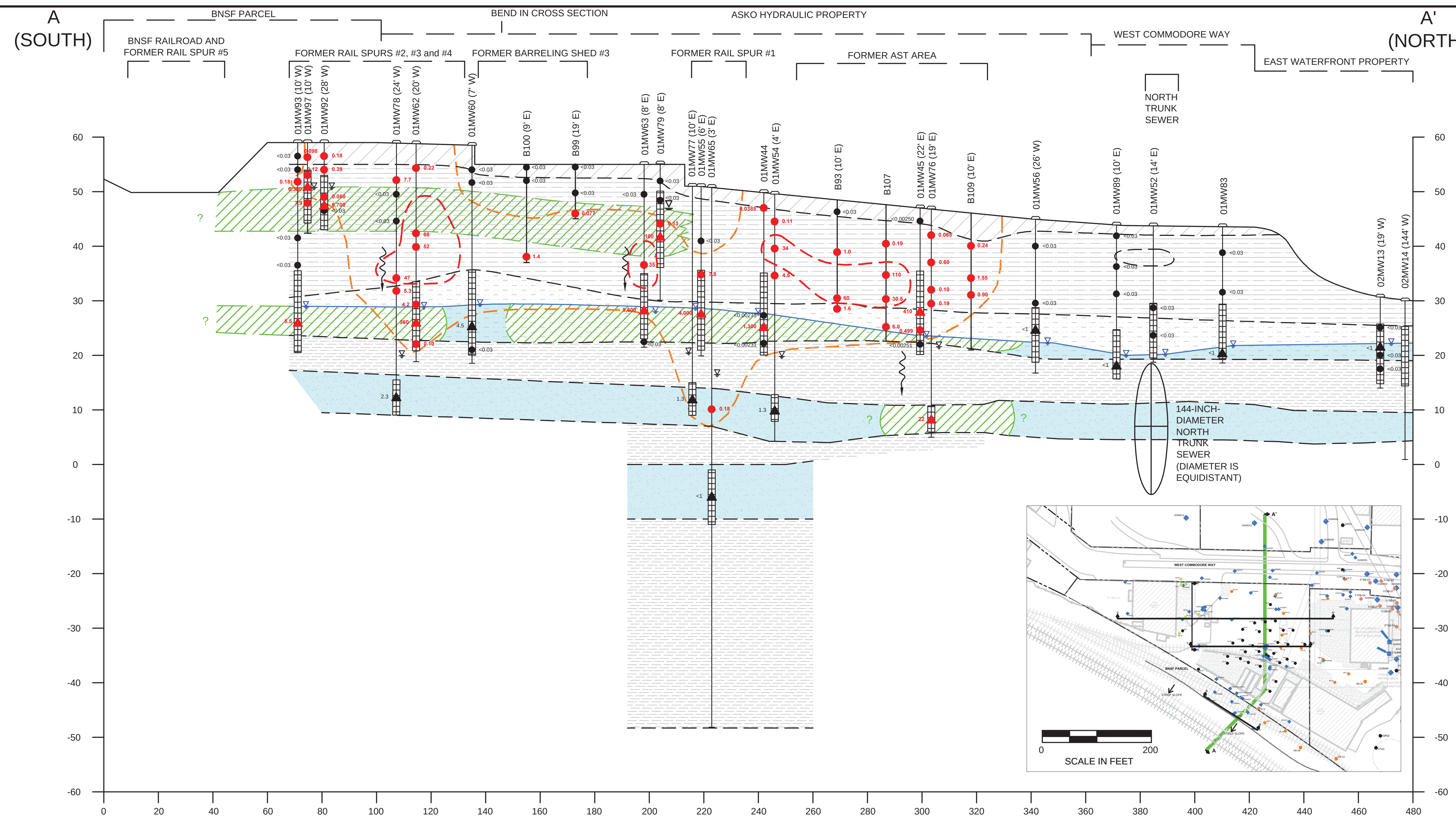
DATE: 05/14/14
DRAWN BY: NAC/BLR
CHECKED BY: PJK/TSB
CAD FILE: 01-600_2013FS_EL

PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

0 25 50 100
APPROXIMATE SCALE IN FEET

FIGURE 8
EXPLORATION LOCATION PLAN



(6' W)	OFFSET 6' WEST FROM SECTION LINE
	MONITORING WELL
	SCREEN INTERVAL
	PERCHED WATER, INTERMEDIATE, OR DEEP ZONE GROUNDWATER LEVEL (MAY 2013)
	SHALLOW ZONE GROUNDWATER LEVEL (MAY 2013)

LEGEND

HISTORICAL CONCENTRATIONS OF TCE IN SOIL (mg/kg):

- CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
- CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

CONCENTRATIONS OF TCE IN GROUNDWATER IN SECOND QUARTER, 2013 (µg/L):

- CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
- CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

- TCE IN SOIL ABOVE MTCA METHOD A CLEANUP LEVEL
- TCE IN SOIL ABOVE MTCA METHOD B CLEANUP LEVEL
- TCE CONTAMINATION IN GROUNDWATER
- GROUNDWATER
- LEAKAGE THROUGH HETEROGENEOUS SOIL MATRIX OR THE SEMI-CONFINING UNIT

- SAND, SILTY SAND, AND GRAVEL (Hf)
- SAND AND SILTY SAND (Hdf)
- SAND, SILT AND CLAY (Hdf)
- SILT AND CLAY (Qpf)
- SAND AND SILTY SAND (Qpf)
- INFERRED CONTACT

AST	ABOVEGROUND STORAGE TANK
TCE	TRICHLOROETHENE
<	RESULT BELOW LABORATORY REPORTING LIMIT
mg/kg	MILLIGRAMS PER KILOGRAM
µg/L	MICROGRAMS PER LITER
MTCA	WASHINGTON STATE MODEL TOXICS CONTROL ACT

47	TCE
RED	DENOTES CONCENTRATION EXCEEDS MTCA METHOD A CLEANUP LEVEL
Hf	HOLOCENE FILL
Hdf	HOLOCENE DEPRESSION FILLINGS
Qpf	PRE-FRASER DEPOSITS

NOTE: ALL LOCATIONS ARE APPROXIMATE.

VERTICAL SCALE IN FEET: 0, 10, 20
HORIZONTAL SCALE IN FEET: 0, 20, 40

5/14/2014

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFR\01-600_2013FS_XAA_F.DWG

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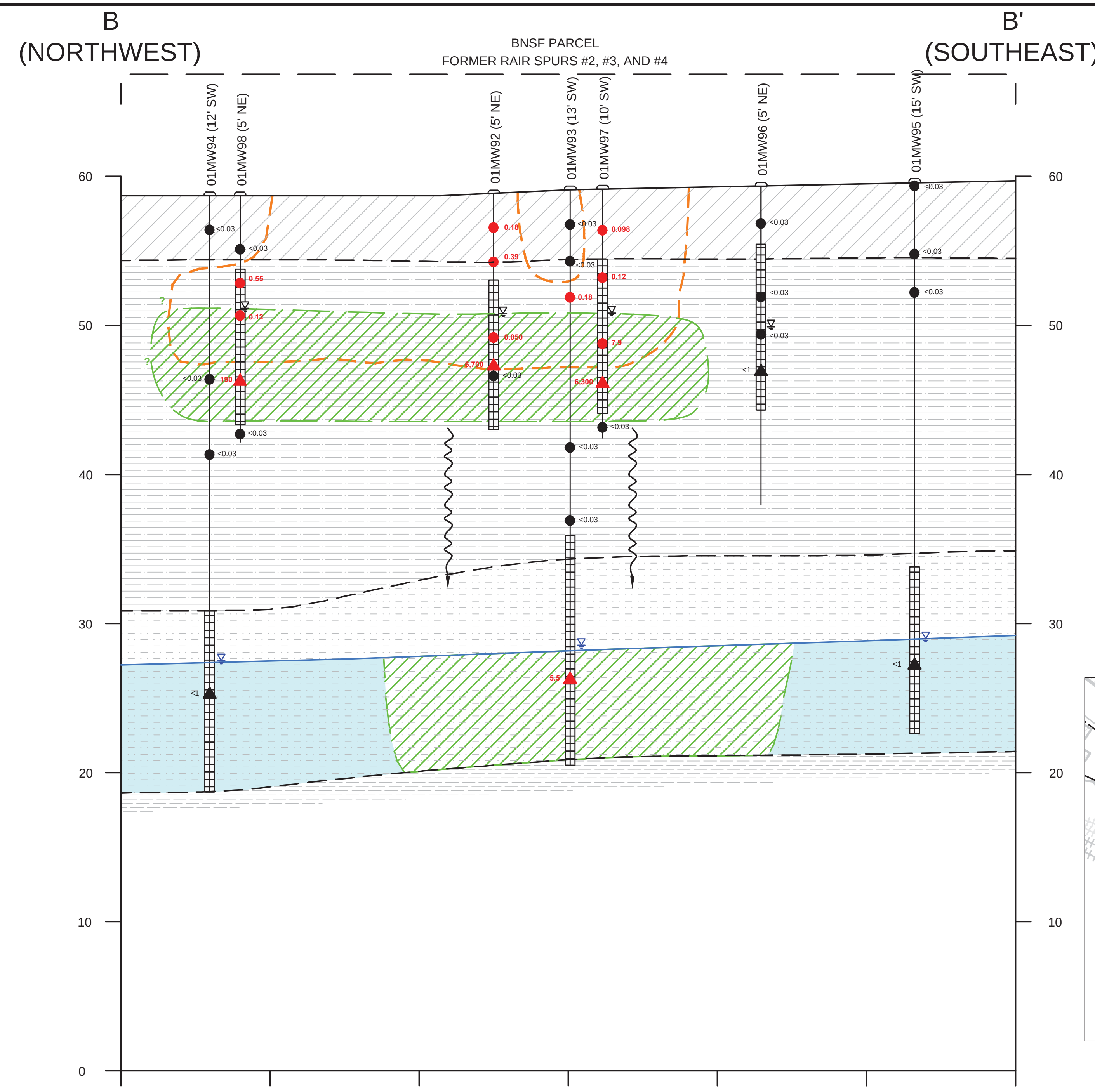
DATE: 05/14/14
DRAWN BY: NAC/BLR
CHECKED BY: PJK/TSB
CAD FILE: 01-600_2013FS_XAA

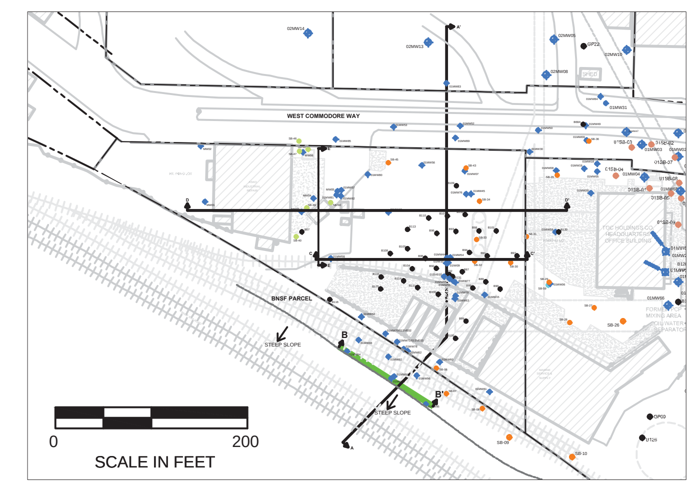
PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

SCALE DEPICTED ABOVE

FIGURE 9
CROSS SECTION A-A'





LEGEND

(6' W)	OFFSET 6' WEST FROM SECTION LINE
	MONITORING WELL
	SCREEN INTERVAL
	PERCHED WATER, INTERMEDIATE, OR DEEP ZONE GROUNDWATER LEVEL (MAY 2013)
	SHALLOW ZONE GROUNDWATER LEVEL (MAY 2013)

HISTORICAL CONCENTRATIONS OF TCE IN SOIL (mg/kg):

- ● CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
- ● CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

CONCENTRATIONS OF TCE IN GROUNDWATER IN SECOND QUARTER, 2013 (μg/L):

- ▲ CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
- ▲ CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

- TCE IN SOIL ABOVE MTCA METHOD A CLEANUP LEVEL
- TCE CONTAMINATION IN GROUNDWATER
- GROUNDWATER
- LEAKAGE THROUGH HETEROGENEOUS SOIL MATRIX OR THE SEMI-CONFINING UNIT

- SAND, SILTY SAND, AND GRAVEL (Hf)
- SAND AND SILTY SAND (Hdf)
- SAND, SILT AND CLAY (Hdf)
- SILT AND CLAY (Qpf)
- SAND AND SILTY SAND (Qpf)
- INFERRED CONTACT

TCE	TRICHLOROETHENE
<	RESULT BELOW LABORATORY REPORTING LIMIT
mg/kg	MILLIGRAMS PER KILOGRAM
μg/L	MICROGRAMS PER LITER
MTCA	WASHINGTON STATE MODEL TOXICS CONTROL ACT
BNSF	BURLINGTON NORTHERN SANTA FE RAILWAY COMPANY

7.9	TCE
RED	DENOTES CONCENTRATION EXCEEDS MTCA METHOD A CLEANUP LEVEL
Hf	HOLOCENE FILL
Hdf	HOLOCENE DEPRESSION FILLINGS
Qpf	PRE-FRASER DEPOSITS

NOTE: ALL LOCATIONS ARE APPROXIMATE.

VERTICAL SCALE IN FEET: 0, 5, 10
HORIZONTAL SCALE IN FEET: 0, 10, 20

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DATE:	05/14/14
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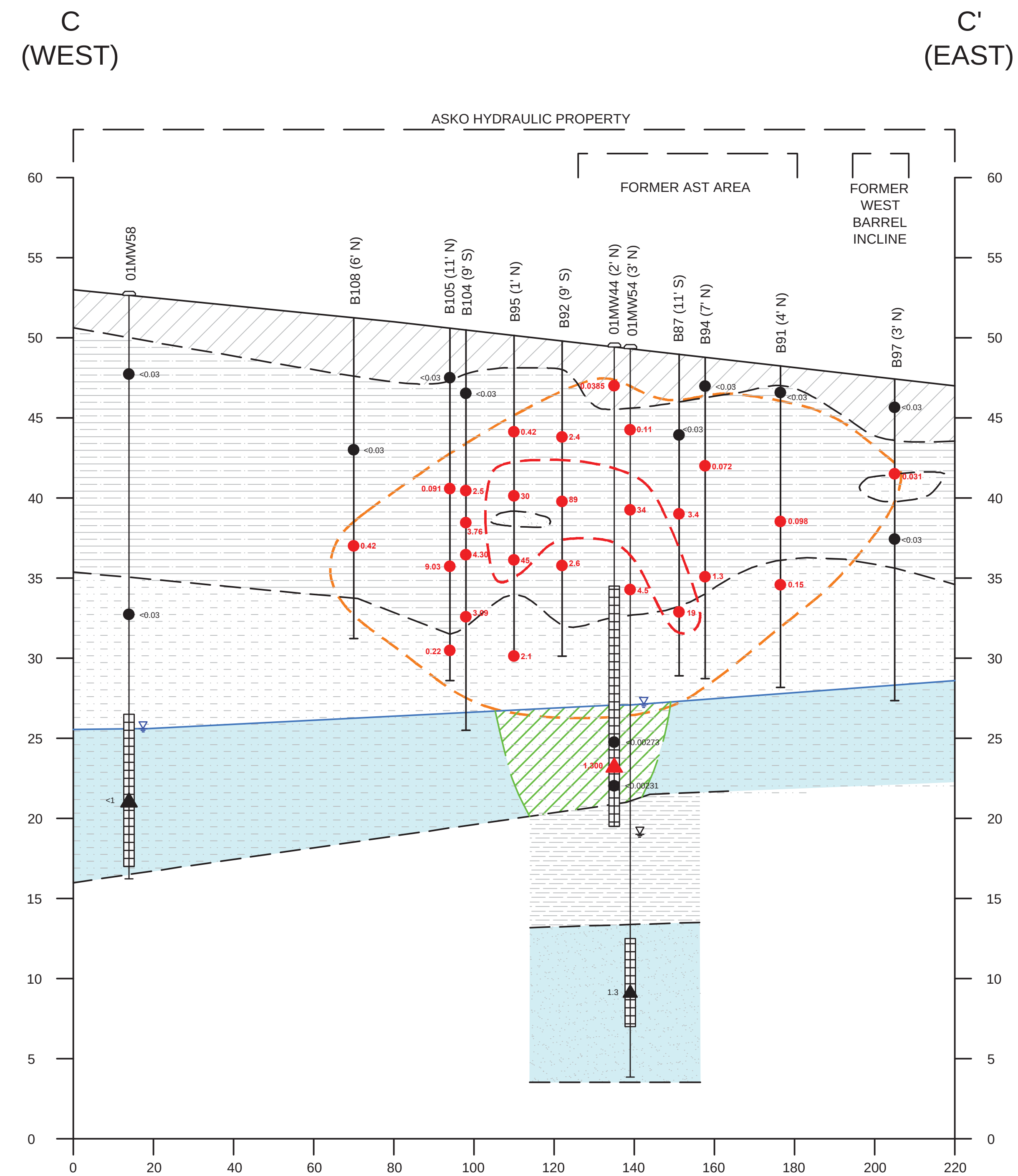
CHECKED BY:	PJK/TSB
CAD FILE:	01-600_2013FS_XBB

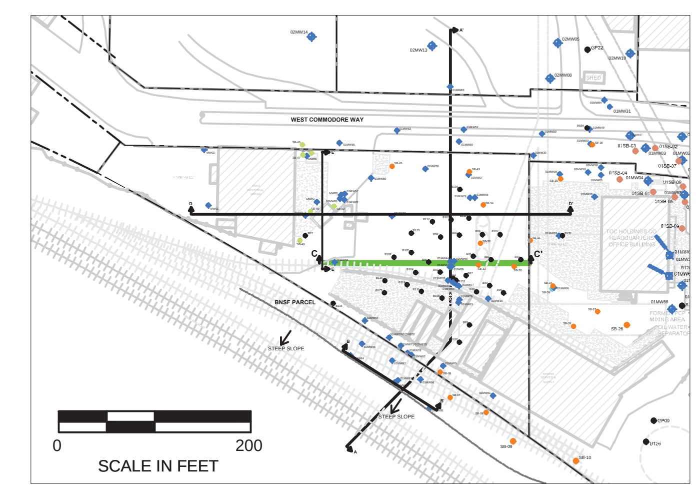
PROJECT NAME:	TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER:	0440-004
STREET ADDRESS:	2805 WEST COMMODORE WAY
CITY, STATE:	SEATTLE, WASHINGTON

REGION:

SCALE DEPICTED ABOVE

FIGURE 10
CROSS SECTION B-B'





LEGEND

(6' W) OFFSET 6' WEST FROM SECTION LINE

MONITORING WELL

SCREEN INTERVAL

PERCHED WATER, INTERMEDIATE, OR DEEP ZONE GROUNDWATER LEVEL (MAY 2013)

SHALLOW ZONE GROUNDWATER LEVEL (MAY 2013)

HISTORICAL CONCENTRATIONS OF TCE IN SOIL (mg/kg):

- CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
- CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

CONCENTRATIONS OF TCE IN GROUNDWATER IN SECOND QUARTER, 2013 (µg/L):

- CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
- CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

TCE IN SOIL ABOVE MTCA METHOD A CLEANUP LEVEL

TCE IN SOIL ABOVE MTCA METHOD B CLEANUP LEVEL

TCE CONTAMINATION IN GROUNDWATER

GROUNDWATER

SAND, SILTY SAND, AND GRAVEL (Hf)

SAND AND SILTY SAND (Hdf)

SAND, SILT AND CLAY (Hdf)

SILT AND CLAY (Qpf)

SAND AND SILTY SAND (Qpf)

INFERRED CONTACT

AST	ABOVEGROUND STORAGE TANK
TCE	TRICHLOROETHENE
<	RESULT BELOW LABORATORY REPORTING LIMIT
mg/kg	MILLIGRAMS PER KILOGRAM
µg/L	MICROGRAMS PER LITER
MTCA	WASHINGTON STATE MODEL TOXICS CONTROL ACT

45	TCE
RED	DENOTES CONCENTRATION EXCEEDS MTCA METHOD A CLEANUP LEVEL
Hf	HOLOCENE FILL
Hdf	HOLOCENE DEPRESSION FILLINGS
Qpf	PRE-FRASER DEPOSITS

NOTE: ALL LOCATIONS ARE APPROXIMATE.

VERTICAL SCALE IN FEET: 0, 5, 10

HORIZONTAL SCALE IN FEET: 0, 20, 40

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DATE: 05/14/14
DRAWN BY: NAC/BLR
CHECKED BY: PJK/TSB
CAD FILE: 01-600_2013FS_XCC

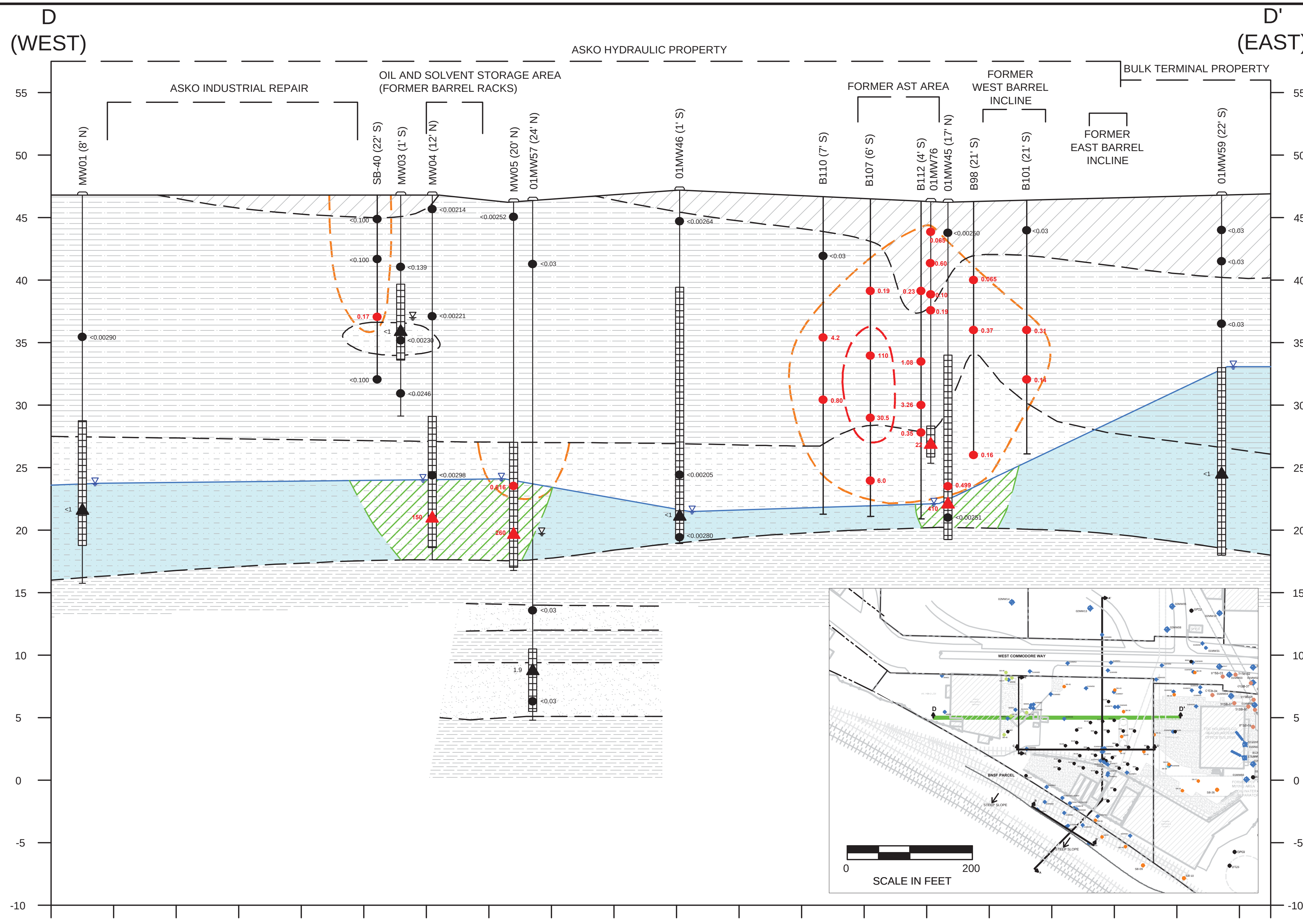
PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

SCALE DEPICTED ABOVE

FIGURE 11
CROSS SECTION C-C'

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFRR\01-600_2013FS_XCC_F.DWG 5/14/2014



LEGEND

(6' W)	OFFSET 6' WEST FROM SECTION LINE
	MONITORING WELL
	SCREEN INTERVAL
	PERCHED WATER, INTERMEDIATE, OR DEEP ZONE GROUNDWATER LEVEL (MAY 2013)
	SHALLOW ZONE GROUNDWATER LEVEL (MAY 2013)

HISTORICAL CONCENTRATIONS OF TCE IN SOIL (mg/kg):

- CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
- CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

CONCENTRATIONS OF TCE IN GROUNDWATER IN SECOND QUARTER, 2013 (µg/L):

- CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL
- CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

- TCE IN SOIL ABOVE MTCA METHOD A CLEANUP LEVEL
- TCE IN SOIL ABOVE MTCA METHOD B CLEANUP LEVEL
- TCE CONTAMINATION IN GROUNDWATER
- GROUNDWATER
- LEAKAGE THROUGH HETEROGENEOUS SOIL MATRIX OR THE SEMI-CONFINING UNIT

- SAND, SILTY SAND, AND GRAVEL (Hf)
- SAND AND SILTY SAND (Hdf)
- SAND, SILT AND CLAY (Hdf)
- SILT AND CLAY (Qpf)
- SAND AND SILTY SAND (Qpf)
- INFERRED CONTACT

AST	ABOVEGROUND STORAGE TANK
TCE	TRICHLOROETHENE
<	RESULT BELOW LABORATORY REPORTING LIMIT
mg/kg	MILLIGRAMS PER KILOGRAM
µg/L	MICROGRAMS PER LITER
MTCA	WASHINGTON STATE MODEL TOXICS CONTROL ACT

110	TCE
RED	DENOTES CONCENTRATION EXCEEDS MTCA METHOD A CLEANUP LEVEL
Hf	HOLOCENE FILL
Hdf	HOLOCENE DEPRESSION FILLINGS
Qpf	PRE-FRASER DEPOSITS

NOTE: ALL LOCATIONS ARE APPROXIMATE.

VERTICAL SCALE IN FEET: 0, 5, 10

HORIZONTAL SCALE IN FEET: 0, 20, 40

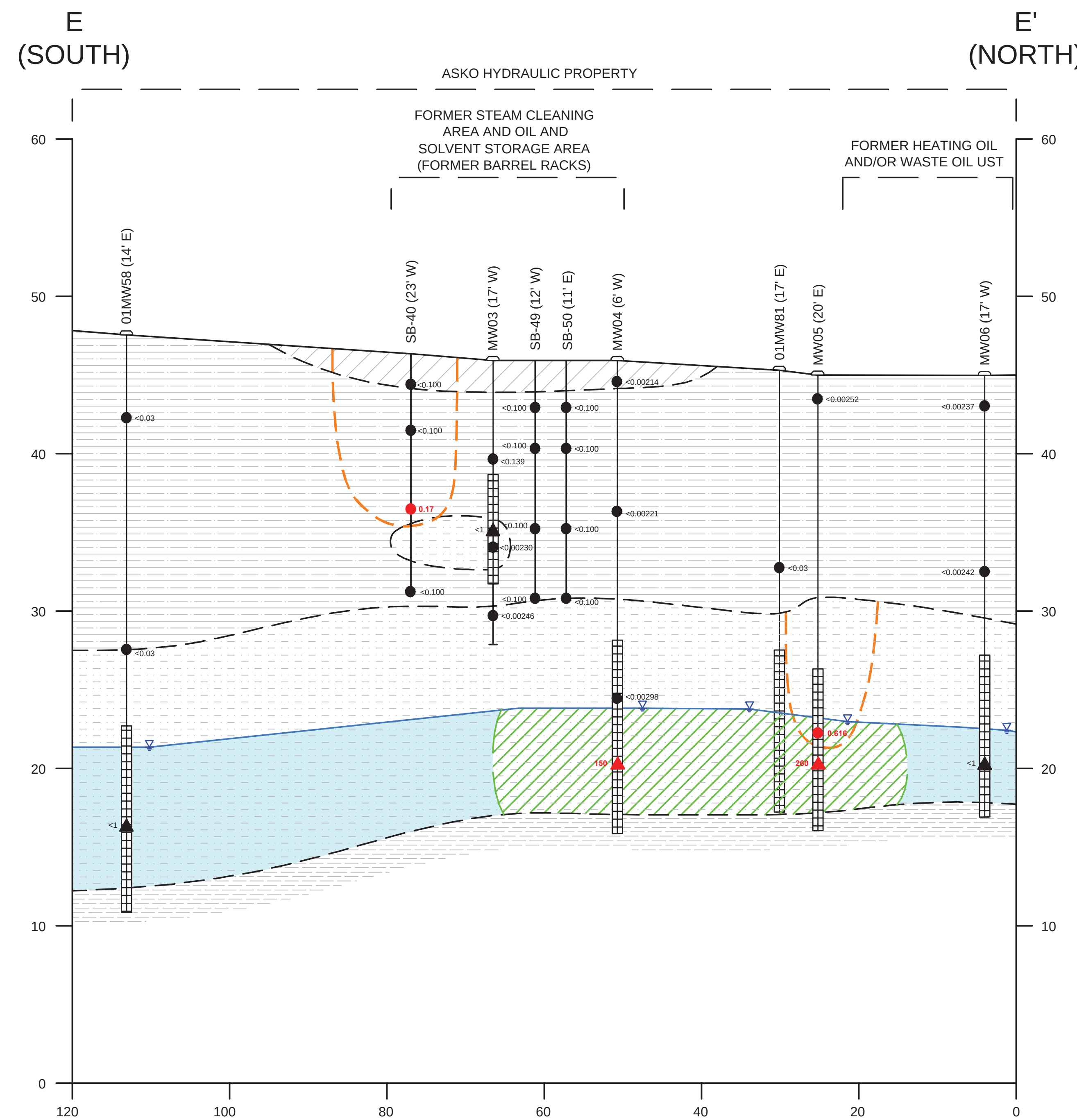
DATE:	05/14/14
DRAWN BY:	NAC/BLR
CHECKED BY:	PJK/TSB
CAD FILE:	01-600_2013FS_XDD

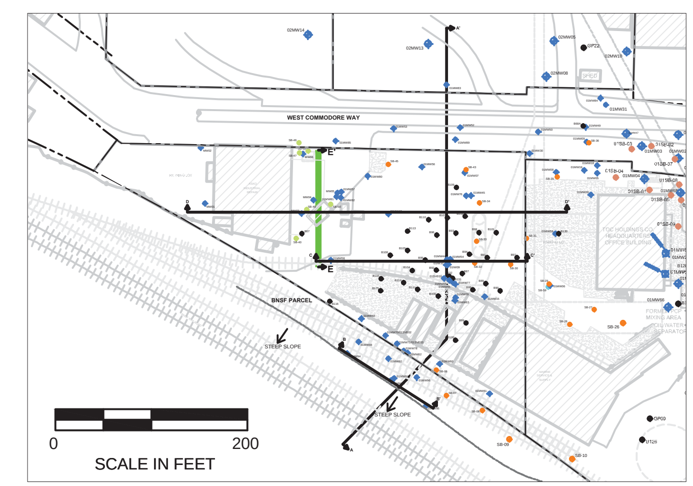
PROJECT NAME:	TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER:	0440-004
STREET ADDRESS:	2805 WEST COMMODORE WAY
CITY, STATE:	SEATTLE, WASHINGTON

REGION:

SCALE DEPICTED ABOVE

FIGURE 12
CROSS SECTION D-D'





LEGEND

(6' W) OFFSET 6' WEST FROM SECTION LINE

MONITORING WELL

SCREEN INTERVAL

PERCHED WATER, INTERMEDIATE, OR DEEP ZONE GROUNDWATER LEVEL (MAY 2013)

SHALLOW ZONE GROUNDWATER LEVEL (MAY 2013)

HISTORICAL CONCENTRATIONS OF TCE IN SOIL (mg/kg):

● CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL

● CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

CONCENTRATIONS OF TCE IN GROUNDWATER IN SECOND QUARTER, 2013 (µg/L):

▲ CONCENTRATION BELOW MTCA METHOD A CLEANUP LEVEL

▲ CONCENTRATION ABOVE MTCA METHOD A CLEANUP LEVEL

TCE IN SOIL ABOVE MTCA METHOD A CLEANUP LEVEL

TCE CONTAMINATION IN GROUNDWATER

GROUNDWATER

LEAKAGE THROUGH HETEROGENEOUS SOIL MATRIX OR THE SEMI-CONFINING UNIT

SAND, SILTY SAND, AND GRAVEL (Hf)

SAND AND SILTY SAND (Hdf)

SAND, SILT AND CLAY (Hdf)

SILT AND CLAY (Qpf)

SAND AND SILTY SAND (Qpf)

INFERRED CONTACT

UST	UNDERGROUND STORAGE TANK
TCE	TRICHLOROETHENE
<	RESULT BELOW LABORATORY REPORTING LIMIT
mg/kg	MILLIGRAMS PER KILOGRAM
µg/L	MICROGRAMS PER LITER
MTCA	WASHINGTON STATE MODEL TOXICS CONTROL ACT

150	TCE
RED	DENOTES CONCENTRATION EXCEEDS MTCA METHOD A CLEANUP LEVEL.
Hf	HOLOCENE FILL
Hdf	HOLOCENE DEPRESSION FILLINGS
Qpf	PRE-FRASER DEPOSITS

NOTE: ALL LOCATIONS ARE APPROXIMATE.

VERTICAL SCALE IN FEET 0 5 10

HORIZONTAL SCALE IN FEET 0 10 20

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DATE: 05/14/14
DRAWN BY: NAC/BLR
CHECKED BY: PJK/TSB
CAD FILE: 01-600_2013FS_XEE

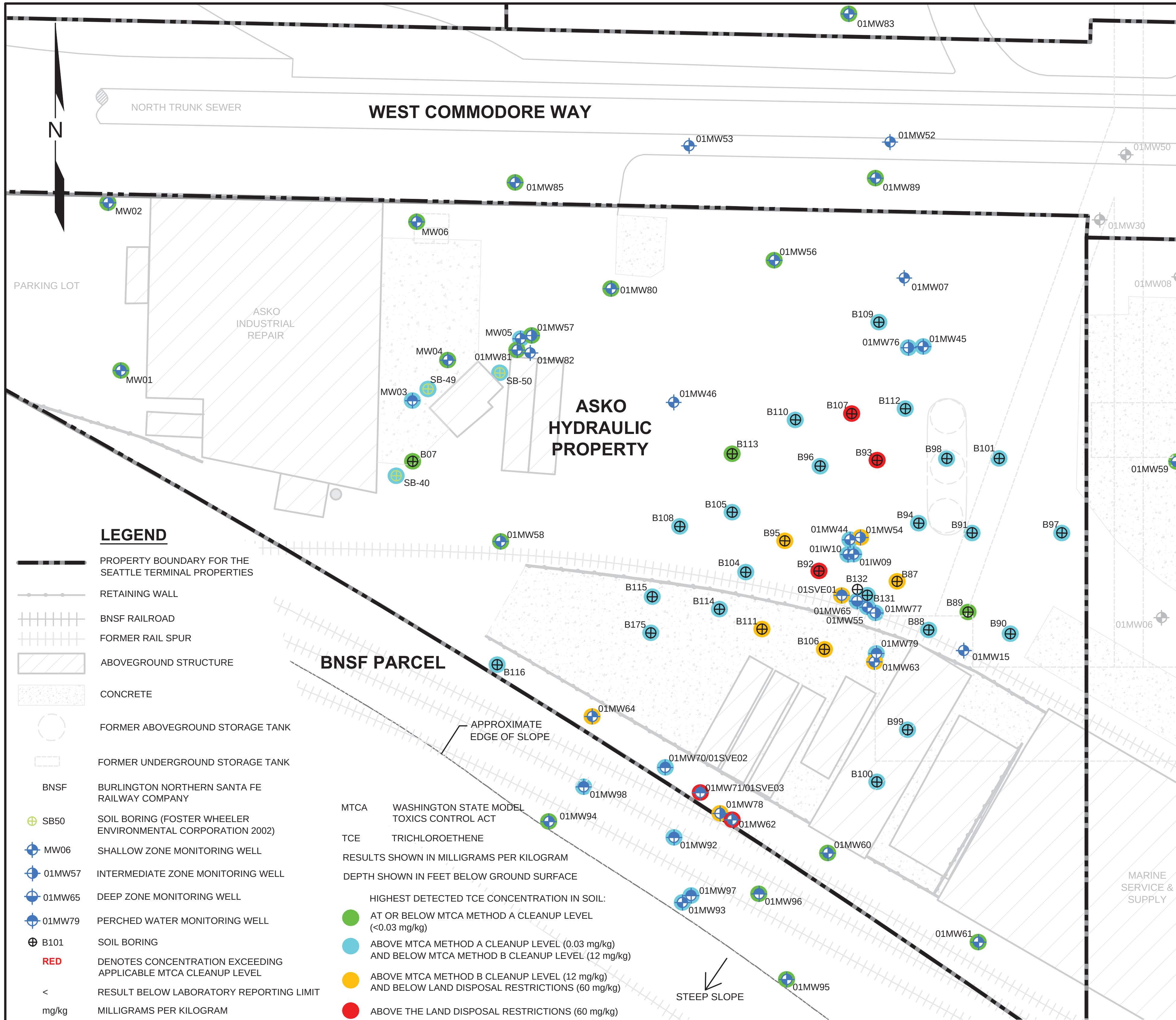
PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

SCALE DEPICTED ABOVE

FIGURE 13
CROSS SECTION E-E'

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFR\01-600_2013FS_XEE_F.DWG
5/14/2014



Sample Location	Date Sampled	Sample Depth	TCE
SB-40	11/21/00	2	<0.100
		5	<0.100
		10	0.17
		15	<0.100
SB-49	11/29/00	2	<0.100
		5	<0.100
		10	<0.100
		15	<0.100
SB-50	11/29/00	2	<0.100
		5	<0.100
		10	<0.100
		15	<0.100
MW01/B01	04/17/06	11	<0.00290
MW02/B02	04/17/06	4.5	<0.00215
		11	0.0031
MW03/B03	04/18/06	6	<0.139
		12	<0.00230
		16	<0.00246
MW04/B04	04/18/06	1	<0.00214
		10	<0.00221
		22	<0.00298
MW05/B05	04/19/06	1.5	<0.00252
		22.5	0.616
MW06/B06	04/19/06	2	<0.00237
		21.5	<0.00242
B07	04/21/06	1.5	<0.00214
01MW44/SB65	09/13/06	2.5	0.0385
		25	<0.00273
		27.5	<0.00231
01MW45/SB66	09/13/06	2.5	<0.00250
		22.5	0.499
		25	<0.00251
01MW54/B076	11/13/08	5	0.11
		10	34
		15	4.5
01MW55/B077	11/13/08	5	<0.03
		15	7.8
01MW56/B078	11/14/08	5	<0.03
		15	<0.03
01MW57/B079	11/14/08	5	<0.03
		32.5	<0.03
		40	<0.03
01MW58/B080	11/14/08	5	<0.03
		20	<0.03
01MW60/B83	12/29/08	5	<0.03
		7.5	<0.03
		37.5	<0.03
01MW61/B84	12/29/08	5	<0.03
		7.5	<0.03
		27.5	<0.03
01MW62/B85	12/30/08	5	0.22
		17.5	66
		20	52
		30	4.2
		37.5	0.10
01MW63/B86	12/30/08	5	<0.03
		17.5	35
		32.5	<0.03
B87	12/29/08	5	<0.03
		10	3.4
		16	19
B88	12/29/08	7	<0.03
		10	0.16
		16	0.82
B89	12/29/08	2	<0.03
		5	<0.03
		11	<0.03
		13	<0.03
B90	12/29/08	3	4.4
		10	<0.03
		16	<0.03
B91	12/29/08	2	<0.03
		10	0.098
		14	0.15
MTCA Method A Cleanup Level			0.03

Sample Location	Date Sampled	Sample Depth	TCE
B92	12/30/08	6	2.4
		10	89
		14	2.6
B93	12/30/08	2	<0.03
		10	1.0
		18	60
		20	1.6
B94	12/30/08	2	<0.03
		7	0.072
		14	1.3
B95	12/30/08	6	0.42
		10	30
		14	45
		20	2.1
B96	12/30/08	2	0.043
		10	0.53
		20	0.96
B97	12/30/08	2	<0.03
		6	0.031
		10	<0.03
B98	12/30/08	6	0.065
		10	0.37
		20	0.16
B99	12/30/08	0.5	<0.03
		5	<0.03
		9	0.077
B100	12/30/08	0.5	<0.03
		3	<0.03
		17	1.4
B101	12/30/08	2	<0.03
		10	0.31
		14	0.14
01MW64/B102	03/17/09	2.5	44
		7.5	15
		17.5	1.26
		20	<0.03
01MW65/B103	03/17/09	40	0.18
B104	03/17/09	4	<0.03
		10	2.5
		14	3.76
		14	4.30
		18	3.09
B105	03/17/09	3	<0.03
		10	0.091
		15	9.03
		20	0.22
B106	03/17/09	12	0.067
		16	5.17
		20	36.0
B107	03/17/09	7	0.19
		13	110
		17	30.5
		22	6.0
B108	03/17/09	8	<0.03
		14	0.42
B109	03/17/09	6	0.24
		12	1.55
		15	0.90
B110	03/17/09	4	<0.03
		10	4.2
		16	0.80
B111	03/18/09	3	0.032
		3	0.040
		18	20.3
B112	03/18/09	7	0.23
		13	1.08
		16	3.26
		18	0.35
B113	03/18/09	11.5	<0.03
B114	03/18/09	4	<0.03
		18	2.82
		21	2.29
B115	03/18/09	3	<0.03
		12	0.037
		18	0.43
MTCA Method A Cleanup Level			0.03

Sample Location	Date Sampled	Sample Depth	TCE
B116	03/18/09	3	0.21
		16	<0.03
B131	12/29/09	10	0.23
	03/29/10	14.5-15	0.50
	03/29/10	15-15.5	0.66
01MW70/01SVE02/ B134	02/11/10	2.5	0.033
		10.5	1.7
01MW71/01SVE03/ B133	02/11/10	5.5	0.80
		20	120
01SVE01/B135	02/11/10	10.5	16
		15	3.8
01IW09/B136	02/12/10	5	0.17
		11.5	0.86
		16	4.3
01IW10/B137	02/12/10	11	1.4
		23	2.6
01MW76/B171	02/28/11	5	0.065
		10	0.60
		15	0.10
		17.5	0.19
01MW77/B172	03/01/11	20	3.1
01MW78/B173	03/02/11	7.5	7.7
		10	<0.03
		15	<0.03
		25	47
		27.5	5.3
01MW79/B174	03/03/11	2.5	<0.03
		7.5	<0.03
		10.5	0.13
B175	03/03/11	2.5	<0.03
		7.5	<0.03
		11	0.72
		15	<0.03
01MW80/B188	04/18/11	2.5	<0.03
		7.5	<0.03
		12.5	<0.03
01MW81/B189	04/18/11	12.5	<0.03
01MW83/B191	04/19/11	5	<0.03
		12.5	<0.03
01MW85/B193	04/20/11	2.5	<0.03
		7.5	<0.03
		12.5	<0.03
01MW89/B197	04/21/11	2.5	<0.03
		7.5	<0.03
		12.5	<0.03
01MW92/B258	08/16/12	2.5	0.18
		5	0.39
		10	0.050
		12.5	<0.03
01MW93/B259	08/16/12	2.5	<0.03
		5	<0.03
		7.5	0.18
		17.5	<0.03
		22.5	<0.03
01MW94/B260	08/17/12	2.5	<0.03
		12.5	<0.03
		17.5	<0.03
01MW95/B261	08/17/12	0.5	<0.03
		5	<0.03
		7.5	<0.03
01MW96/B264	05/07/13	2.5	<0.03
		7.5	<0.03
		10	<0.03
01MW97/B265	05/07/13	3	0.098
		6	0.12
		11	7.9
01MW98/B266	05/07/13	3.5	<0.03
		6	0.55
		8	0.12
		16	<0.03
01MW59/B082	11/17/08	2.5	<0.03
		5	<0.03
		10	<0.03
MTCA Method A Cleanup Level			0.03

5/14/2014

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SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

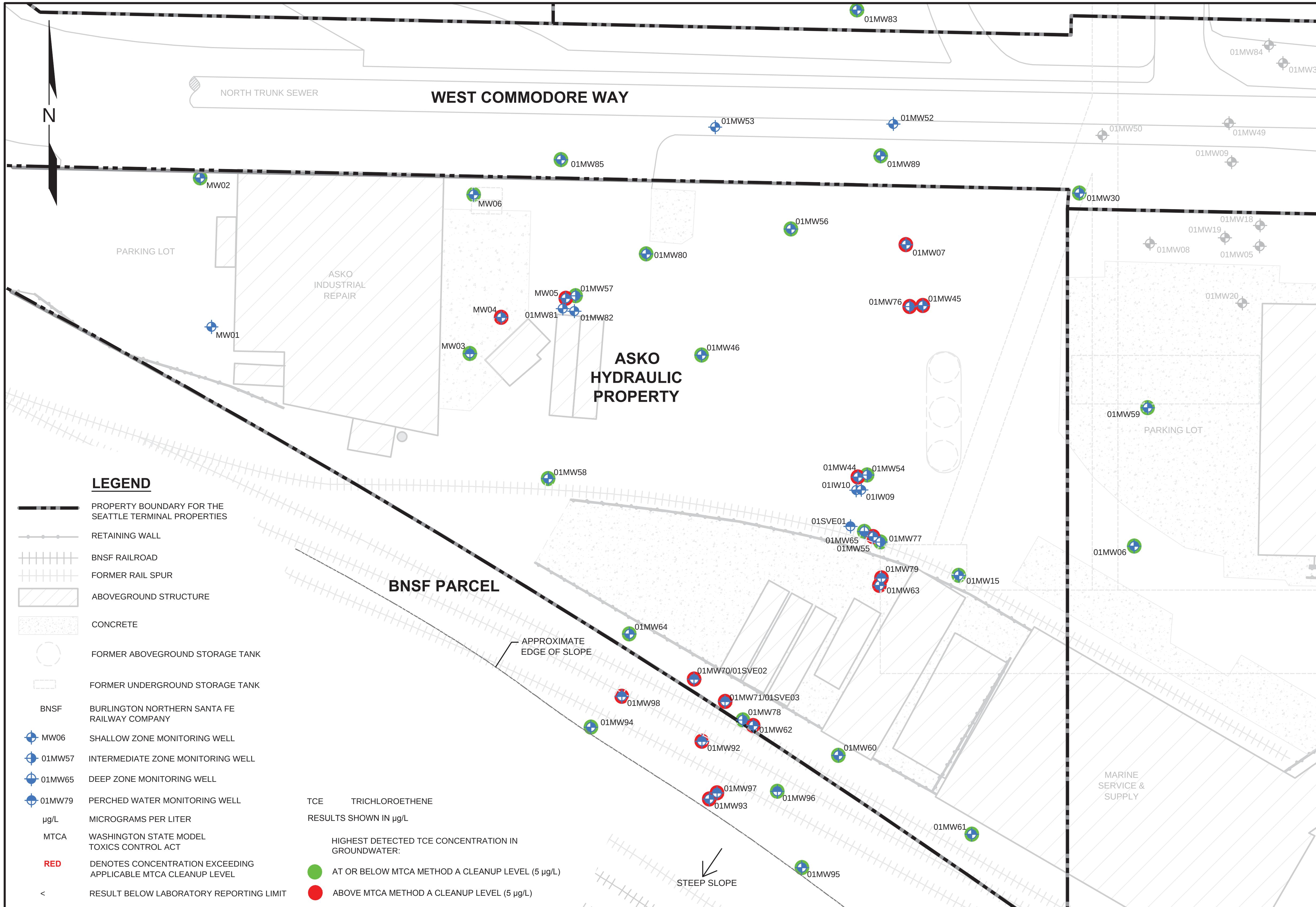
DATE: 05/14/14
DRAWN BY: NAC/BLR
CHECKED BY: PJK/TSB
CAD FILE: 01-600_2013FS_SD_TCE

PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

0 20 40 80
APPROXIMATE SCALE IN FEET

FIGURE 14
HISTORICAL SOIL ANALYTICAL RESULTS FOR TCE



Sample Location	Date Sampled	TCE
West Commodore Way		
Shallow Water-Bearing Zone		
01MW30	04/04/13	<1
01MW83	04/01/13	<1
01MW85	04/01/13	<1
01MW89	04/01/13	<1
ASKO Hydraulic Property		
Perched Water		
MW03	04/01/13	<1
01MW70	04/02/13	360
01MW71	04/02/13	3,600
01MW79	04/02/13	100
Shallow Water-Bearing Zone		
MW02	04/01/13	<1
MW04	04/02/13	130
MW05	04/02/13	260
MW06	04/01/13	<1
01MW07	04/02/13	7.9
01MW15	04/03/13	1.9
01MW44	04/03/13	1,300
01MW45	04/03/13	410
01MW46	04/03/13	<1
01MW55	04/03/13	4,000
01MW56	04/02/13	<1
01MW58	04/02/13	<1
01MW60	04/02/13	4.5
01MW61	04/02/13	<1
01MW62	04/02/13	890
01MW63	04/03/13	9,000
01MW64	04/02/13	<1
01MW80	04/03/13	<1
Intermediate Water-Bearing Zone		
01MW54	04/01/13	1.3
01MW57	04/01/13	<1
01MW76	04/03/13	22
01MW77	04/01/13	<1
01MW78	04/01/13	2.3
Deep Water-Bearing Zone		
01MW65	04/01/13	<1
BNSF Parcel		
Perched Water		
01MW92	05/10/13	6,700
01MW96	05/10/13	<1
01MW97	05/10/13	6,300
01MW98	05/10/13	190
Shallow Water-Bearing Zone		
01MW93	05/13/13	5.5
01MW94	05/10/13	<1
01MW95	05/10/13	<1
Bulk Terminal Property		
Shallow Water-Bearing Zone		
01MW06	04/03/13	<1
01MW59	04/03/13	<1
MTCA Method A Cleanup Level		5

5/14/2014

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFRR\01-600_2013FS_GD_TCE_F.DWG

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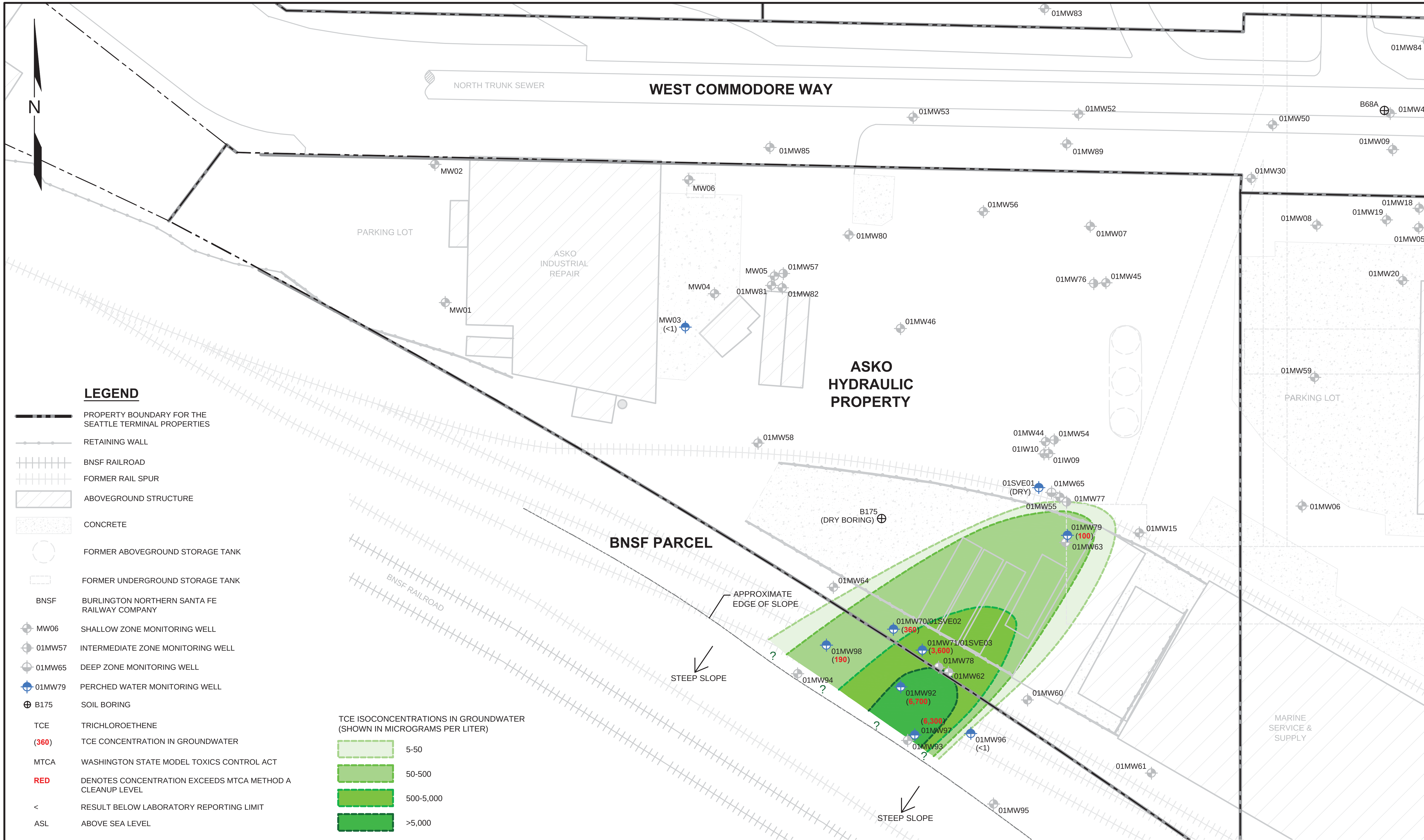
CAD FILE: 01-600_2013FS_GD_TCE

PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

0 20 40 80
APPROXIMATE SCALE IN FEET

FIGURE 15
GROUNDWATER ANALYTICAL RESULTS FOR TCE (SECOND QUARTER 2013)



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CITY, STATE: SEATTLE, WASHINGTON

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FIGURE 16

TCE ISOCONCENTRATION MAP
PERCHED WATER
(ELEVATION 40 TO 50 FEET ASL)
SECOND QUARTER, 2013

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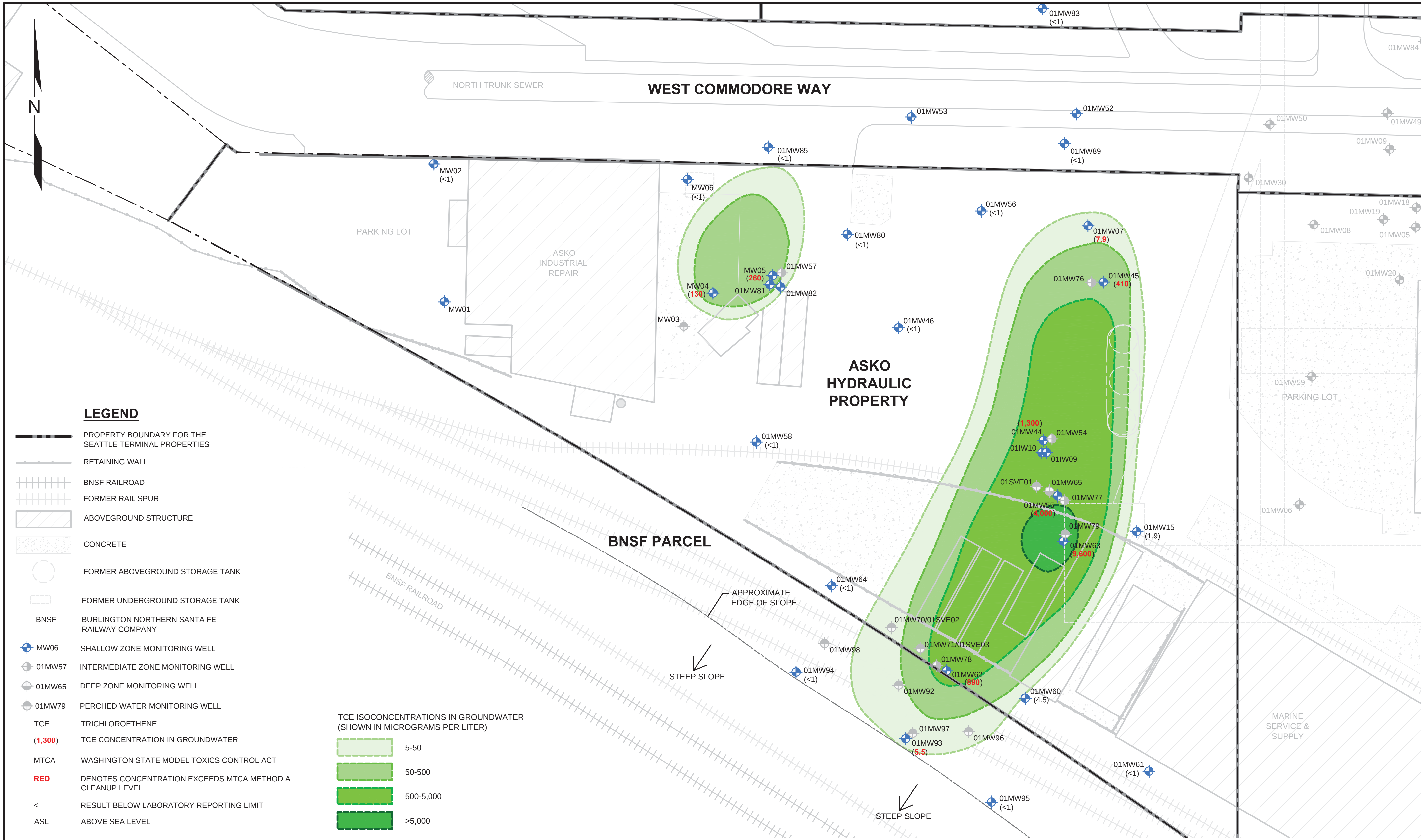

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CITY, STATE: SEATTLE, WASHINGTON

REGION:

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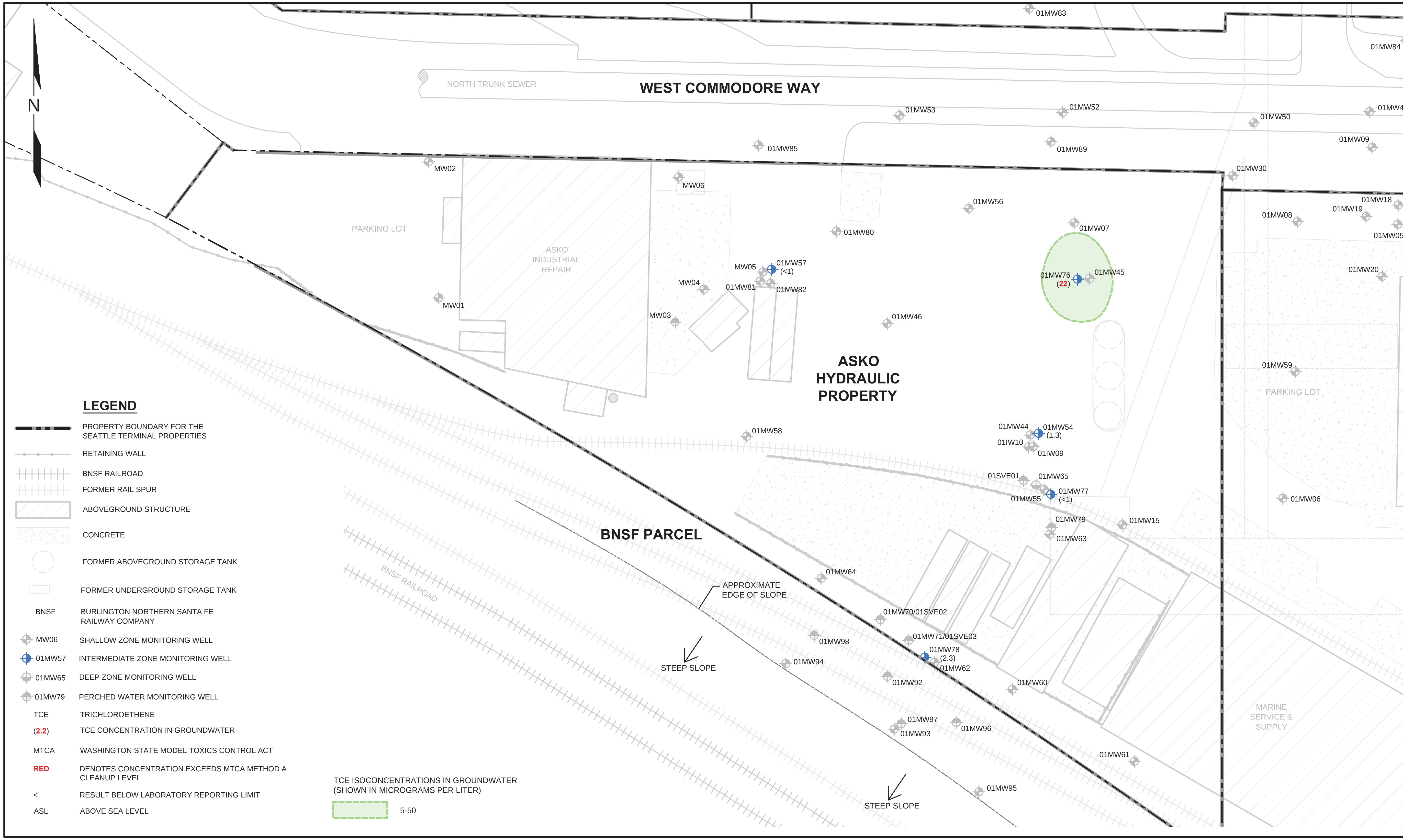
APPROXIMATE SCALE IN FEET

FIGURE 17
TCE ISOCONCENTRATION MAP
SHALLOW WATER-BEARING ZONE
(ELEVATION 17 TO 27 FEET ASL)
SECOND QUARTER, 2013



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CAD FILE: 01-600_2013FS_GDISO_TCE_I

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PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

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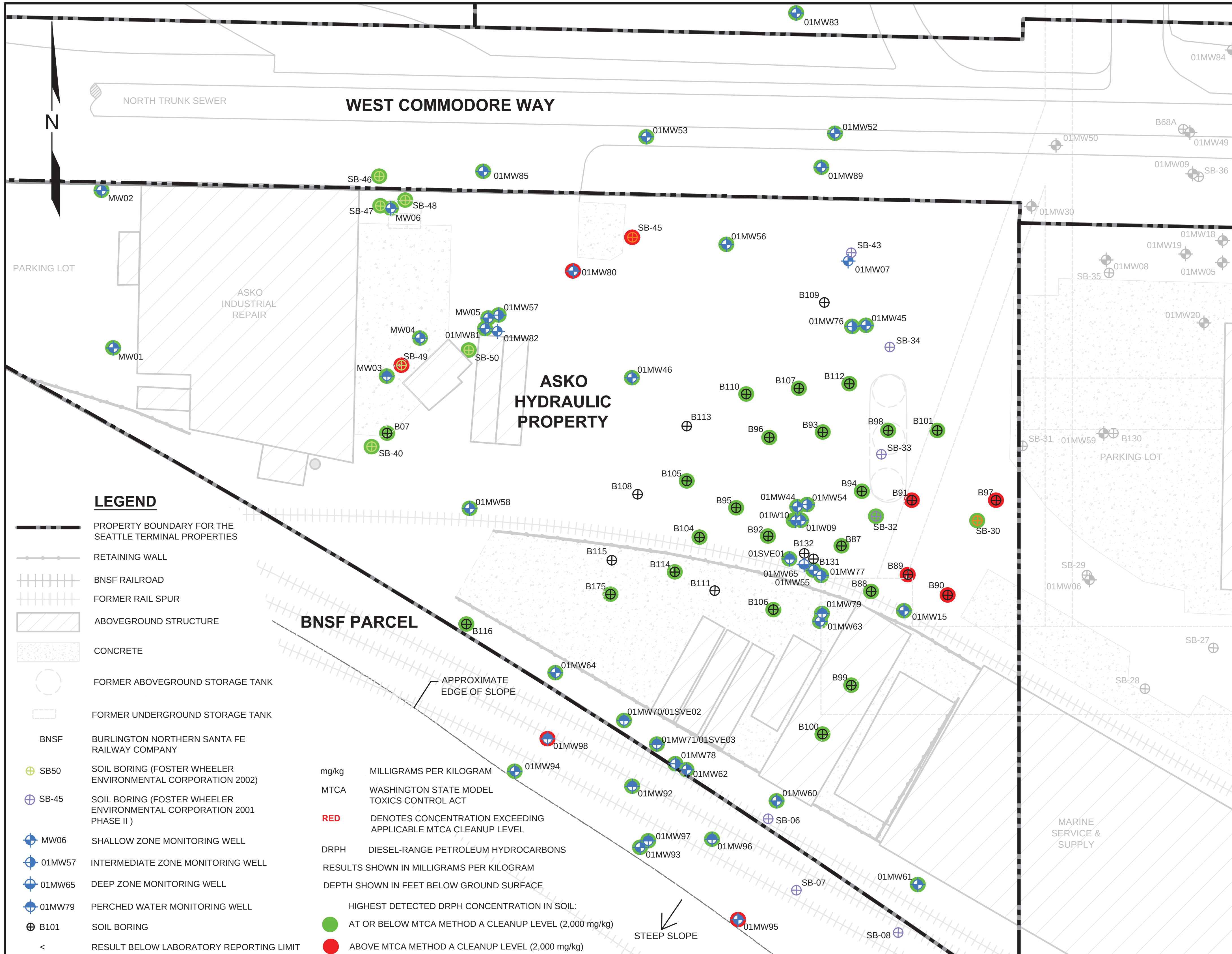
APPROXIMATE SCALE IN FEET

FIGURE 18
TCE ISOCONCENTRATION MAP
INTERMEDIATE WATER BEARING ZONE
(ELEVATION 2.5 TO 13 FEET ASL)
SECOND QUARTER, 2013

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFRR\01-600_2013FS_GDISO_TCE_I_F.DWG 5/14/2014



Sample Location	Date Sampled	Sample Depth	DRPH
SB-46	11/28/00	2	90.8
		5	<10.0
		10	10.7
		15	<10.0
		20	<10.0
		25	<10.0
01MW52/B73	12/05/07	15	<50
		20	<50
01MW53/B75	12/06/07	15	<50
		20	<50
		35	<50
		40	<50
01MW83/B191	04/19/11	5	<50
		12.5	<50
01MW85/B193	04/20/11	2.5	<50
		7.5	<50
		12.5	<50
01MW89/B197	4/21/11	2.5	<50
		7.5	<50
		12.5	<50
SB-40	11/21/00	2	<10.0
		5	<10.0
		10	8.05
		15	<10.0
SB-47	11/28/00	5	87.9
		10	<10.0
		15	<10.0
		20	<10.0
		25	<10.0
SB-48	11/29/00	2	<10.0
		5	<10.0
		10	<10.0
		15	<10.0
		20	<10.0
		25	<10.0
SB-49	11/29/00	2	2,770
		5	339
		10	<10.0
		15	<10.0
SB-50	11/29/00	2	<10.0
		5	<10.0
		10	<10.0
		15	<10.0
SB-30	2001	2	832
SB-32	2001	5	15.7
SB-45	2001	2	2,500
		5	2,200
01MW15/SB-58	07/19/01	2	116
		5	21.4
		10	<10.0
		15	<10.0
		25	<10.0
MW01/B01	04/17/06	11	<10.5
MW02/B02	04/17/06	4.5	<11.6
		11	<11.2
MW03/B03	04/18/06	6	1,300
		12	<12.3
		16	<12.8
MW04/B04	04/18/06	1	706
		10	<12.1
		22	<11.5
MW05/B05	04/19/06	1.5	86.4
		22.5	<12.1
MW06/B06	04/19/06	2	897
		12.5	<11.2
B07	04/21/06	1.5	394
01MW44/SB65	09/13/06	2.5	<11.4
		22.5	<11.8
		25	<12.1
01MW45/SB66	09/13/06	2.5	32.0
		22.5	<11.5
		25	<12.3
01MW46/SB67	09/13/06	2.5	182
		22.5	<10.9
		27.5	<11.9
01MW54/B076	11/13/08	5	<50
		10	<50
01MW55/B077	11/13/08	5	91
		15	<50
01MW56/B078	11/14/08	5	<50
		15	<50
01MW57/B079	11/14/08	5	<50
		32.5	<50
MTCA Method A Cleanup Level			2,000

Sample Location	Date Sampled	Sample Depth	DRPH
01MW58/B080	11/14/08	5	<50
		20	<50
01MW60/B83	12/29/08	5	1,200
		7.5	1,500
01MW61/B84	12/29/08	5	220
		7.5	<50
01MW62/B85	12/30/08	5	<50
		17.5	<50
		20	<50
01MW63/B86	12/30/08	5	<50
		17.5	<50
B87	12/29/08	16	<50
B88	12/29/08	10	<50
B89	12/29/08	11	110
		13	4,300
B90	12/29/08	3	10,000
B91	12/29/08	2	8,300
B92	12/30/08	10	<50
B93	12/30/08	10	<50
B94	12/30/08	7	140
B95	12/30/08	14	<50
B96	12/30/08	20	<50
B97	12/30/08	6	2,900
B98	12/30/08	6	<50
B99	12/30/08	0.5	970
		5	120
B100	12/30/08	0.5	<50
		3	610
B101	12/30/08	2	<50
01MW64/B102	03/17/09	2.5	320
		5	<50
		7.5	<50
B104	03/17/09	14	<50
B105	03/17/09	15	<50
B106	03/17/09	20	<50
B107	03/17/09	13	<50
B110	03/17/09	11	<50
B112	03/18/09	16	<50
B114	03/18/09	18	<50
B116	03/18/09	3	1,900
		7	<50
01MW70/01SVE02/B134	02/11/10	2.5	<50
		10.5	<50
01MW71/01SVE03/B133	02/11/10	5.5	<50
01SVE01/B135	02/11/10	10.5	<50
01IW09/B136	02/12/10	11.5	<50
01IW10/B137	02/12/10	11	<50
01MW76/B171	02/28/11	22.5	<50
01MW77/B172	03/01/11	20	<50
01MW78/B173	03/02/11	7.5	<50
		27.5	<50
01MW79/B174	03/03/11	2.5	<50
		7.5	<50
		10.5	<50
B175	03/03/11	2.5	<50
		7.5	<50
		11	<50
		15	<50
01MW80/B188	04/18/11	2.5	2,300
		7.5	2,300
		12.5	<50
01MW81/B189	04/18/11	12.5	<50
01MW92/B258	08/16/12	2.5	<50
		5	<50
		10	<50
01MW93/B259	08/16/12	2.5	<50
		7.5	<50
		17.5	<50
01MW94/B260	08/17/12	2.5	<50
		12.5	<50
		17.5	<50
01MW95/B261	08/17/12	0.5	140
		2.5	<50
		5	3,000
		7.5	<50
01MW96/B264	05/07/13	2.5	<50
		7.5	68
		10	<50
01MW97/B265	05/07/13	3	<50
		6	<50
		11	<50
01MW98/B266	05/07/13	3.5	<50
		6	4,100
		8	<50
MTCA Method A Cleanup Level			2,000

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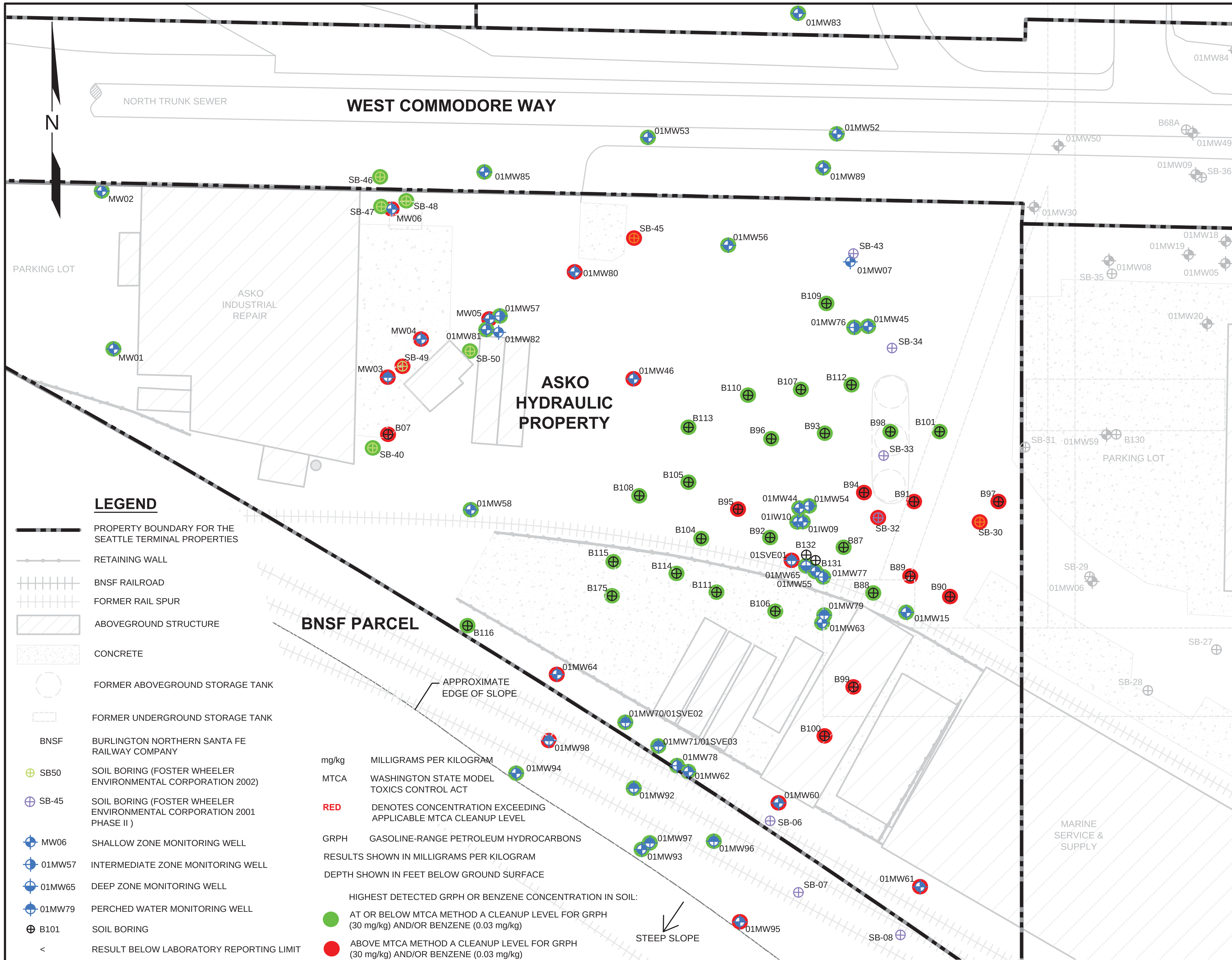
FIGURE 19
HISTORICAL SOIL ANALYTICAL RESULTS FOR DRPH

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFRR\01-600_2013FS_SD_DRPH_F.DWG 5/14/2014



Sample Location	Date Sampled	Sample Depth	GRPH	Benzene
SB-46	11/28/00	2	<5.00	<0.050
		5	<5.00	<0.050
		10	<5.00	<0.050
		15	<5.00	<0.050
		20	<5.00	<0.050
		25	<5.00	<0.050
01MW52/B73	12/05/07	15	<2	<0.03
		20	<2	<0.03
01MW53/B75	12/06/07	15	<2	<0.02
		20	<2	<0.02
		35	<2	<0.02
		40	<2	<0.02
01MW83/B191	04/19/11	5	<2	<0.02
		12.5	<2	<0.02
01MW85/B193	04/20/11	2.5	<2	<0.02
		7.5	<2	<0.02
		12.5	<2	<0.02
01MW89/B197	4/21/11	2.5	<2	<0.02
		7.5	<2	<0.02
		12.5	<2	<0.02
SB-40	11/21/00	2	<5.00	<0.050
		5	<5.00	<0.050
		10	<5.00	<0.050
		15	<5.00	<0.050
SB-47	11/28/00	5	<5.00	<0.050
		10	<5.00	<0.050
		15	<5.00	<0.050
		20	<5.00	<0.050
		25	<5.00	<0.050
SB-48	11/29/00	2	<5.00	<0.050
		5	<5.00	<0.050
		10	<5.00	<0.050
		15	<5.00	<0.050
		20	<5.00	<0.050
		25	<5.00	<0.050
SB-49	11/29/00	2	264	–
		5	467	–
		10	<5.00	–
		15	<5.00	–
SB-50	11/29/00	2	<5.00	–
		5	<5.00	–
		10	<5.00	–
		15	<5.00	–
SB-30	2001	2	5,120	<1.0
SB-32	2001	5	216	<0.2
SB-45	2001	2	3,940	<2.5
		5	577	<0.5
01MW15/SB-58	07/19/01	2	<5.00	<0.0500
		5	<5.00	<0.0500
		10	<5.00	<0.0500
		15	<5.00	<0.0500
		25	<5.00	<0.0500
MW01/B01	04/17/06	11	<4.87	<0.00174
MW02/B02	04/17/06	4.5	<5.61	<0.00129
		11	<5.11	<0.00138
MW03/B03	04/18/06	6	4,720	<1.39
		12	<5.41	<0.00138
		16	<5.23	<0.00148
MW04/B04	04/18/06	1	306	<0.00128
		10	<4.71	<0.00133
		22	<5.02	<0.00179
MW05/B05	04/19/06	1.5	57.3	<0.00151
		22.5	<4.78	0.00439
MW06/B06	04/19/06	2	140	<0.00142
		12.5	<5.28	<0.00145
B07	04/21/06	1.5	143	<0.00128
		3	57.3	<0.0160
01MW44/SB65	09/13/06	2.5	<5.65	<0.00143
		22.5	<6.48	--
		25	<5.90	<0.00164
		27.5	<4.70	<0.00139
01MW45/SB66	09/13/06	2.5	26.5	<0.00150
		22.5	<4.70	0.00238
		25	<5.11	<0.00150
01MW46/SB67	09/13/06	2.5	95.6	<0.00159
		22.5	<5.64	<0.00123
		27.5	<5.29	<0.00168
01MW54/B076	11/13/08	5	<2	<0.03
		10	9	<0.03
		15	–	<0.03
01MW55/B077	11/13/08	5	21	<0.03
		15	3	<0.03
01MW56/B078	11/14/08	5	<2	<0.03
		15	<2	<0.03
01MW57/B079	11/14/08	5	<2	<0.03
		32.5	<2	<0.03
		40	–	<0.03
01MW58/B080	11/14/08	5	<2	<0.03
		20	<2	<0.03
01MW60/B83	12/29/08	5	240	<0.03
		7.5	1,600	0.61
		15	<2	<0.02
		37.5	--	<0.03
01MW61/B84	12/29/08	5	30	<0.03
		7.5	<2	<0.03
01MW62/B85	12/30/08	5	<2	<0.03
		17.5	27	<0.03
		20	11	<0.03
MTCA Method A Cleanup Level			30	0.03

Sample Location	Date Sampled	Sample Depth	GRPH	Benzene
01MW63/B86	12/30/08	5	<2	<0.03
		17.5	22	<0.03
B87	12/29/08	16	8	<0.03
B88	12/29/08	10	6	<0.03
B89	12/29/08	11	420	<0.03
		13	9,700	0.25
B90	12/29/08	3	380	0.081
B91	12/29/08	2	800	<0.03
B92	12/30/08	10	19	<0.03
B93	12/30/08	10	<2	<0.03
B94	12/30/08	7	52	<0.03
B95	12/30/08	14	9	0.041
B96	12/30/08	20	<2	<0.03
B97	12/30/08	6	1,600	<0.3
B98	12/30/08	6	<2	<0.03
B99	12/30/08	0.5	54	0.21
		5	<2	<0.03
B100	12/30/08	0.5	<2	<0.03
		3	96	<0.03
B101	12/30/08	2	10	<0.03
01MW64/B102	03/17/09	2.5	68	<0.02
		5	<2	<0.02
		7.5	3	<0.02
		17.5	--	<0.02
		20	--	<0.02
01MW65/B103	03/17/09	40	--	<0.02
B104	03/17/09	10	--	<0.02
		14	3	<0.02
		14	--	<0.02
		18	--	<0.02
B105	03/17/09	10	--	<0.02
		15	<2	<0.02
B106	03/17/09	16	--	<0.02
		20	<2	<0.02
B107	03/17/09	13	3	<0.02
		17	--	<0.02
		22	--	<0.02
B108	03/17/09	14	--	<0.02
B109	03/17/09	12	--	<0.02
		15	--	<0.02
B110	03/17/09	10	--	<0.02
		11	<2	<0.02
		16	--	<0.02
B111	03/17/10	3	--	<0.02
		3	--	<0.02
		18	--	<0.02
B112	03/18/09	13	--	<0.02
		16	<2	<0.02
B113	03/18/09	11.5	--	<0.02
B114	03/18/09	18	<2	<0.02
		21	–	<0.02
B115	03/18/09	3	--	<0.02
		15	--	<0.02
B116	03/18/09	3	<2	<0.02
		16	--	<0.02
01MW70/01SVE02/B134	02/11/10	2.5	<2	<0.02
		10.5	<2	<0.02
01MW71/01SVE03/B133	02/11/10	5.5	<2	<0.02
01SVE01/B135	02/11/10	10.5	<2	0.04
01IW09/B136	02/12/10	11.5	<2	<0.02
01IW10/B137	02/12/10	11	2	<0.02
01MW76/B171	02/28/11	22.5	<2	<0.02
01MW77/B172	03/01/11	20	<2	<0.02
01MW78/B173	03/02/11	7.5	4.4	<0.02
		27.5	3.8	<0.02
01MW79/B174	03/03/11	2.5	<2	0.027
		7.5	<2	<0.02
		10.5	<2	<0.02
B175	03/03/11	2.5	<2	<0.02
		7.5	<2	<0.02
		11	<2	<0.02
		15	<2	<0.02
01MW80/B188	04/18/11	2.5	95	<0.02
		7.5	260	<0.02
		12.5	<2	<0.02
01MW81/B189	04/18/11	12.5	<2	<0.02
01MW92/B258	08/16/12	2.5	<2	<0.02
		5	<2	<0.02
		10	<2	<0.02
01MW93/B259	08/16/12	2.5	<2	<0.02
		7.5	<2	<0.02
		17.5	<2	<0.02
01MW94/B260	08/17/12	2.5	<2	<0.02
		12.5	<2	<0.02
		17.5	<2	<0.02
01MW95/B261	08/17/12	0.5	<2	<0.02
		2.5	<2	<0.02
		5	240	<0.02
		7.5	8.7	<0.02
01MW96/B264	05/07/13	2.5	30	<0.02
		7.5	16	<0.02
		10	<2	<0.02
01MW97/B265	05/07/13	3	<2	<0.02
		6	2.2	<0.02
		11	3.2	<0.02
01MW98/B266	05/07/13	3.5	<2	<0.02
		6	130	<0.02
		8	<2	<0.02
MTCA Method A Cleanup Level			30	0.03

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PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

0 20 40 80
APPROXIMATE SCALE IN FEET

FIGURE 20
HISTORICAL SOIL ANALYTICAL RESULTS FOR GRPH AND BENZENE

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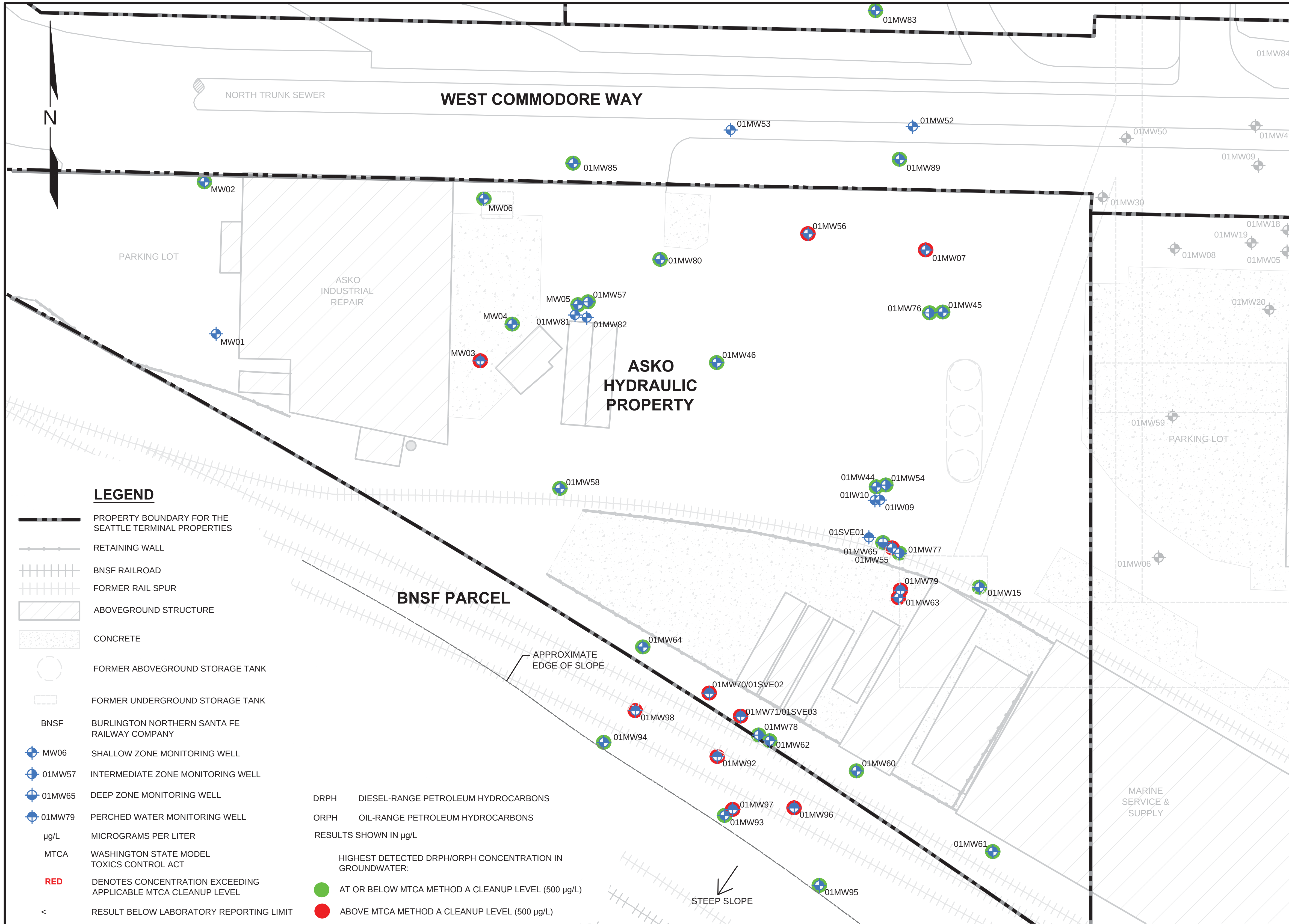

Sample Location	Date Sampled	DRPH	ORPH
East Waterfront Property			
Shallow Water-Bearing Zone			
01MW83	04/01/13	<50	<250
West Commodore Way			
Shallow Water-Bearing Zone			
01MW85	04/01/13	140	<250
01MW89	04/01/13	310	<250
ASKO Hydraulic Property			
Perched Water			
MW03	04/01/13	1,000	<250
01MW70	04/02/13	1,200	1,000
01MW71	04/02/13	1,500	1,400
01MW79	04/02/13	1,200	660
Shallow Water-Bearing Zone			
MW02	04/01/13	460	<250
MW04	04/02/13	240	<250
MW05	04/02/13	290	<250
MW06	04/01/13	310	<250
01MW07	04/02/13	860	<250
01MW15	04/03/13	240	<250
01MW44	04/03/13	290	<250
01MW45	04/03/13	380	<250
01MW46	04/03/13	130	<250
01MW55	04/03/13	630	370
01MW56	04/02/13	1,000	<250
01MW58	04/02/13	250	<250
01MW60	04/02/13	120	<250
01MW61	04/02/13	230	<250
01MW62	04/02/13	110	<250
01MW63	04/03/13	800	340
01MW64	04/02/13	120	<250
01MW80	04/03/13	240	<250
Intermediate Water-Bearing Zone			
01MW54	04/01/13	<50	<250
01MW57	04/01/13	<50	<250
01MW76	04/03/13	<50	<250
01MW77	04/01/13	79	<250
01MW78	04/01/13	<50	<250
Deep Water-Bearing Zone			
01MW65	04/01/13	<50	<250
BNSF Parcel			
Perched Water			
01MW92	05/10/13	3,400	770
01MW96	05/10/13	2,000	380
01MW97	05/10/13	3,200	740
01MW98	05/10/13	4,000	820
Shallow Water-Bearing Zone			
01MW93	05/13/13	<50	<250
01MW94	05/10/13	56	<250
01MW95	05/10/13	<50	<250
MTCA Method A Cleanup Level		500	500

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PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

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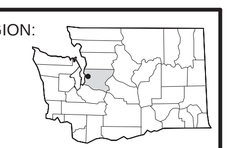


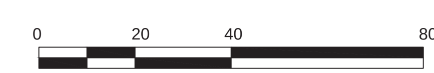
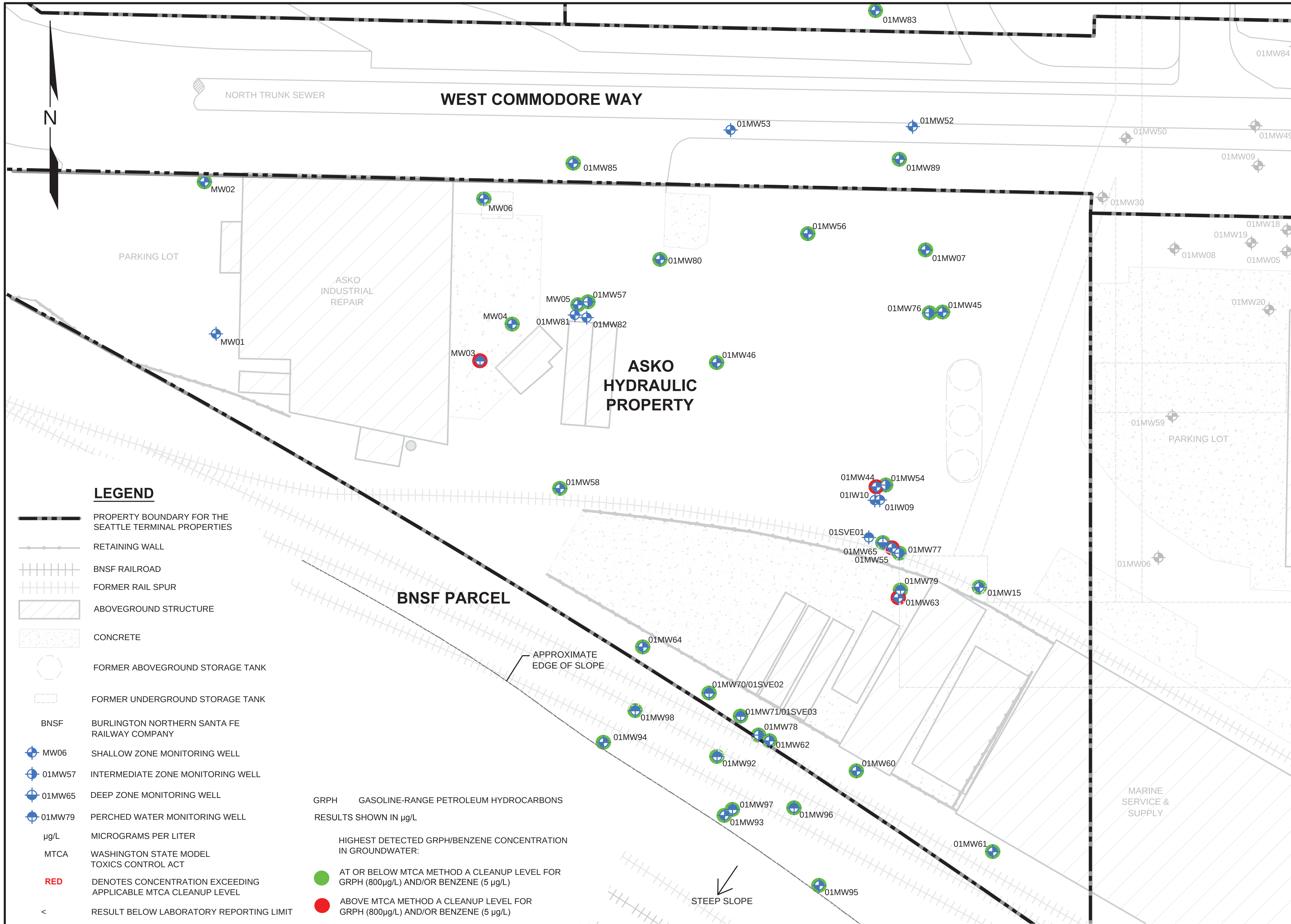


FIGURE 21
GROUNDWATER ANALYTICAL RESULTS FOR DRPH AND ORPH (SECOND QUARTER 2013)



Sample Location	Date Sampled	GRPH	Benzene
East Waterfront Property			
Shallow Water-Bearing Zone			
01MW83	04/01/13	<100	<1
West Commodore Way			
Shallow Water-Bearing Zone			
01MW85	04/01/13	<100	<1
01MW89	04/01/13	<100	<1
ASKO Hydraulic Property			
Perched Water			
MW03	04/01/13	810	3.4
01MW70	04/02/13	160	<1
01MW71	04/02/13	330	<1
01MW79	04/02/13	<100	<1
Shallow Water-Bearing Zone			
MW02	04/01/13	<100	<1
MW04	04/02/13	<100	<1
MW05	04/02/13	<100	<1
MW06	04/01/13	<100	<1
01MW07	04/02/13	<100	<1
01MW15	04/03/13	<100	<1
01MW44	04/03/13	290	13
01MW45	04/03/13	200	2.2
01MW46	04/03/13	<100	<1
01MW55	04/03/13	1,100	2.0
01MW56	04/02/13	<100	<1
01MW58	04/02/13	<100	<1
01MW60	04/02/13	<100	<1
01MW61	04/02/13	<100	<1
01MW62	04/02/13	290	<1
01MW63	04/03/13	2,200	5.6
01MW64	04/02/13	<100	<1
01MW80	04/03/13	<100	<1
Intermediate Water-Bearing Zone			
01MW54	04/01/13	<100	<1
01MW57	04/01/13	<100	<1
01MW76	04/03/13	<100	<1
01MW77	04/01/13	<100	<1
01MW78	04/01/13	<100	<1
Deep Water-Bearing Zone			
01MW65	04/01/13	<100	<1
BNSF Parcel			
Perched Water			
01MW92	05/10/13	770	<1
01MW96	05/10/13	<100	<1
01MW97	05/10/13	620	<1
01MW98	05/10/13	170	<1
Shallow Water-Bearing Zone			
01MW93	05/13/13	<100	<1
01MW94	05/10/13	<100	<1
01MW95	05/10/13	<100	<1
MTCA Method A Cleanup Level		800	5

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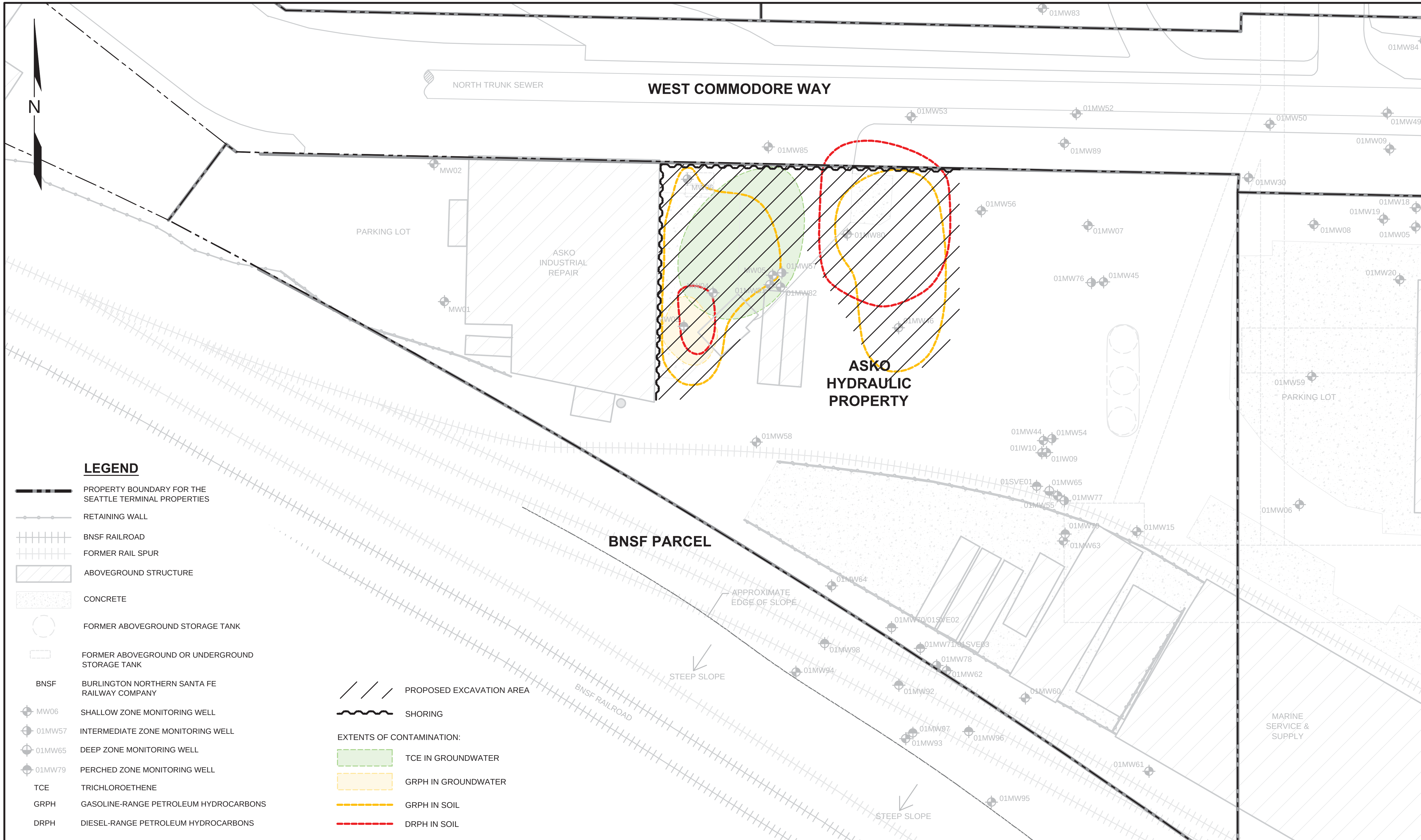
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

FIGURE 22
GROUNDWATER ANALYTICAL RESULTS FOR GRPH AND BENZENE (SECOND QUARTER 2013)

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFRR\01-600_2013FS_GD_GB F.DWG 5/14/2014



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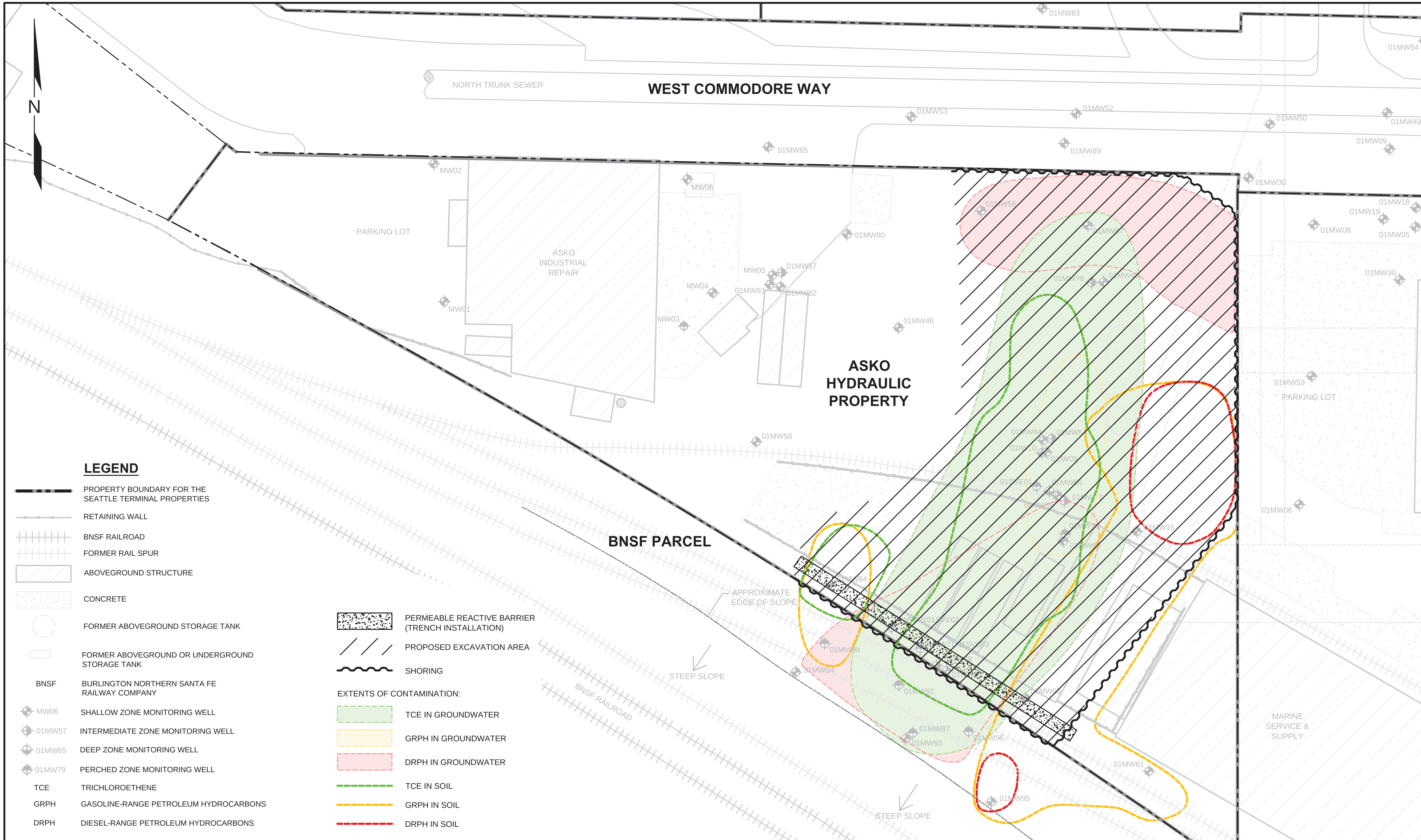
PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
SES PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

FIGURE 23A

CLEANUP ACTION ALTERNATIVE 1 (PHASE I) EXCAVATION WITH OFF-SITE TREATMENT AND DISPOSAL



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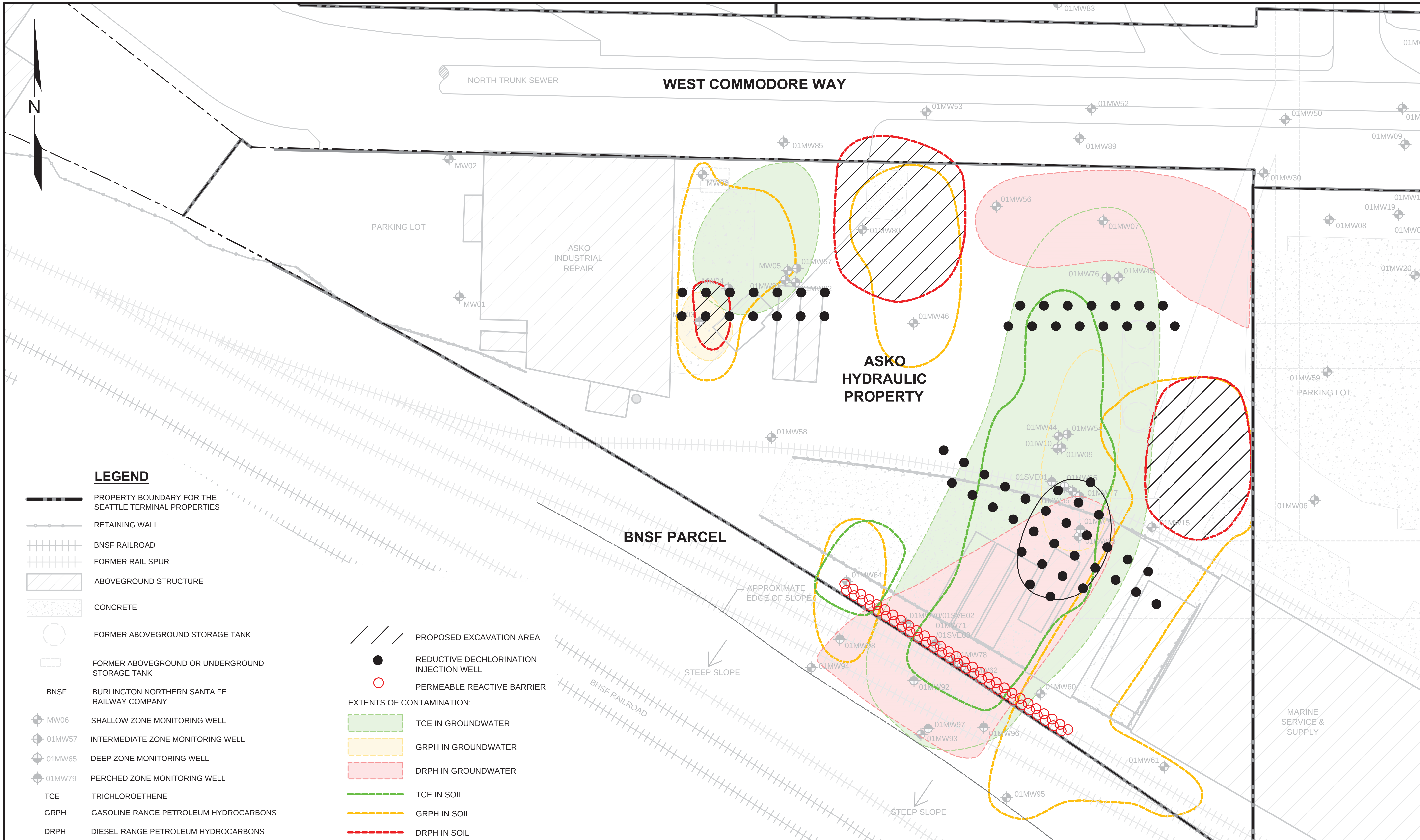
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

0 20 40 80
APPROXIMATE SCALE IN FEET

FIGURE 23B

CLEANUP ACTION ALTERNATIVE 1 (PHASE 2) EXCAVATION WITH OFF-SITE TREATMENT AND DISPOSAL



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CITY, STATE: SEATTLE, WASHINGTON

REGION:

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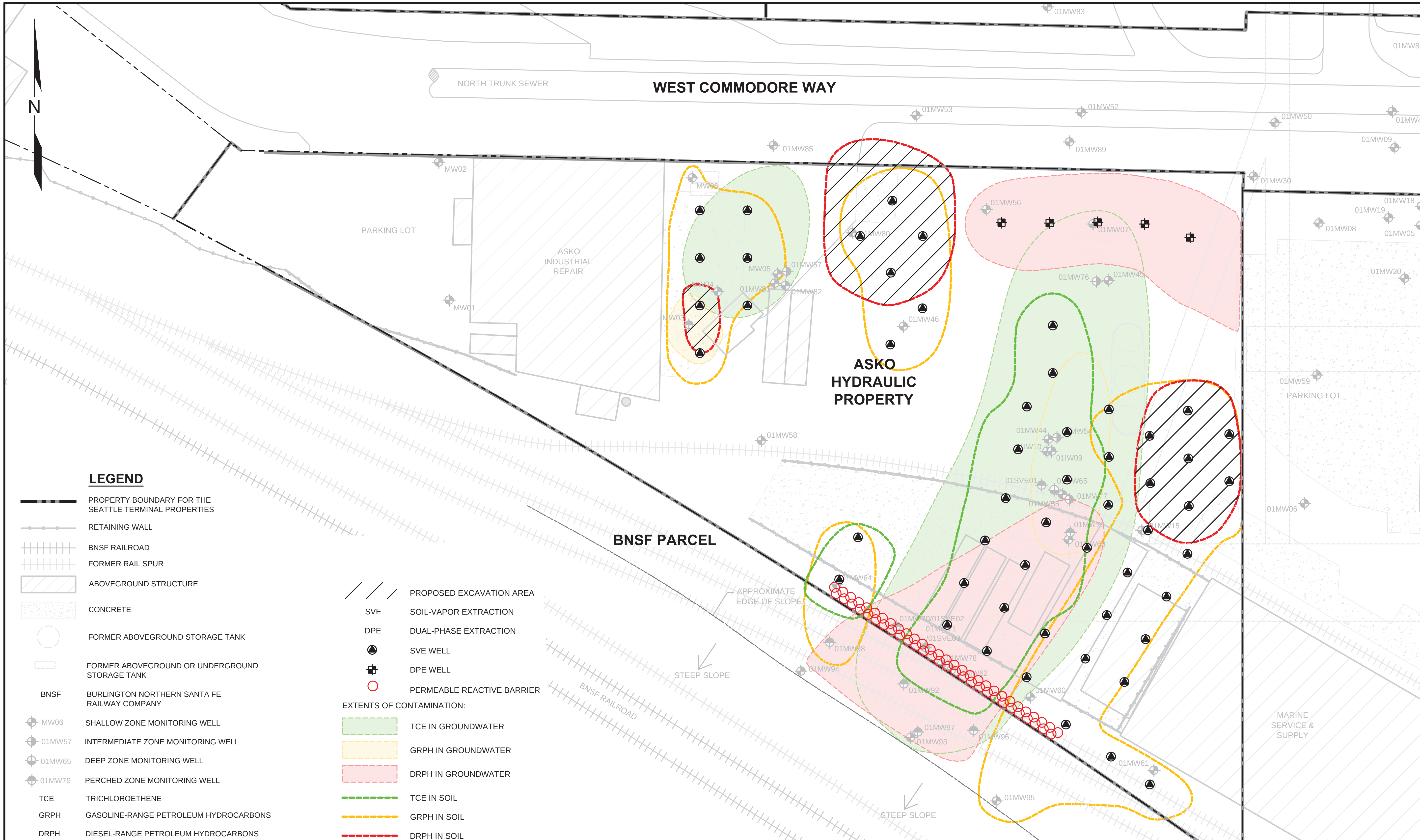
APPROXIMATE SCALE IN FEET

FIGURE 24A
CLEANUP ACTION ALTERNATIVE 2 (PHASE 1)
REDUCTIVE DECHLORINATION



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APPROXIMATE SCALE IN FEET

FIGURE 24B
CLEANUP ACTION ALTERNATIVE 2 (PHASE 2)
SVE & DPE

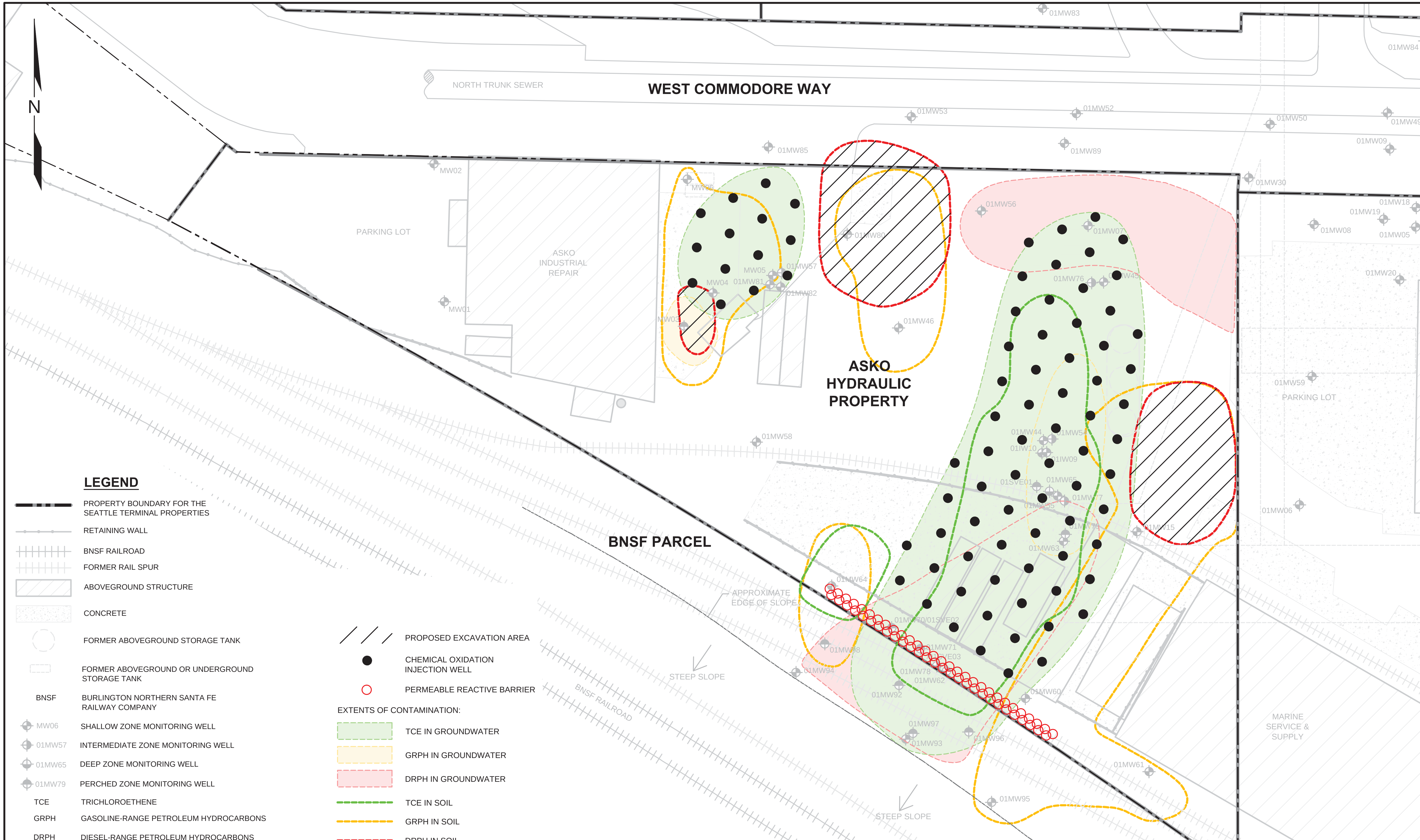

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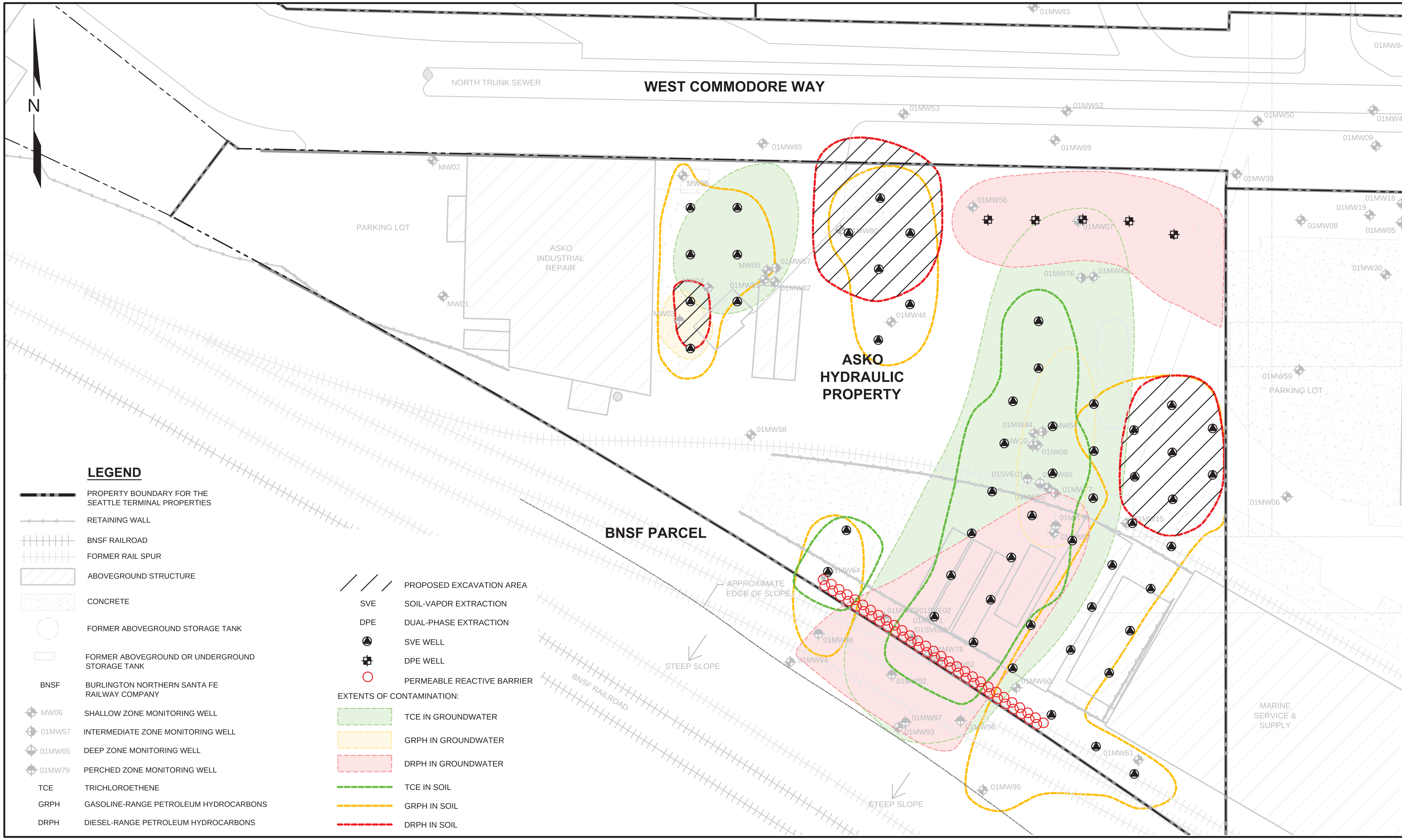
FIGURE 25A
CLEANUP ACTION ALTERNATIVE 3 (PHASE 1)
IN SITU CHEMICAL OXIDATION

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFRR\01-600_2013FS_CA3_1 F.DWG 5/14/2014



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P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFRR\01-600_2013FS_CA3_2_F.DWG

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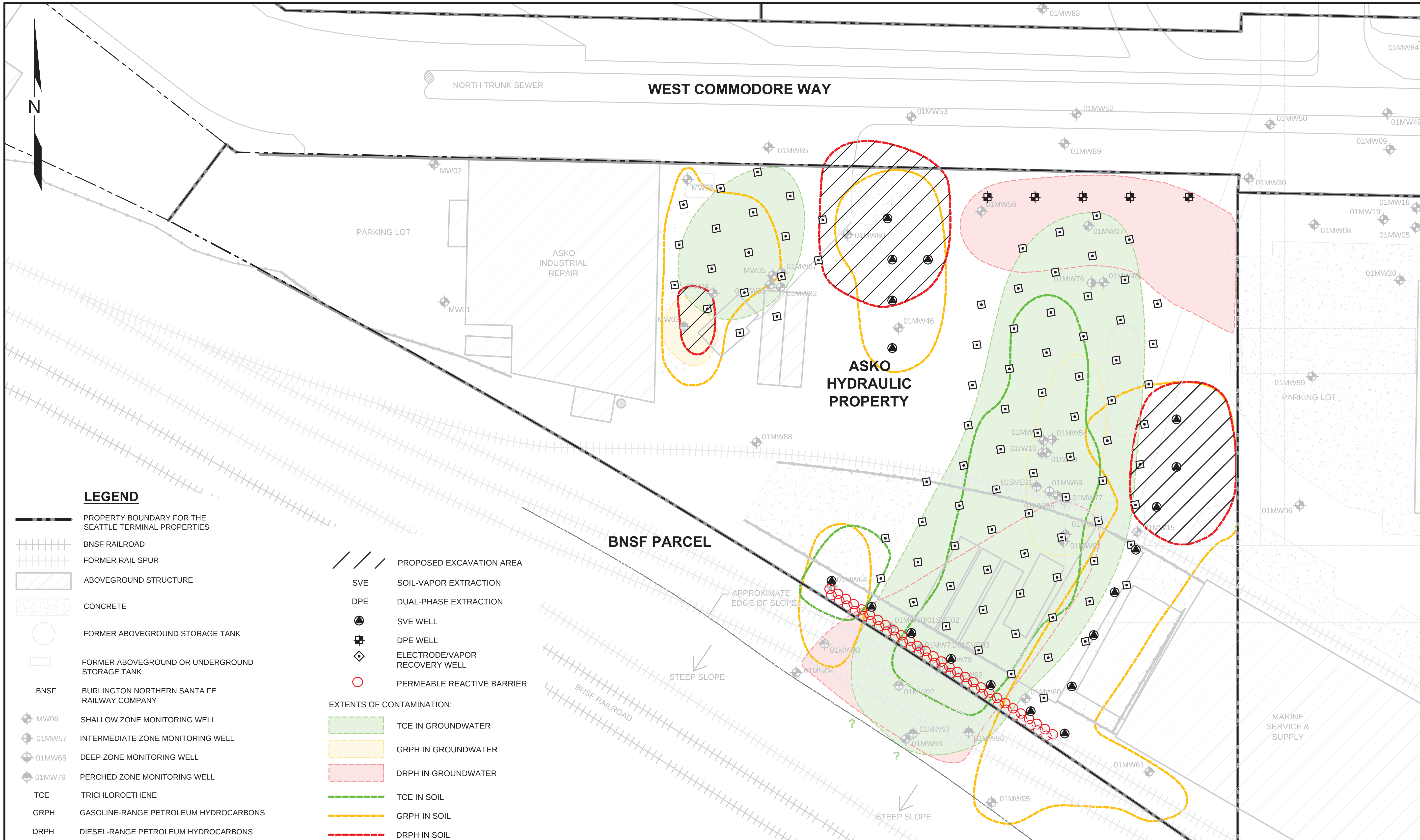
SES PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

0 20 40 80
APPROXIMATE SCALE IN FEET

FIGURE 25B
CLEANUP ACTION ALTERNATIVE 3 (PHASE 2)
SVE & DPE



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P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\TECHNICAL\CAD\2013\ASKO\FS\DFRR\01-600_2013FS_CA4_F.DWG

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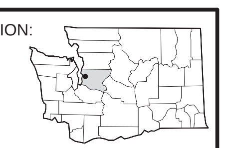
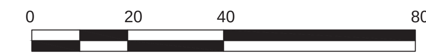
CHECKED BY: TWM
CAD FILE: 01-600_2013FS_CA4

PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
SES PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:





APPROXIMATE SCALE IN FEET

FIGURE 26

CLEANUP ACTION ALTERNATIVE 4
ELECTRICAL RESISTANCE HEATING, SVE, DPE, AND EXCAVATION

TABLES

Table 1
Preliminary Cleanup Levels
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

SOIL	
Chemicals of Concern	**Cleanup Levels (mg/kg)**
Gasoline-Range Petroleum Hydrocarbons	30[(1)]
Diesel-Range Petroleum Hydrocarbons	2,000[(1)]
Oil-Range Petroleum Hydrocarbons	2,000[(1)]
Benzene	0.03[(1)]
Toluene	7[(1)]
Ethylbenzene	6[(1)]
Total Xylenes	9[(1)]
PCE	0.05[(1)]
TCE	0.03[(1)]
cis-1,2-Dichloroethene	160[(2)]
trans-1,2-Dichloroethene	1,600[(2)]
1,1-Dichloroethene	4,000[(2)]
1,2-Dichloroethane	11[(3)]
Vinyl Chloride	0.67[(3)]
MTBE	0.1[(1)]
1,2-Dibromoethane	0.005[(1)]
1,2,4-Trimethyl-benzene	NE
1,3,5-Trimethyl-benzene	800[(2)]
Acetone	72,000[(2)]
Isopropylbenzene	8,000[(2)]
Naphthalene	5[(1)]
n-Butylbenzene	NE
n-Propylbenzene	NE
p-Isopropyltoluene	NE
sec-Butylbenzene	NE
tert-Butylbenzene	NE
2-Butanone	48,000[(2)]
Arsenic	20[(1)]
Barium	16,000[(2)]
Cadmium	2[(1)]
Chromum	2,000[(1)]
Lead	250[(1)]
Mercury	2[(1)]
Selenium	400[(2)]
Silver	400[(2)]
Ethanol	NE
Pentachlorophenol	2.5[(3)]
1-Methylnaphthalene	5[(1)]
2-Methylnaphthalene	5[(1)]
Acenaphthene	4,800[(2)]
Acenaphthylene	NE
Fluorene	3,200[(2)]
Phenanthrene	NE
Anthracene	24,000[(2)]
Fluoranthene	3,200[(2)]
Pyrene	2,400[(2)]
Benzo(g,h,i)perylene	NE
Benzo(a) anthracene	NE
Chrysene	NE
Benzo(a)pyrene	0.1[(1)]
Benzo(b) fluoranthene	NE
Benzo(k) fluoranthene	NE
Indeno(1,2,3-cd)pyrene	NE
Dibenz(a,h) anthracene	NE

Table 1
Preliminary Cleanup Levels
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

GROUNDWATER	
Chemicals of Concern	**Cleanup Levels (µg/L)**
Gasoline-Range Petroleum Hydrocarbons	800[(4)]
Diesel-Range Petroleum Hydrocarbons	500[(4)]
Oil-Range Petroleum Hydrocarbons	500[(4)]
Benzene	5[(4)]
Toluene	1,000[(4)]
Ethylbenzene	700[(4)]
Total Xylenes	1,000[(4)]
PCE	5[(4)]
TCE	5[(4)]
cis-1,2-Dichloroethene	16[(5)]
trans-1,2-Dichloroethene	160[(5)]
1,1-Dichloroethene	400[(5)]
1,2-Dichloroethane	5[(4)]
Pentachlorophenol	0.22[(6)]
Vinyl Chloride	0.2[(4)]
Total and Dissolved Lead	15[(4)]
MTBE	20[(4)]
1,2-Dibromoethane	0.01[(4)]
Tetrachloroethene	5[(4)]
Trichloroethene	5[(4)]
1,2,4 Trimethylbenzene	NE
1,3,5 Trimethylbenzene	80[(5)]
Naphthalene	160[(4)]
Acetone	7,200[(5)]
Isopropylbenzene	800[(5)]
n-Butylbenzene	NE
n-Hexane	480[(5)]
n-Propylbenzene	NE
p-Isopropyltoluene	NE
sec-Butylbenzene	NE
tert-Butylbenzene	NE
2-Butanone	4,800[(5)]
Ethanol	NE
Total and Dissolved Arsenic	5[(4)]
Total and Dissolved Barium	3,200[(5)]
Total and Dissolved Cadmium	5[(4)]
Total and Dissolved Chromium	50[(4)]
Total and Dissolved Mercury	2[(4)]
Total and Dissolved Selenium	80[(5)]
Total and Dissolved Silver	80[(5)]
1-Methylnaphthalene	160[(4)]
2-Methylnaphthalene	160[(4)]
Acenaphthene	960[(5)]
Acenaphthylene	NE
Fluorene	640[(5)]
Phenanthrene	NE
Anthracene	4,800[(5)]
Fluoranthene	640[(5)]
Pyrene	480[(5)]
Benzo(g,h,i)perylene	NE
Benz(a) anthracene	0.1[(4)]

Table 1
Preliminary Cleanup Levels
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

GROUNDWATER	
Chemicals of Concern	**Cleanup Levels (µg/L)**
Chrysene	0.1[(4)]
Benzo(a)pyrene	0.1[(4)]
Benzo(b) fluoranthene	0.1[(4)]
Benzo(k) fluoranthene	0.1[(4)]
Indeno(1,2,3-cd)pyrene	0.1[(4)]
Dibenz(a,h) anthracene	0.1[(4)]

NOTES:

[(1)]MTCA Method A Soil Cleanup Levels for Unrestricted Land Uses, Table 740-1 of Section 900 of Chapter 173-340 of the Washington Administrative Code, revised November 2007.

[(2)]CLARC, Soil, Method B Cleanup Levels, Non-Carcinogen, Standard Formula Value, Direct Contact (ingestion only), CLARC website <https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx>.

[(3)]CLARC, Soil, Method B Cleanup Levels, Carcinogen, Standard Formula Value, Direct Contact (ingestion only), CLARC website <https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx>.

[(4)]MTCA Method A Cleanup Levels for Ground Water, Table 720-1 of Section 900 of Chapter 173-340 of the Washington Administrative Code, revised November 2007.

[(5)]CLARC, Groundwater, Method B Cleanup Levels, Non-Carcinogen, Standard Formula Value, CLARC website <https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx>.

[(6)]MTCA Cleanup Regulation, CLARC, Ground Water Method C, Carcinogen, Standard Formula Value, CLARC website <https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx>.

µg/L = micrograms per liter
CLARC = Cleanup Levels and Risk Calculation
mg/kg = milligrams per kilogram
MTCA = Model Toxics Control Act
MTBE = methyl t-butyl ether
NE = not established
PCE = tetrachloroethene
TCE = trichloroethene

Table 2
Remedial Component Screening Matrix
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

Component Group	Component Options	Retained for Inclusion in Cleanup Action Alternatives?	Rationale for Inclusion or Exclusion
Passive Remediation			
	No Further Action	No	Not retained because the current Site conditions pose unacceptable risks that require remediation.
	Monitored Natural Attenuation	Yes	Retained as a component of all cleanup action alternatives. Not retained for use as a sole administrative or engineering control.
	Low Permeability Containment Cap	No	Not retained because the existence of a cap is not compatible with prospective future land uses.
	Environmental Covenant	No	Not retained because does not meet current remedial action objectives to comply with ARARs and Site-specific cleanup standards to demonstrate compliance and obtain an NFA determination from Ecology for unrestricted land uses.
	Passive Treatment Wall or Permeable Reactive Barrier	Yes	Technology is effective for COPCs in groundwater. Retained for barrier implementation at upgradient Property boundary with BNSF.
In Situ Physical Treatment			
	Soil Vapor Extraction	Yes	Retained because it is a demonstrated technology for remediation of COPCs in soil and Site conditions are favorable for effective use of this technology.
	Air Sparging	No	Not retained because air sparging is not compatible with bioremedation and chemical oxidation technologies which have been retained as viable cleanup action alternatives.
	Surfactant Washing	No	Not retained because this technology is mediated in the saturated zone and is not effective in treating unsaturated zone soil contamination.
	Cosolvent Washing	No	Not retained because this technology is mediated in the saturated zone and is not effective in treating unsaturated zone soil contamination.
	Pump and Treat	No	Not retained because this technology is mediated in the saturated zone and is not effective in treating unsaturated zone soil contamination.
	Dual-Phase Extraction	Yes	Retained because technology is demonstrated to be effective for remediation of COPCs and Site conditions are favorable for use of this technology.
In Situ Thermal			
	Resistive Thermal with SVE	Yes	Retained because it is a demonstrated technology for remediation of COPCs and is more effective from a technical and cost standpoint than other technologies within the same component group.
	Conductive Thermal with SVE	No	Not retained because Resistive Thermal with SVE is a demonstrated technology for remediation of COPCs and is more effective from a technical and cost standpoint than these technologies.
	Radio Frequency/Electromagnetic Thermal with SVE	No	
	Steam Injection with SVE and Groundwater Extraction	No	
	Hot Air Injection with SVE	No	
	Hot Water Injection with SVE and Groundwater Extraction	No	
Source Removal			
	Excavation without Shoring	No	Not retained because excavation without shoring is not feasible to implement due to the proximity of structures and rights-of-way.
	Excavation with Shoring		
	Secant Pile Wall - Impervious Wall	No	Not considered necessary - an impervious shoring system is not needed at the Site because of the planned use of a dewatering system.
	Sheet Pile Wall - Impervious Wall	No	Not considered necessary - an impervious shoring system is not needed at the Site because of the planned use of a dewatering system.
	Soldier Pile Wall - Non-Impervious Wall	Yes	Retained as the selected excavation with shoring alternative due to the anticipated excavation and dewatering methods.
Ex Situ Source Treatment			
	Surfactant Washing	No	Not retained because these components are not cost competitive with other technologies at this scale and would result in another waste stream requiring disposal.
	Cosolvent Washing	No	
	Chemical Oxidation	No	
	Land Disposal with Thermal Desorption	No	Not retained as Land Disposal is more cost-competitive.
	Land Disposal	Yes	Retained for chlorinated solvent and petroleum hydrocarbon-contaminated soil.

Table 2
Remedial Component Screening Matrix
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

Component Group	Component Options	Retained for Inclusion in Cleanup Action Alternatives?	Rationale for Inclusion or Exclusion
In Situ Chemical Oxidation			
	Heated Sodium Persulfate	No	Not retained because this technology is more costly than use of permanganate in the saturated zone.
	Hydrogen Peroxide	No	Not retained because this technology has Insufficient oxidation potential.
	Ozonation	No	Not retained because this technology would be implemented by gas injection which is considered less effective than use of permanganate for COPCs.
	Permanganate	Yes	Retained because the technology is demonstrated to be effective for remediation of CVOCs and Site conditions are favorable for use of this technology.
	Fenton's Reagent	No	Not retained because this technology is a difficult process to control and costly to implement compared to other technologies.
Containment/Immobilization			
	Bituminization	No	Not retained because these technologies reduce the mobility of hazardous substances but not their toxicity or volume. These technologies are typically implemented ex situ.
	Emulsified Asphalt	No	
	Modified Sulfur Cement	No	
	Polyethylene Extrusion	No	Not retained because this technology is not well developed.
	Pozzolan/Portland Cement	No	Not retained because the technology reduces the mobility of hazardous substances but not the toxicity or volume. The technology is typically implemented ex situ.
	Vitrification/Molten Glass	No	Not retained because this technology is not cost competitive with other technologies in this group and is difficult to implement. This technology also presents an increased short-term risk of injury during installation and operation.
	Slurry Wall Containment	No	Not retained because these technologies reduce the mobility of hazardous substances but not their toxicity or volume. The technologies are typically implemented ex situ.
	Sheet Pile Wall Containment	No	
	Pump and Treat for Hydraulic Containment	No	Not retained because this component will not address soil contamination.
Phytoremediation			
	Hydraulic Control	No	Not retained because these technologies are unable to remediate groundwater contamination because of the depth of contamination, nor are these technologies compatible with the future land use at the Site.
	Phyto-Degradation	No	
	Phyto-Volatilization	No	
	Phyto-Accumulation	No	
	Phyto-Stabilization	No	
	Enhanced Rhizosphere Biodegradation	No	
In Situ Bioremediation			
	Aerobic Bioremediation	Yes	Retained in conjunction with SVE for treatment of contaminated media.
	Anaerobic Bioremediation	Yes	Retained because technology is demonstrated to be effective for remediation of CVOCs and Site conditions are favorable for use of this technology.

NOTES:

BNSF = Burlington Northern Sante Fe Railway Company

COPC = chemical of potential concern

CVOC = chlorinated volatile organic compound

SVE = soil vapor extraction

Table 3
Cleanup Action Alternative 1
Feasibility Level Cost Estimate
Excavation with Shoring and Off-Site Land Disposal
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

PRESENT CAPITAL COST ITEM	QTY	UNIT	UNIT PRICE	COST	TOTALS
Direct Capital					
Remedial Excavation					
Geotechnical Oversight	1	ls	$ 30,000	$ 30,000	
Shoring	16,360	sf	$ 75	$ 1,227,000	
Well Decommissioning	30	each	$ 350	$ 10,500	
Site Controls (fencing)	500	lf	$ 7.50	$ 3,750	
Temporary Dewatering Treatment	1	ls	$ 75,000	$ 75,000	
Excavation, Handling, and Segregation of Soil	24,210	ton	$ 24	$ 581,040	
Transportation and Disposal of Land Banned Soil	1,211	ton	$ 480	$ 581,040	
Transportation and Disposal of TCE-impacted Soil (Dangerous Waste) to Subtitle C Landfill	6,053	ton	$ 186	$ 1,125,765	
Transportation and Disposal of TCE-impacted Soil (Non-listed or Contained-out) to Subtitle D Landfill	14,526	ton	$ 90	$ 1,307,340	
Transportation of PCS	1,220	ton	$ 25	$ 30,500	
Disposal of PCS at Permitted Facility	1,220	ton	$ 38	$ 46,360	
Transportation and Disposal of Clean Overburden	1,220	ton	$ 35	$ 42,700	
Clean Backfill and Compaction	24,210	ton	$ 20	$ 484,200	
Subtotal Remedial Excavation					$ 5,545,195
Permeable Reactive Barrier					
Zero-valent Iron for Permeable Reactive Barrier	430	ton	$ 1,050	$ 451,500	
Sand	210	ton	$ 15	$ 3,150	
Pea Gravel	90	ton	$ 15	$ 1,350	
Iron Shipping	430	ton	$ 100	$ 43,000	
Sand Hauling	210	ton	$ 10	$ 2,100	
Pea Gravel Hauling	90	ton	$ 10	$ 900	
Subtotal Permeable Reactive Barrier					$ 502,000
Compliance Monitoring					
Well Installation for Quarterly Groundwater Monitoring	20	each	$ 3,000	$ 60,000	
Subtotal Compliance Monitoring					$ 60,000
Subtotal Direct Capital					$ 6,107,195
Indirect Capital (as percentages of Direct Capital)					
Design, Permitting, and Work Plans (6%)				$ 366,440	
Mobilization (1%)				$ 61,080	
Professional Labor for Construction Oversight (7%)				$ 427,510	
Field Equipment and Supplies (1%)				$ 61,080	
Laboratory Testing (field verification and waste profiling; 1%)				$ 61,080	
Site Restoration and Demobilization (1%)				$ 61,080	
Regulatory Reporting (3%)				$ 183,220	
Subtotal Indirect Capital					$ 1,221,490
Total Capital					$ 7,328,685

FUTURE O&M AND OTHER DIRECT COST ITEMS(1)	ANNUAL COST(2)		PRESENT WORTH OF ANNUAL AND FUTURE CAPITAL COST	
	Discount Rate =	-0.8%	n (years) = 5	
Quarterly Groundwater Monitoring and Reporting (assume 20 wells)	$ 56,000		$ 286,800	
Decommission Monitoring Wells (20 wells at $350 each)			$ 7,000	
Present Worth Cost of Annual and Future Capital Cost				$ 293,800
TOTAL PRESENT WORTH COST (Sum of Total Capital and Present Worth of Annual and Future Capital Cost)(3)(4)(5)				$ 7,622,490

NOTES:

(1) Additional direct costs such as project management, regulatory communications and reporting, and other technical support services not specifically listed are not included in any future annual costs.

(2) Annual cost is year 2013 cost.

(3) This feasibility level cost should not be considered a design cost estimate or guaranteed cost.

(4) Excludes electrical costs for all systems.

(5) Cost rounded up to nearest $1,000.

lf = linear feet
ls = lump sum
n = number of years of compliance monitoring and O&M
O&M = operation and maintenance
PCS = petroleum-contaminated soil
QTY = quantity
sf = square feet
TCE = trichloroethene
ton = number of bank cubic yards x 1.5 ton/bank cubic yard

SoundEarth Strategies

Table 4
Cleanup Action Alternative 2
Feasibility Level Cost Estimate
Reductive Dechlorination for CVOCs in Groundwater
DPE for DRPH in Groundwater
SVE for CVOCs in Soil
Excavation for DRPH in Soil

PRESENT CAPITAL COST ITEM	QTY	UNIT	UNIT PRICE	COST	TOTALS
Direct Capital					
Remedial Excavation					
Site Controls (fencing)	500	lf	$ 7.50	$ 3,750	
Well Decommissioning	3	each	$ 350	$ 1,050	
Excavation, Handling, and Segregation of PCS	2,550	ton	$ 24	$ 61,200	
Transportation of PCS	2,550	ton	$ 25	$ 63,750	
Disposal of PCS at Permitted Facility	2,550	ton	$ 38	$ 96,900	
Clean Backfill and Compaction	2,550	ton	$ 20	$ 51,000	
Subtotal Remedial Excavation					$ 277,650
Reductive Dechlorination					
Edible Oil Injection Wells, Installed	61	each	$ 2,500	$ 152,500	
Edible Oil Injection System	1	ls	$ 50,000	$ 50,000	
First Injection Edible Oil Substrate	1	ls	$ 120,000	$ 120,000	
Second Contingency Injection Substrate	1	ls	$ 40,000	$ 40,000	
Bioaugmentation	1	ls	$ 50,000	$ 50,000	
Aquifer pH adjustment (for bioaugmentation)	1	ls	$ 5,000	$ 5,000	
Subtotal Reductive Dechlorination					$ 417,500
Soil Vapor Extraction and Dual-Phase Extraction System					
SVE Wells, Installed	53	each	$ 3,500	$ 185,500	
DPE Wells, Installed	6	each	$ 4,000	$ 24,000	
Trenches for SVE/DPE Including Piping, Fittings and Backfill	1	ls	$ 180,000	$ 180,000	
Total Fluids Pumps for DPE	6	each	$ 2,800	$ 16,800	
Remediation Equipment, Enclosure, and Controls	1	ls	$ 180,000	$ 180,000	
Electrical and Control Installation	1	ls	$ 20,000	$ 20,000	
Transportation of Trench Cuttings	250	ton	$ 25	$ 6,250	
Disposal of Trench Cuttings	250	ton	$ 38	$ 9,500	
Subtotal SVE and DPE System					$ 622,050
Permeable Reactive Barrier					
Mobilization for 48" Ø caisson rig	1	ls	$ 5,000	$ 5,000	
Drilling Services (approximately 56 4-foot Ø borings to 48 feet bgs)	2,690	lf	$ 100	$ 269,000	
Handling of Soil	1,880	ton	$ 20	$ 37,600	
Transportation and Disposal of TCE-impacted Soil (Dangerous Waste) to Subtitle C Landfill	620	ton	$ 186	$ 115,320	
Transportation and Disposal of TCE-impacted Soil (Non-listed or Contained-out) to Subtitle D Landfill	1,260	ton	$ 90	$ 113,400	
Clean structural fill for drilled caissons	2,040	ton	$ 35	$ 71,400	
Zero-valent Iron for Permeable Reactive Barrier	590	ton	$ 1,050	$ 619,500	
Sand	280	ton	$ 15	$ 4,200	
Pea Gravel	130	ton	$ 15	$ 1,950	
Iron Shipping	590	ton	$ 100	$ 59,000	
Sand Hauling	280	ton	$ 10	$ 2,800	
Pea Gravel Hauling	130	ton	$ 10	$ 1,300	
Subtotal Permeable Reactive Barrier					$ 1,300,470
Subtotal Direct Capital					$ 2,617,670
Indirect Capital (as percentages of Direct Capital)					
Design, Permitting, and Work Plans (9%)				$ 235,590	
Mobilization (1%)				$ 26,180	
Professional Labor for Construction Oversight (12%)				$ 314,120	
Field Equipment and Supplies (1%)				$ 26,180	
Laboratory Testing (field verification and waste profiling) (1%)				$ 26,180	
Site Restoration and Demobilization (1%)				$ 26,180	
Regulatory Reporting (4%)				$ 104,700	
Subtotal Indirect Capital					$ 759,130
Total Capital					$ 3,376,800

SoundEarth Strategies

Table 4
Cleanup Action Alternative 2
Feasibility Level Cost Estimate
Reductive Dechlorination for CVOCs in Groundwater
DPE for DRPH in Groundwater
SVE for CVOCs in Soil
Excavation for DRPH in Soil

FUTURE O&M AND OTHER DIRECT COST ITEMS[1]	ANNUAL COST[2]	PRESENT WORTH OF ANNUAL AND FUTURE CAPITAL COST	
	Discount Rate = 0.1%		n (years)
Quarterly Groundwater Monitoring (assume 20 wells)	$ 56,000	$ 556,900	10
Monthly O&M of SVE/DPE System	$ 90,000	$ 617,300	7
Post-remediation Confirmation Soil Sampling		$ 25,000	
Decommission Monitoring wells (20 wells @ $350 each)		$ 7,000	
Decommission Edible Oil Injection Wells (61 wells @ $350 each)		$ 21,350	
Decommission SVE and DPE wells (59 wells @ $350 each)		$ 20,650	
Decommission SVE and DPE System		$ 35,000	
Present Worth Cost of Annual and Future Capital Cost			$ 1,283,200
TOTAL PRESENT WORTH COST (Sum of Total Capital and Present Worth of Annual and Future Capital Cost)[3][4][5]			$ 4,660,000

NOTES:

[1]Additional direct costs such as project management, regulatory communications and reporting, and other technical support services not specifically listed are not included in any future annual costs.

[2]Annual cost is year 2013 cost.

[3]This feasibility level cost should not be considered a design cost estimate or guaranteed cost.

[4]Excludes electrical costs for all systems.

[5]Cost rounded up to nearest $1,000.

bgs = below ground surface

DPE = dual-phase extraction

lf = linear feet

ls = lump sum

n = number of years of compliance monitoring and O&M

O&M = operation and maintenance

PCS = petroleum-contaminated soil

QTY = quantity

SVE = soil vapor extraction

TCE = trichloroethene

ton = number of bank cubic yards x 1.5 ton/bank cubic yard

SoundEarth Strategies

Table 5
Cleanup Action Alternative 3
Feasibility Level Cost Estimate
ISCO for CVOCs in Groundwater
DPE for DRPH in Groundwater
SVE for CVOCs in Soil
Excavation for DRPH in Soil

PRESENT CAPITAL COST ITEM	QTY	UNIT	UNIT PRICE	COST	TOTALS
Direct Capital					
Remedial Excavation					
Site Controls (fencing)	500	lf	$ 7.50	$ 3,750	
Well Decommissioning	3	each	$ 350	$ 1,050	
Excavation, Handling, and Segregation of PCS	2,550	ton	$ 24	$ 61,200	
Transportation of PCS	2,550	ton	$ 25	$ 63,750	
Disposal of PCS at Permitted Facility	2,550	ton	$ 38	$ 96,900	
Clean Backfill and Compaction	2,550	ton	$ 20	$ 51,000	
Subtotal Remedial Excavation					$ 277,650
In Situ Chemical Oxidation					
Chemical Oxidation Injection Wells, Installed	82	each	$ 2,560	$ 209,920	
Permanganate Injection System	1	ls	$ 75,000	$ 75,000	
First Injection Permanganate Chemicals	145,200	lb	$ 1.50	$ 217,800	
Second Injection Permanganate Chemicals	72,600	lb	$ 1.50	$ 108,900	
Subtotal Chemical Oxidation					$ 611,620
Soil Vapor Extraction and Dual-Phase Extraction System					
SVE Wells, Installed	53	each	$ 3,500	$ 185,500	
DPE Wells, Installed	6	each	$ 4,000	$ 24,000	
Trenches for SVE/DPE Including Piping, Fittings and Backfill	1	ls	$ 180,000	$ 180,000	
Total Fluids Pumps for DPE	6	each	$ 2,800	$ 16,800	
Remediation Equipment, Enclosure, and Controls	1	ls	$ 180,000	$ 180,000	
Electrical and Control Installation	1	ls	$ 20,000	$ 20,000	
Transportation of Trench Cuttings	250	ton	$ 25	$ 6,250	
Disposal of Trench Cuttings	250	ton	$ 38	$ 9,500	
Subtotal SVE and DPE System					$ 622,050
Permeable Reactive Barrier					
Mobilization for 48" Ø caisson rig	1	ls	$ 5,000	$ 5,000	
Drilling Services (approximately 56 4-foot Ø borings to 48 feet bgs)	2,690	lf	$ 100	$ 269,000	
Handling of Soil	1,880	ton	$ 20	$ 37,600	
Transportation and Disposal of TCE-impacted Soil (Dangerous Waste) to Subtitle C Landfill	620	ton	$ 186	$ 115,320	
Transportation and Disposal of TCE-impacted Soil (Non-listed or Contained-out) to Subtitle D Landfill	1,260	ton	$ 90	$ 113,400	
Clean structural fill for drilled caissons	2,040	ton	$ 35	$ 71,400	
Zero-valent Iron for Permeable Reactive Barrier	590	ton	$ 1,050	$ 619,500	
Sand	280	ton	$ 15	$ 4,200	
Pea Gravel	130	ton	$ 15	$ 1,950	
Iron Shipping	590	ton	$ 100	$ 59,000	
Sand Hauling	280	ton	$ 10	$ 2,800	
Pea Gravel Hauling	130	ton	$ 10	$ 1,300	
Subtotal Permeable Reactive Barrier					$ 1,300,470
Subtotal Direct Capital					$ 2,811,790
Indirect Capital (as percentages of Direct Capital)					
Design, Permitting, and Work Plans (9%)				$ 253,070	
Mobilization (1%)				$ 28,120	
Professional Labor for Construction Oversight (12%)				$ 337,420	
Field Equipment and Supplies (1%)				$ 28,120	
Laboratory Testing (Field Verification and Waste Profiling) (1%)				$ 28,120	
Site Restoration and Demobilization (1%)				$ 28,120	
Regulatory Reporting (4%)				$ 112,480	
Subtotal Indirect Capital					$ 815,450
Total Capital					$ 3,627,240

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Table 5
Cleanup Action Alternative 3
Feasibility Level Cost Estimate
ISCO for CVOCs in Groundwater
DPE for DRPH in Groundwater
SVE for CVOCs in Soil
Excavation for DRPH in Soil

FUTURE O&M AND OTHER DIRECT COST ITEMS[1]	ANNUAL COST[2]	PRESENT WORTH OF ANNUAL AND FUTURE CAPITAL COST	
	Discount Rate = 0.1%		n (years)
Quarterly Groundwater Monitoring (assume 20 wells)	$ 56,000	$ 556,900	10
Monthly O&M of SVE/DPE System	$ 90,000	$ 617,300	7
Post-remediation Confirmation Soil Sampling		$ 25,000	
Decommission Monitoring wells (20 wells @ $350 each)		$ 7,000	
Decommission edible oil injection wells (81 wells @ $350 each)		$ 28,350	
Decommission SVE and DPE wells (59 wells @ $350 each)		$ 20,650	
Decommission SVE and DPE System		$ 35,000	
Present Worth Cost of Annual and Future Capital Cost			$ 1,290,200
TOTAL PRESENT WORTH COST (Sum of Total Capital and Present Worth of Annual and Future Capital Cost)[3][4][5]			$ 4,917,440

NOTES:

[1]Additional direct costs such as project management, regulatory communications and reporting, and other technical support services not specifically listed are not included in any future annual costs.

[2]Annual cost is year 2013 cost.

[3]This feasibility level cost should not be considered a design cost estimate or guaranteed cost.

[4]Excludes electrical costs for all systems.

[5]Cost rounded up to nearest $1,000.

bgs = below ground surface
DPE = dual-phase extraction
lb = pound
lf = linear feet
ls = lump sum
n = number of years of compliance monitoring and O&M
O&M = operation and maintenance
PCS = petroleum-contaminated soil
QTY = quantity
sf = square feet
SVE = soil vapor extraction
TCE = trichloroethene
ton = number of bank cubic yards x 1.5 ton/bank cubic yard

Table 6
Cleanup Action Alternative 4
Feasibility Level Cost Estimate
ERH for CVOCs in Groundwater
DPE for DRPH in Groundwater
SVE for CVOCs in Soil
Excavation for DRPH in Soil

PRESENT CAPITAL COST ITEM	QTY	UNIT	UNIT PRICE	COST	TOTALS
Direct Capital					
Remedial Excavation					
Site Controls (fencing)	500	lf	$ 7.50	$ 3,750	
Well Decommissioning	3	each	$ 350	$ 1,050	
Excavation, Handling, and Segregation of PCS	2,550	ton	$ 24	$ 61,200	
Transportation of PCS	2,550	ton	$ 25	$ 63,750	
Disposal of PCS at Permitted Facility	2,550	ton	$ 38	$ 96,900	
Clean Backfill and Compaction	2,550	ton	$ 20	$ 51,000	
Subtotal Remedial Excavation					$ 277,650
Electrical Resistive Heating					
Electrode Materials Mobilization	1	each	$ 589,000	$ 589,000	
ERH Well Drilling (4-inch Ø wells to 32 feet)	72	each	$ 4,000	$ 288,000	
Handling of TCE-impacted Soil	30	tons	$ 20	$ 600	
Transportation and Disposal of TCE-impacted Soil (Dangerous Waste) to Subtitle C Landfill	30	tons	$ 186	$ 5,580	
Subsurface Installation	1	ls	$ 139,000	$ 139,000	
Surface Installation and Start-up	1	ls	$ 389,000	$ 389,000	
Demobilization and Final Report	1	ls	$ 37,000	$ 37,000	
Electrical Permit and Utility Connection to PCU	1	ls	$ 35,000	$ 35,000	
Electrical Energy Usage	1	ls	$ 1,000,000	$ 1,000,000	
Vapor and Condensate Recovery, Treatment, and Disposal	1	ls	$ 150,000	$ 150,000	
Other Operational Costs	1	ls	$ 33,000	$ 33,000	
Electrical Energy Usage: Contingency 25%	1	ls	$ 250,000	$ 250,000	
Subtotal Electrical Resistive Heating					$ 2,916,180
Soil Vapor Extraction and Dual-Phase Extraction System					
SVE Wells, Installed	19	each	$ 3,500	$ 66,500	
DPE Wells, Installed	5	each	$ 4,000	$ 20,000	
Trenches for SVE/DPE Including piping, Fittings, and Backfill	1	ls	$ 90,000	$ 90,000	
Total Fluids Pumps for DPE	5	each	$ 2,800	$ 14,000	
Remediation Equipment, Enclosure, and Controls	1	ls	$ 150,000	$ 150,000	
Electrical and Control Installation	1	ls	$ 20,000	$ 20,000	
Transportation of Trench Cuttings	250	ton	$ 25	$ 6,250	
Disposal of Trench Cuttings	250	ton	$ 38	$ 9,500	
Subtotal SVE and DPE System					$ 376,250
Permeable Reactive Barrier					
Mobilization for 48" Ø caisson rig	1	ls	$ 5,000	$ 5,000	
Drilling Services (approximately 56 4-foot Ø borings to 48 feet bgs)	2,690	lf	$ 100	$ 269,000	
Handling of Soil	1,880	ton	$ 20	$ 37,600	
Transportation and Disposal of TCE-impacted Soil (Dangerous Waste) to Subtitle C Landfill	620	ton	$ 186	$ 115,320	
Transportation and Disposal of TCE-impacted Soil (contained-out) to Subtitle D Landfill	1,260	ton	$ 90	$ 113,400	
Clean structural fill for drilled caissons	2,040	ton	$ 35	$ 71,400	
Zero-valent Iron for Permeable Reactive Barrier	590	ton	$ 1,050	$ 619,500	
Sand	280	ton	$ 15	$ 4,200	
Pea Gravel	130	ton	$ 15	$ 1,950	
Iron Shipping	590	ton	$ 100	$ 59,000	
Sand Hauling	280	ton	$ 10	$ 2,800	
Pea Gravel Hauling	130	ton	$ 10	$ 1,300	
Subtotal Permeable Reactive Barrier					$ 1,300,470
Subtotal Direct Capital					$ 4,870,550
Indirect Capital (as percentages of Direct Capital)					
Design, Permitting, and Work Plans (6%)				$ 292,240	
Mobilization (1%)				$ 48,710	
Professional Labor for Construction Oversight (7%)				$ 340,940	
Field Equipment and Supplies (1%)				$ 48,710	
Laboratory Testing (field verification and waste profiling) (1%)				$ 48,710	
Site Restoration and Demobilization (1%)				$ 48,710	
Regulatory Reporting (3%)				$ 146,120	
Subtotal Indirect Capital					$ 974,140
Total Capital					$ 5,844,690

Table 6
Cleanup Action Alternative 4
Feasibility Level Cost Estimate
ERH for CVOCs in Groundwater
DPE for DRPH in Groundwater
SVE for CVOCs in Soil
Excavation for DRPH in Soil

FUTURE O&M AND OTHER DIRECT COST ITEMS[1]	ANNUAL COST[2]	PRESENT WORTH OF ANNUAL AND FUTURE CAPITAL COST		
	Discount Rate =	-0.2%		n (years)
Quarterly Groundwater Monitoring (assume 20 wells)	$ 56,000		$ 452,100	8
Monthly O&M of SVE/DPE System	$ 80,000		$ 565,800	7
Post-remediation Confirmation Soil Sampling			$ 25,000	
Decommission Monitoring wells (20 wells @ $350each)			$ 7,000	
Decommission ERH wells (72 wells @ $350 each)			$ 25,200	
Decommission SVE and DPE wells (24 wells @ $350 each)			$ 8,400	
Decommission SVE and DPE System			$ 30,000	
Present Worth Cost of Annual and Future Capital Cost				$ 1,113,500
TOTAL PRESENT WORTH COST (Sum of Total Capital and Present Worth of Annual and Future Capital Cost)[3][4][5]				$ 6,958,190

NOTES:

[1]Additional direct costs such as project management, regulatory communications and reporting, and other technical support services not specifically listed are not included in any future annual costs.

[2]Annual cost is year 2013 cost.

[3]This feasibility level cost should not be considered a design cost estimate or guaranteed cost.

[4]Excludes electrical costs for all systems.

[5]Cost rounded up to nearest $1,000.

bgs = below ground surface

DPE = dual-phase extraction

ERH = electrical resistive heating

lf = linear feet

ls = lump sum

n = number of years of compliance monitoring and O&M

O&M = operation and maintenance

PCS = petroleum-contaminated soil

PCU = power control unit

QTY = quantity

SVE = soil vapor extraction

TCE = trichloroethene

ton = number of bank cubic yards x 1.5 ton/bank cubic yard

Table 7
Cleanup Action Alternatives Summary
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

Cleanup Action Alternatives	Summary Description	Washington State Department of Ecology Evaluation Criteria/Relative Ranking (1 = Low 10 = High)						Ranking Score[1]	Estimated Present Worth Cost (x$1,000)
		Protectiveness	Permanence	Effectiveness over the Long Term	Management of Short-Term Risks	Technical and Administrative Implementability	Consideration of Public Concerns		
Cleanup Action Alternative 1, Excavation with Off-Site Land Disposal	Remove sources of trichloroethene- and petroleum-contaminated soil by excavating soil to a maximum depth of 32 feet bgs. Import clean fill and backfill and compact to initial grade. Remediate groundwater by monitored natural attenuation.	10	9	9	5	5	N/A	**38**	7,622
Cleanup Action Alternative 2, Reductive Dechlorination for CVOCs in Groundwater; DPE for TPH in Groundwater; SVE for GRPH in Soil; and Excavation for DRPH in Soil	Inject edible oil substrate for reductive dechlorination of chlorinated hydrocarbons in the saturated zone. Provide SVE to remediate volatile chlorinated and GRPH soil contamination. Perform DPE to remediate TPH in groundwater. Excavate DRPH in soil for offsite disposal.	6	6	7	7	8	N/A	**34**	4,660
Cleanup Action Alternative 3, Chemical Oxidation for CVOCs in Groundwater; DPE for TPH in Groundwater SVE for GRPH in Soil; Excavation for DRPH in Soil	Inject permanganate to chemically oxidize chlorinated hydrocarbons in the saturated zone. Provide SVE to remediate volatile chlorinated and GRPH soil contamination. Perform DPE to remediate TPH in groundwater. Excavate DRPH in soil for off-site disposal.	6	6	8	5	8	N/A	**33**	4,917
Cleanup Action Alternative 4, ERH for CVOCs in Groundwater, DPE for TPH in Groundwater, SVE for GRPH in Soil, Excavation for DRPH in Soil	Use electrical resistance heating to facilitate the transfer of dissolved-phase chlorinated hydrocarbons and GRPH in groundwater to the vapor phase. Recover vapors in heated and unheated areas using SVE. Install DPE wells to remediate DRPH in groundwater. Excavate DRPH in soil for off-site disposal.	9	9	8	5	5	N/A	**36**	6,958

NOTES:

[1] Ranking score is the sum of the individual criterion ranking scores.

bgs = below ground surface

CVOC = chlorinated volatile organic compound

DPE = dual-phase extraction

DRPH = diesel-range petroleum hydrocarbons

ERH = electrical resistive heating

GRPH = gasoline-range petroleum hydrocarbons

N/A = not applicable

SVE = soil vapor extraction

TPH = total petroleum hydrocarbons

CHARTS

Chart 1
Cost and Relative Ranking of Cleanup Action Alternatives
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

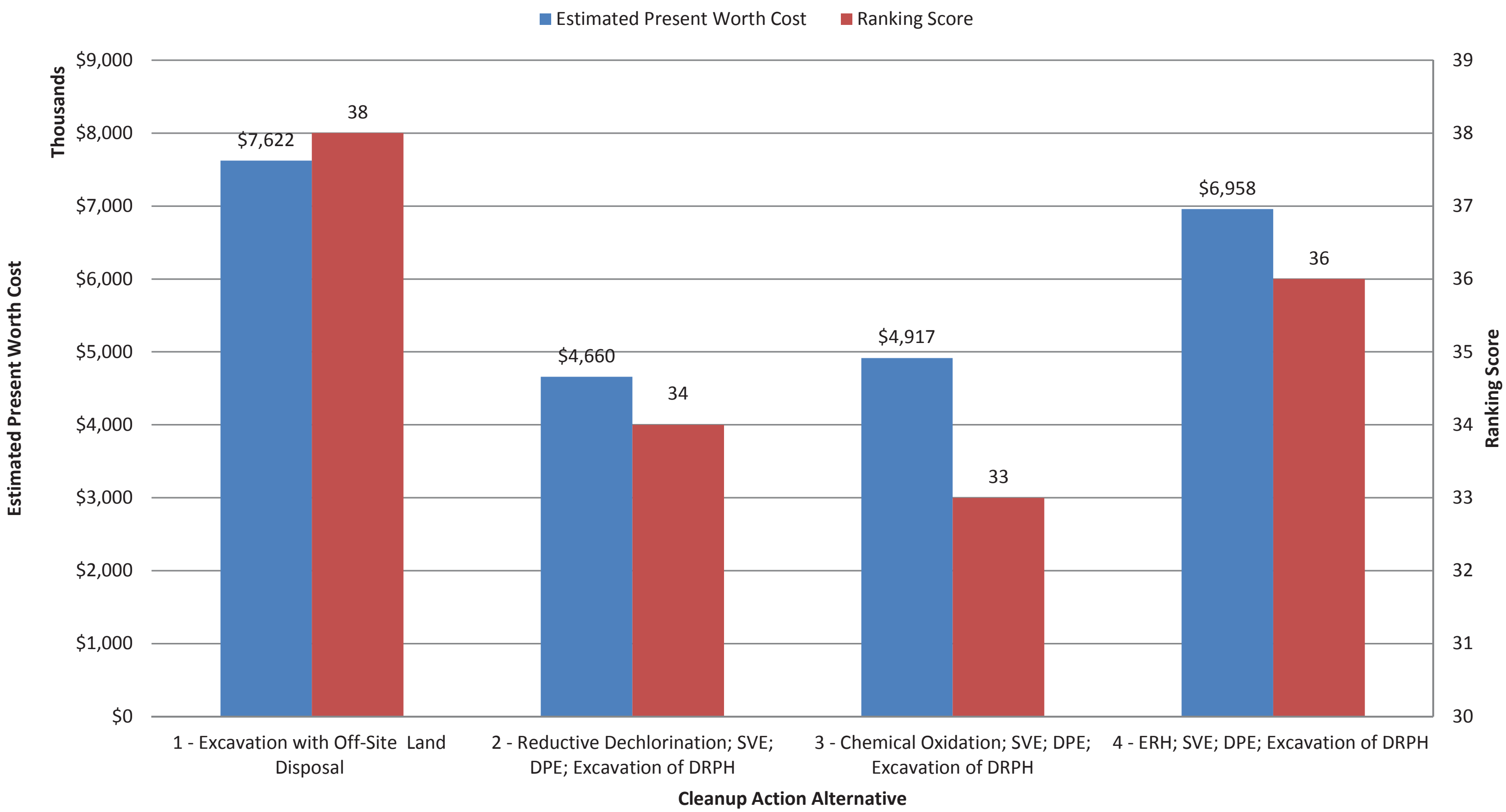
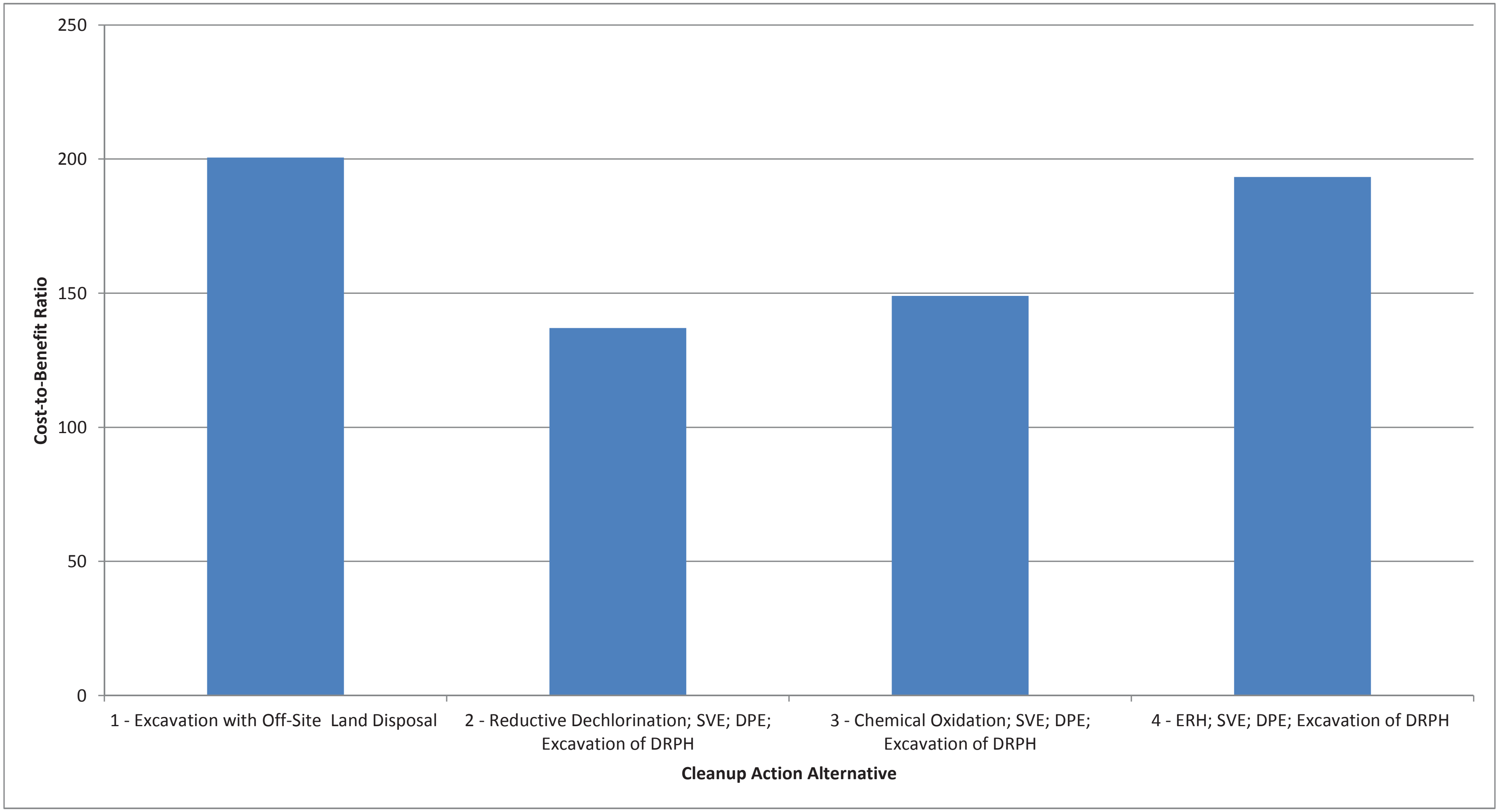


Chart 2
Cost and Relative Ranking of Cleanup Action Alternatives
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington



APPENDIX A
AQUIFER TESTING DATA SUMMARY

Slug Testing Field Methods and Data Analysis

SoundEarth Strategies

Table A1
Slug Testing - Field Methods and Data Analysis
TOC Holdings Co. Facility No. 01-600
2737 W. Commodore Way
Seattle, Washington

Date of Test	Well ID[(1)]	Water-Bearing Zone	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Initial DTW (ft btoc)	Screen Submerged	Saturated Screen Length[(2)] (ft)	Estimated K-value[(3)] (cm/sec)	Estimated K-Value[(3)] (ft/day)
ASKO Hydraulic Property									
3/27/2009	01MW44	Shallow	15	30	22.63	No	15	1.8E-03	5.1
3/27/2009	01MW44 (Test 2)	Shallow	15	30	22.63	No	15	1.6E-03	4.5
3/26/2009	01MW62	Shallow	24	39	31.16	No	15	1.2E-03	3.4
Bulk Terminal Property									
3/27/2009	01MW03	Shallow	10	25	12.70	No	15	7.1E-04	2.0
8/10/2009	01MW21	Shallow	5	22.5	7.49	No	15	3.0E-05	0.085
3/27/2009	01MW38	Shallow	7.5	22.5	7.94	No	15	1.8E-03	5.1
3/27/2009	01MW40	Shallow	7	22	15.16	No	15	1.3E-03	3.7
3/27/2009	01MW59	Shallow	13	29	14.37	No	15.5	9.1E-04	2.6
East Waterfront Property									
3/26/2009	02MW14	Shallow	4	15	10.10	No	11	2.0E-03	5.7
Geometric mean for shallow water-bearing zone								8.8E-04	2.5
ASKO Hydraulic Property									
3/26/2009	01MW57	Intermediate	35.5	41	26.75	Yes	5.5	1.0E-03	2.8
3/26/2009	01MW65	Deep	52	62	34.35	Yes	10	2.2E-03	6.2

NOTES:

Testing procedure used was Rising Head.

Analytical Method used was Bouwer and Rice, 1976.

Bouwer 1989. The Bouwer and Rice Slug Test - An Update. *Groundwater* 27 no 3: 304-309.

[(1)] All wells are 2-inch diameter, with 8.25-inch diameter sandpacks.

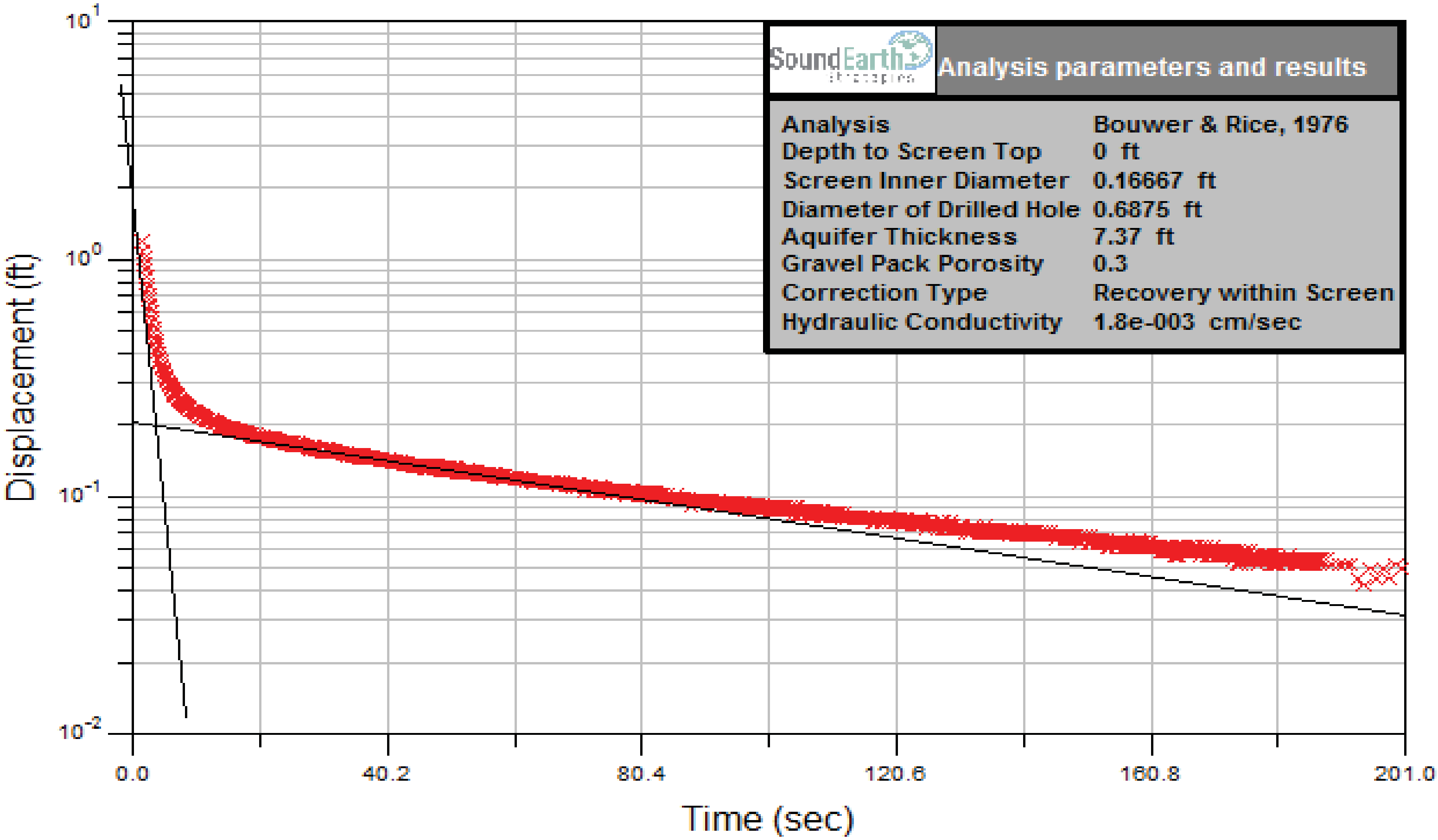
[(2)] All wells were assumed to be fully penetrating (Aquifer thickness=length of saturated screen). For the 01MW65 and 01MW57, the screened interval fully penetrates a sand layer bounded above and below by silt.

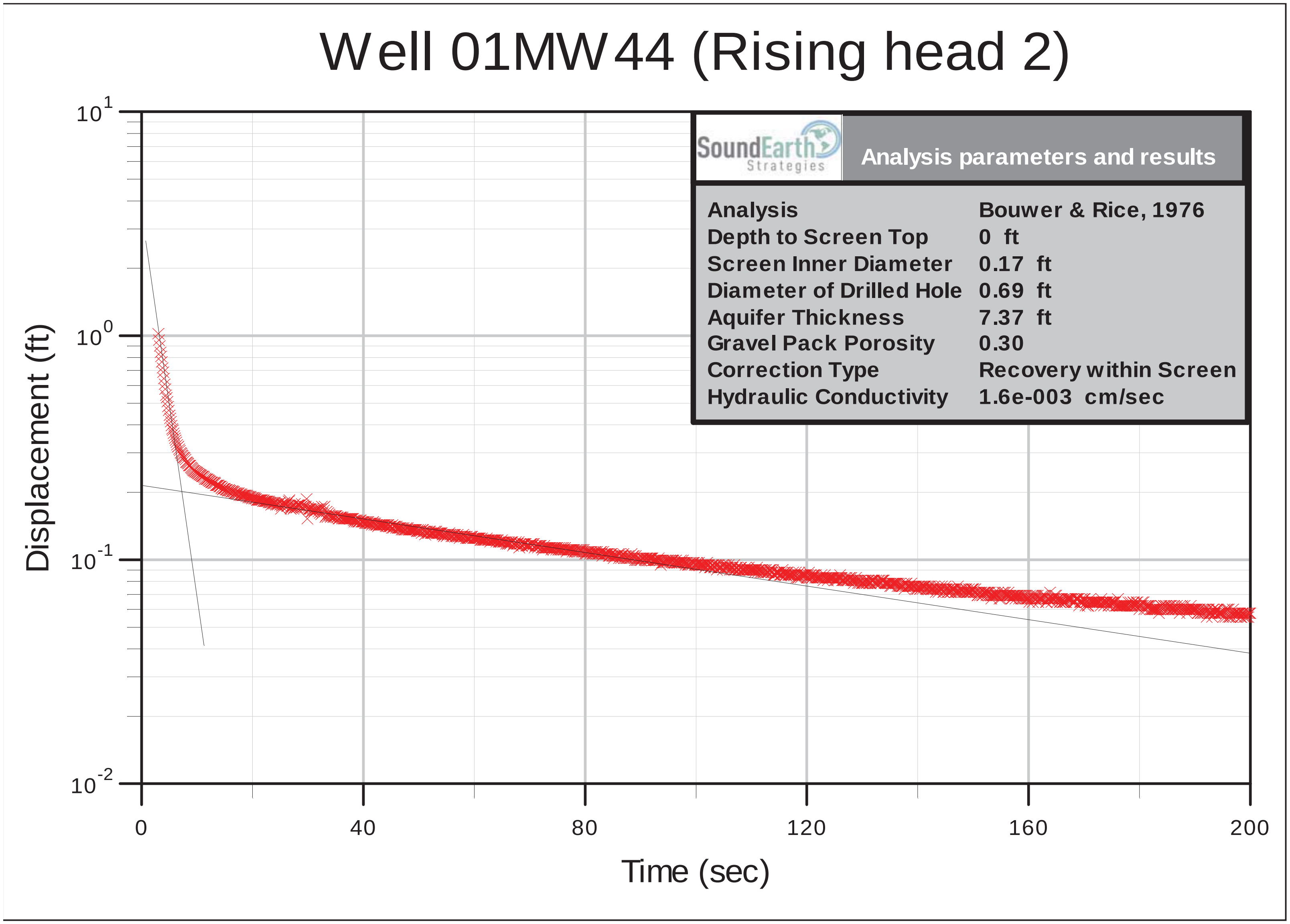
[(3)] For wells screened across the water table, the sand-pack recovery correction in the Bouwer and Rice analysis was used. Following Bouwer (1989), the first semi-log linear slope in the recovery data was assumed to represent sand pack drainage, and the immediately following curved portion of the data was interpreted to represent an intermediate transition into drainage from native material. The subsequent middle-time semi-log linear slope in the recovery data was used to estimate aquifer hydraulic conductivity. For wells 01MW65 and 01MW57 (submerged screens), the first semi-log slope was used to estimate hydraulic conductivity.

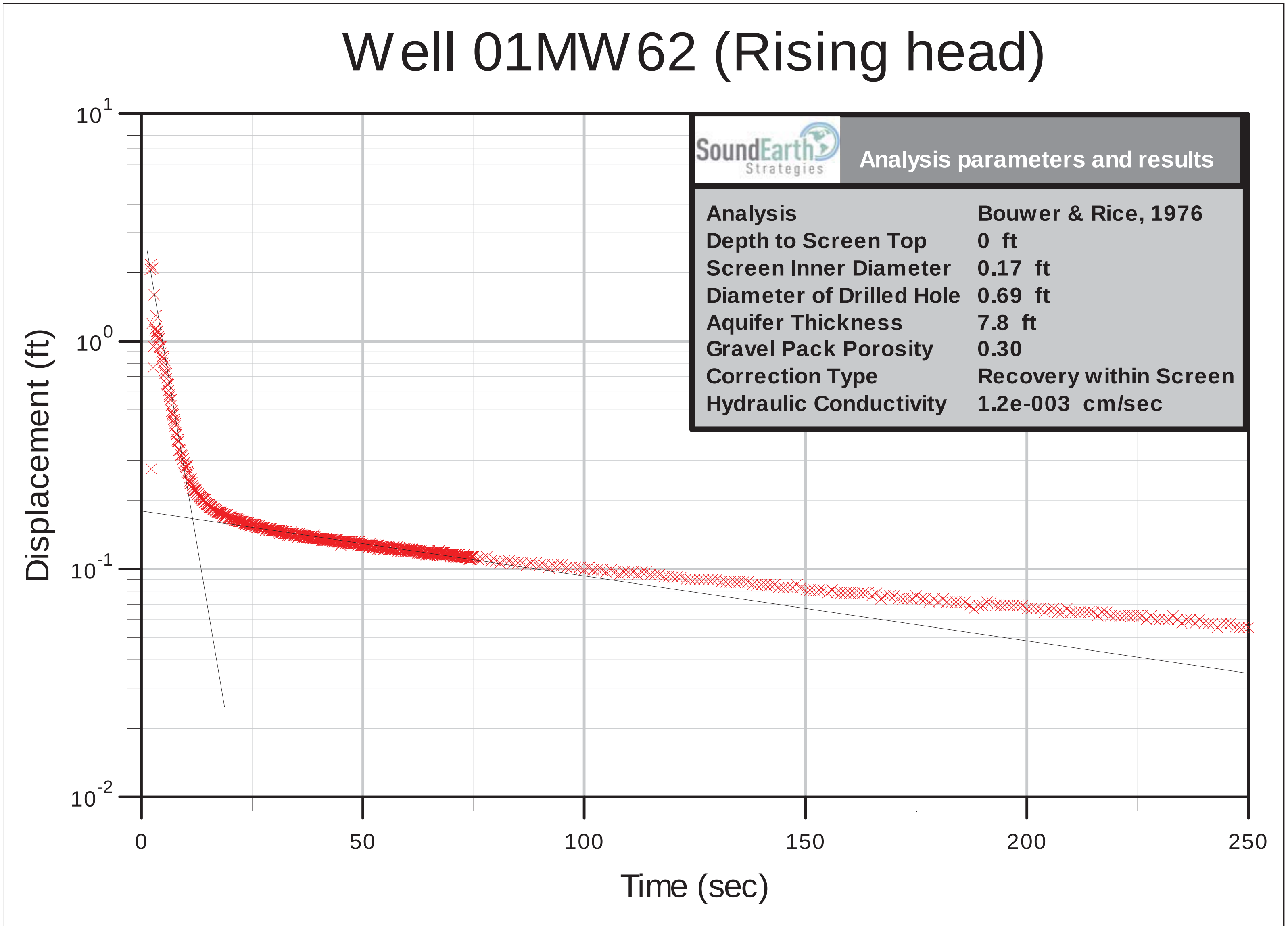
bgs = below ground surface
btoc = below top of casing
cm/sec = centimeters per second
DTW = depth to water
K = hydraulic conductivity
ft = feet
ft/day = feet per day

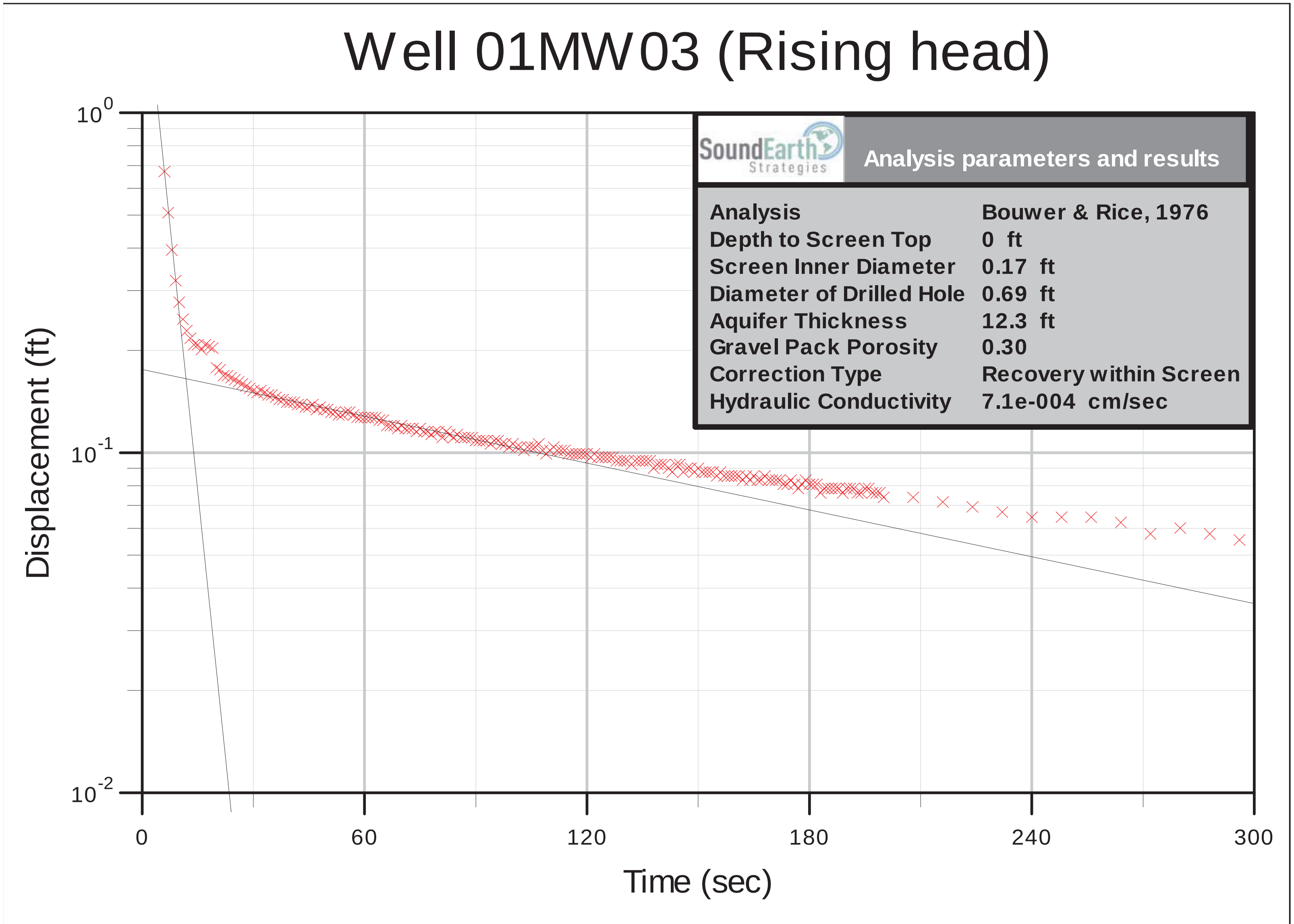
Slug Testing - Field Methods and Data Analysis
TOC Holdings Co. Facility No. 01-600
2737 W. Commodore Way
Seattle, Washington

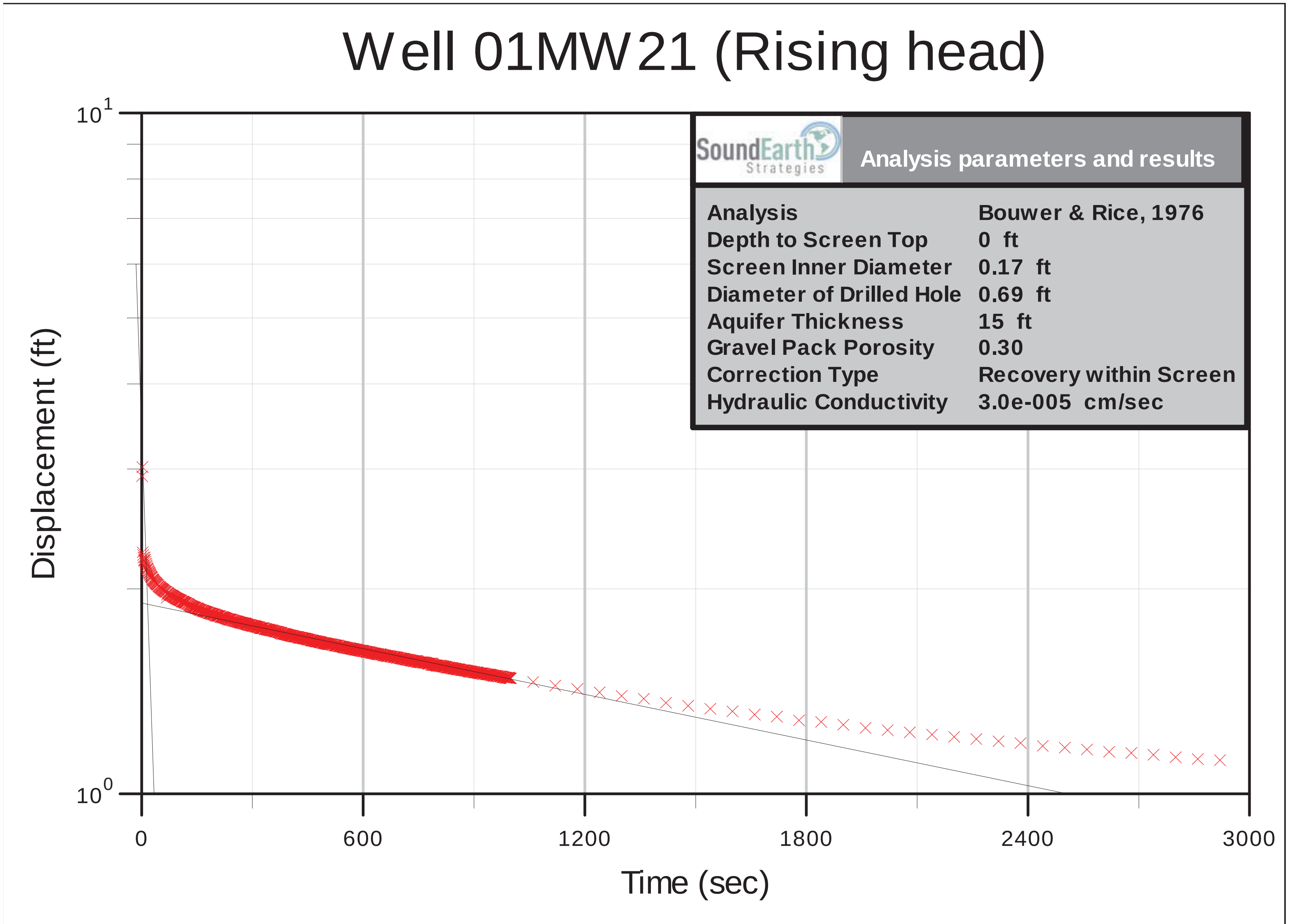
01MW44_Rising

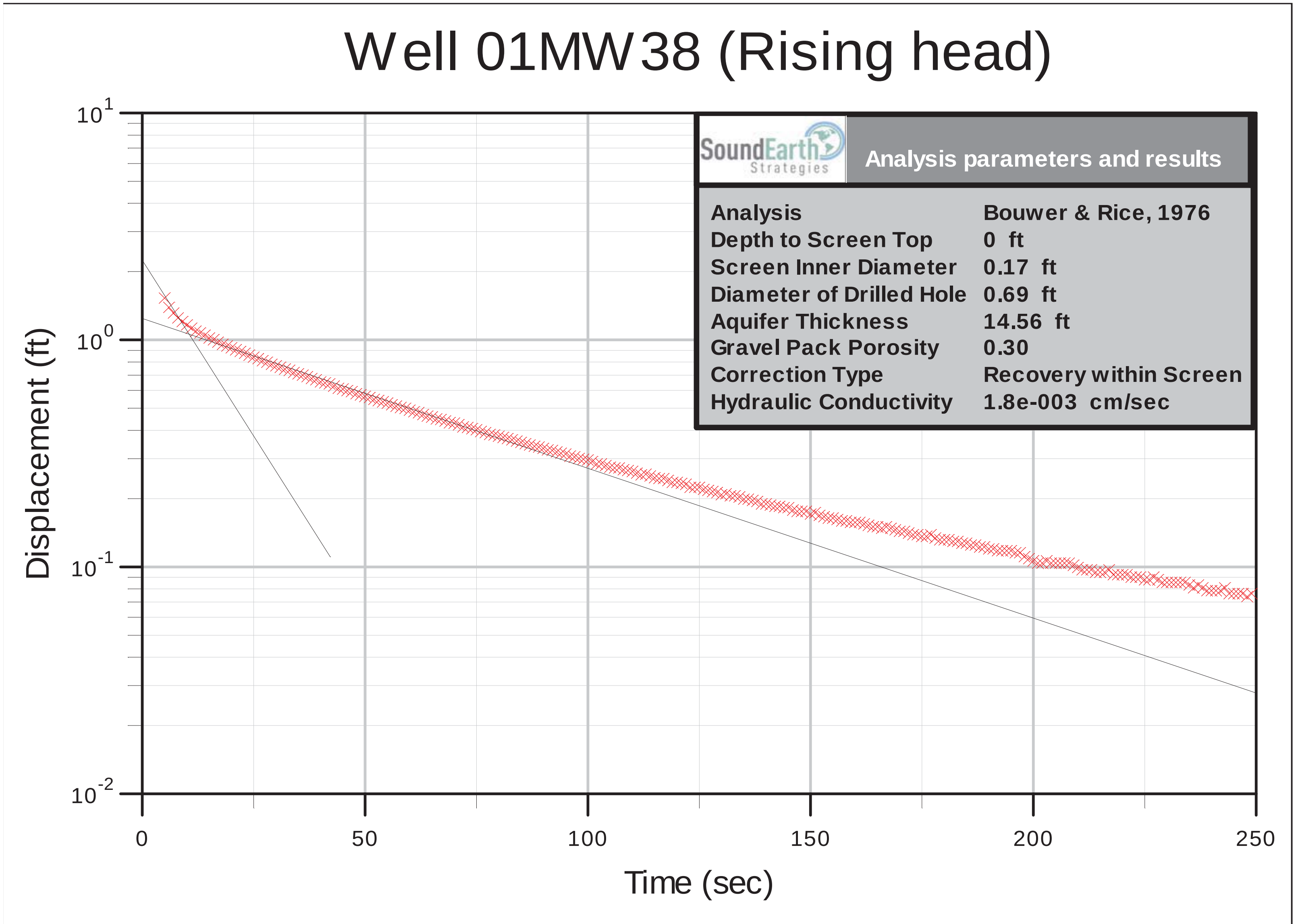


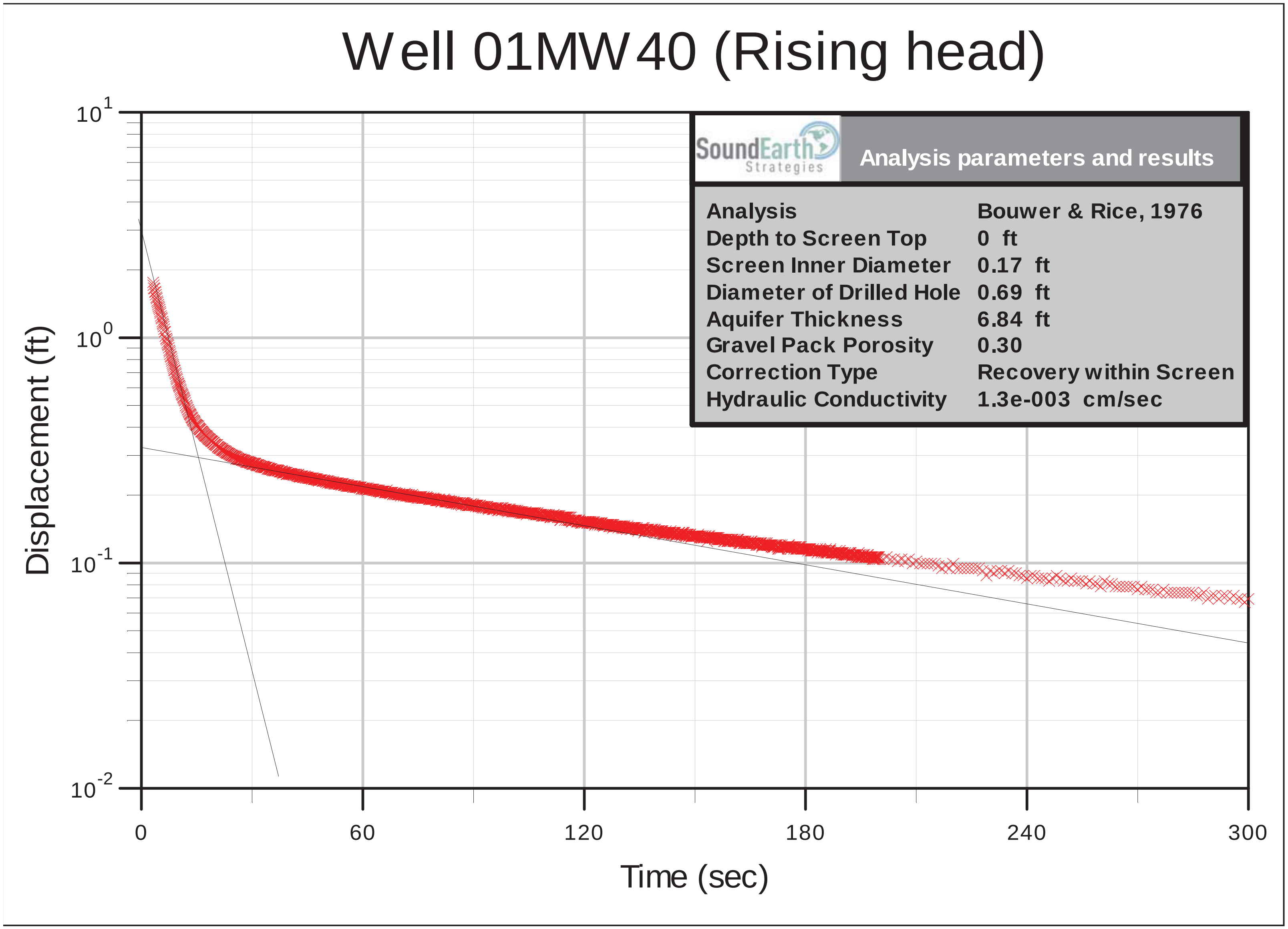

Well 01MW44 (Rising head 2)
Analysis parameters and results
Analysis Bouwer & Rice, 1976
Depth to Screen Top 0 ft
Screen Inner Diameter 0.17 ft
Diameter of Drilled Hole 0.69 ft
Aquifer Thickness 7.37 ft
Gravel Pack Porosity 0.30
Correction Type Recovery within Screen
Hydraulic Conductivity 1.6e-003 cm/sec
Displacement (ft)
Time (sec)

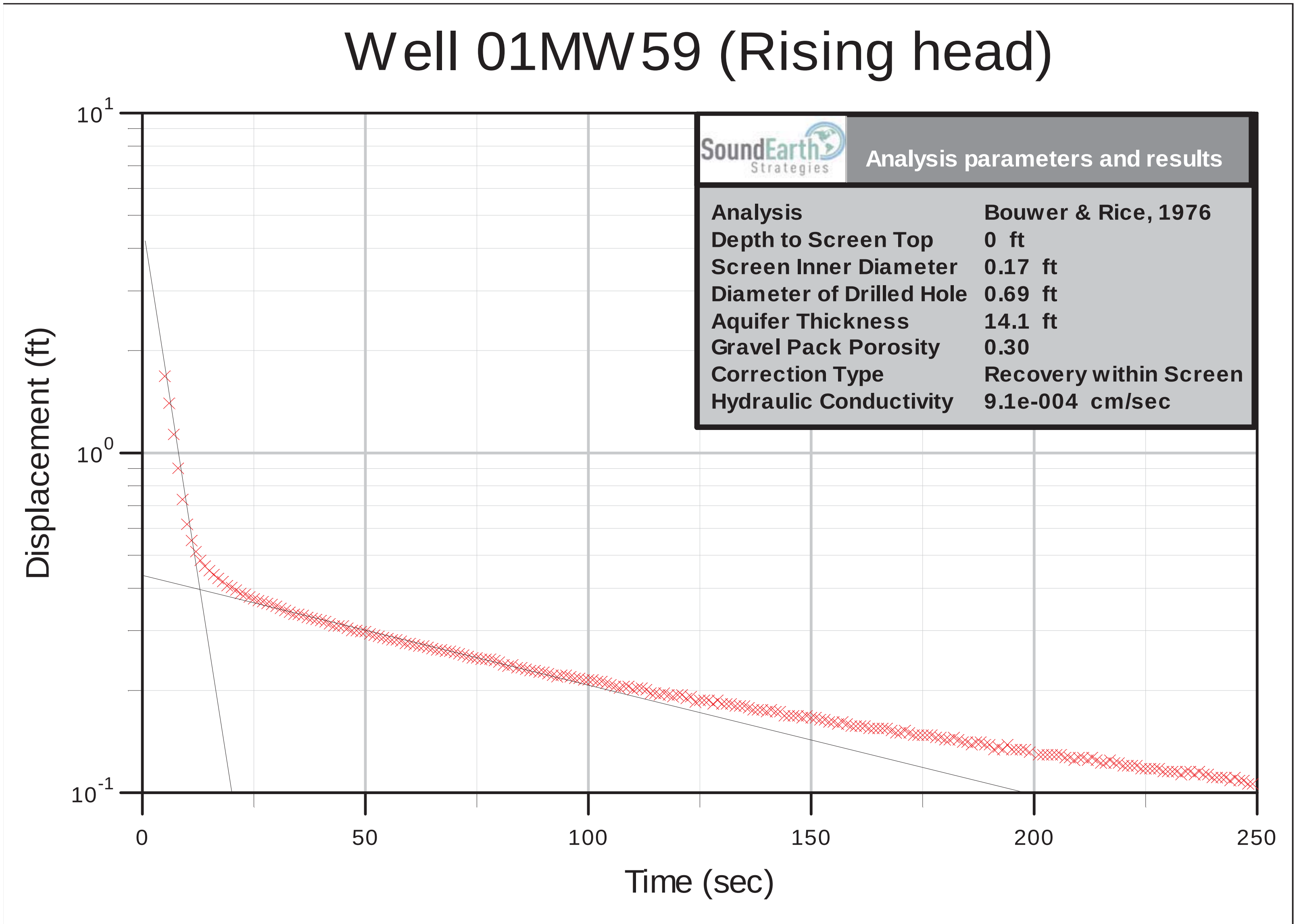

Well 01MW62 (Rising head)
Analysis parameters and results
Analysis Bouwer & Rice, 1976
Depth to Screen Top 0 ft
Screen Inner Diameter 0.17 ft
Diameter of Drilled Hole 0.69 ft
Aquifer Thickness 7.8 ft
Gravel Pack Porosity 0.30
Correction Type Recovery within Screen
Hydraulic Conductivity 1.2e-003 cm/sec
Displacement (ft)
10^{1}
10^{0}
10^{-1}
10^{-2}
0
50
100
150
200
250
Time (sec)


Well 01MW03 (Rising head)
Analysis parameters and results
Analysis Bouwer & Rice, 1976
Depth to Screen Top 0 ft
Screen Inner Diameter 0.17 ft
Diameter of Drilled Hole 0.69 ft
Aquifer Thickness 12.3 ft
Gravel Pack Porosity 0.30
Correction Type Recovery within Screen
Hydraulic Conductivity 7.1e-004 cm/sec
Displacement (ft)
10^{0}
10^{-1}
10^{-2}
Time (sec)
0
60
120
180
240
300

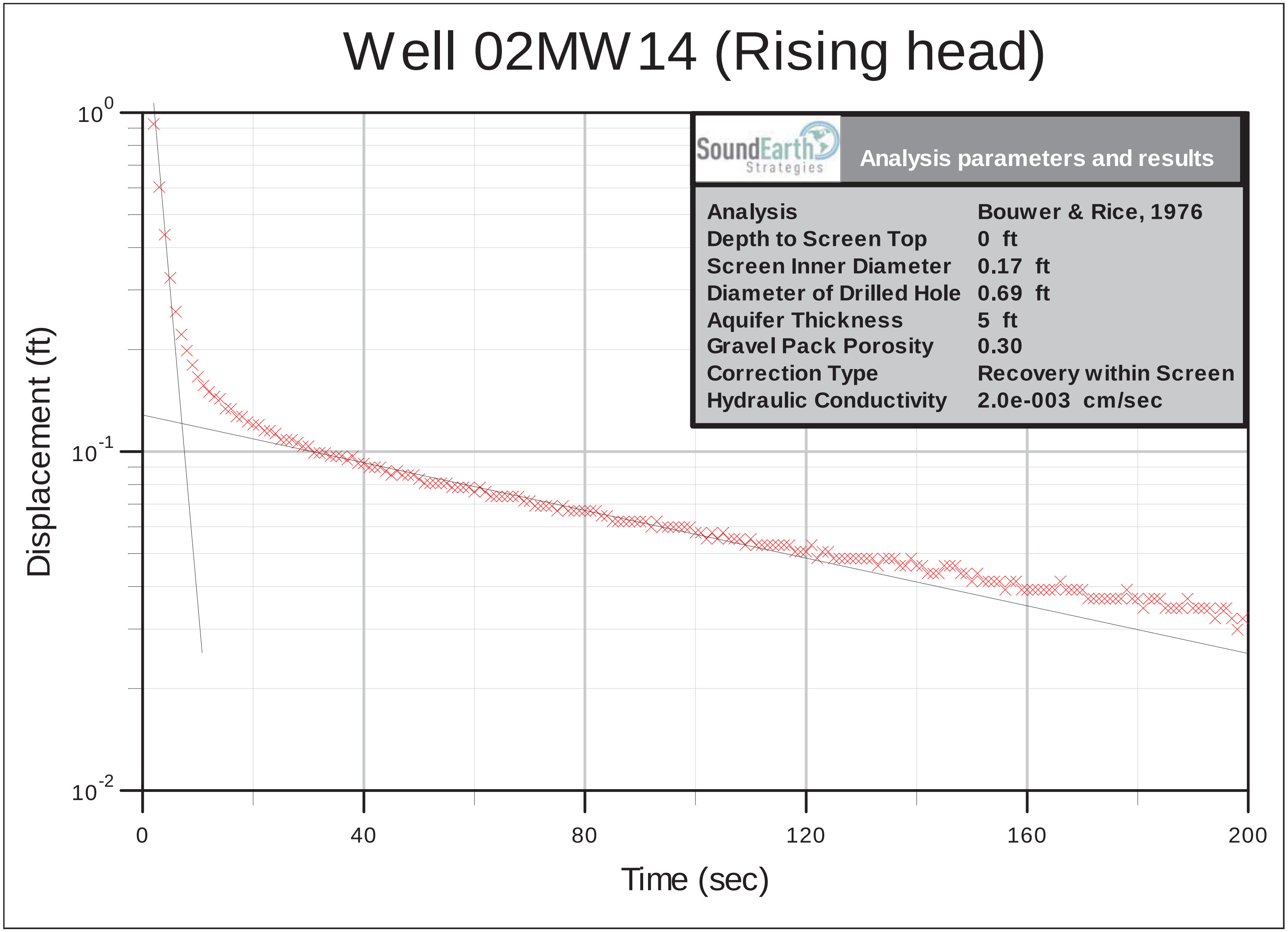

Well 01MW21 (Rising head)
Analysis parameters and results
Analysis Bouwer & Rice, 1976
Depth to Screen Top 0 ft
Screen Inner Diameter 0.17 ft
Diameter of Drilled Hole 0.69 ft
Aquifer Thickness 15 ft
Gravel Pack Porosity 0.30
Correction Type Recovery within Screen
Hydraulic Conductivity 3.0e-005 cm/sec
Displacement (ft)
10^1
10^0
0
600
1200
1800
2400
3000
Time (sec)

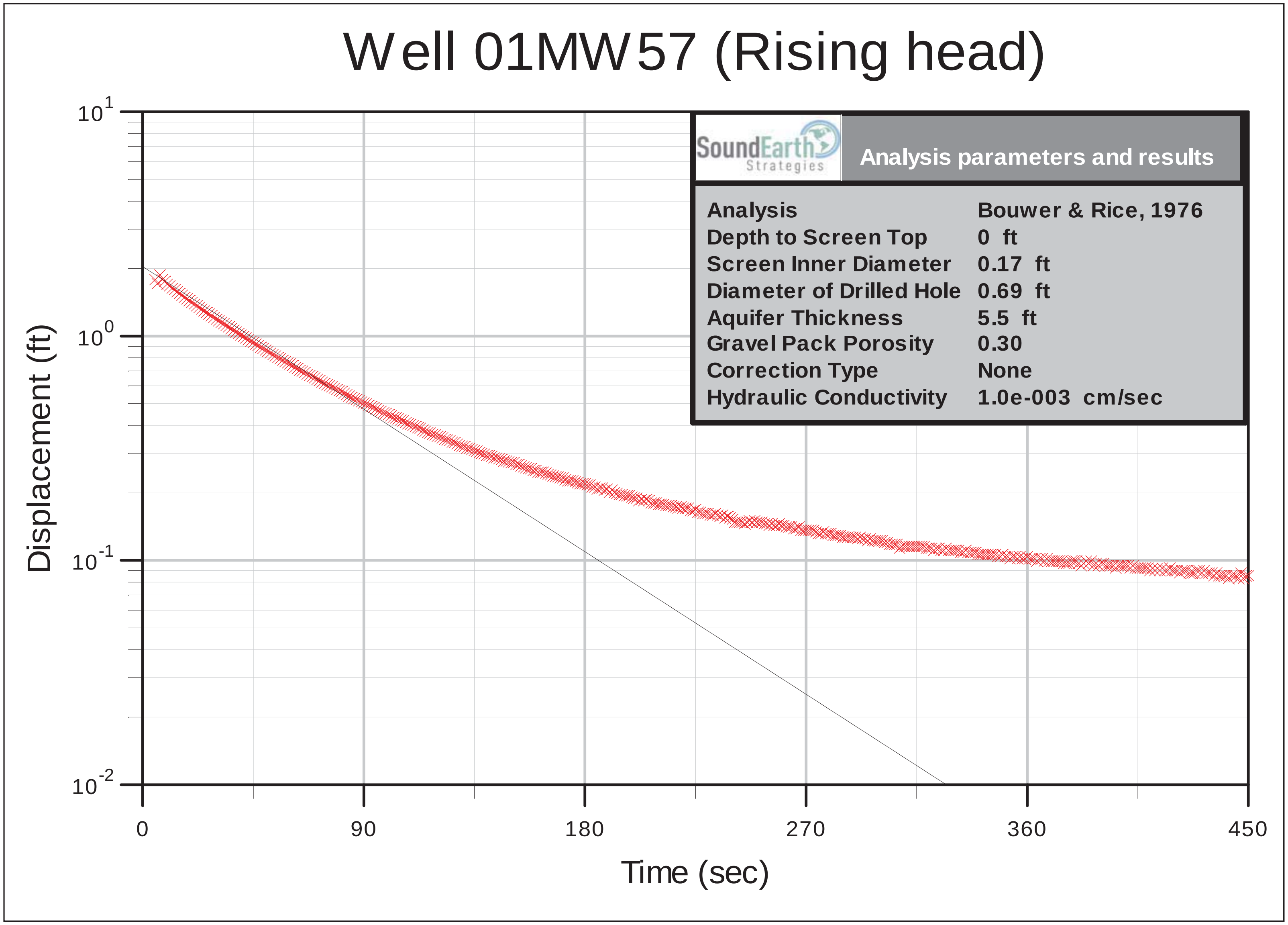

Well 01MW38 (Rising head)
Analysis parameters and results
Analysis Bouwer & Rice, 1976
Depth to Screen Top 0 ft
Screen Inner Diameter 0.17 ft
Diameter of Drilled Hole 0.69 ft
Aquifer Thickness 14.56 ft
Gravel Pack Porosity 0.30
Correction Type Recovery within Screen
Hydraulic Conductivity 1.8e-003 cm/sec
Displacement (ft)
Time (sec)
10^1
10^0
10^-1
10^-2
0
50
100
150
200
250

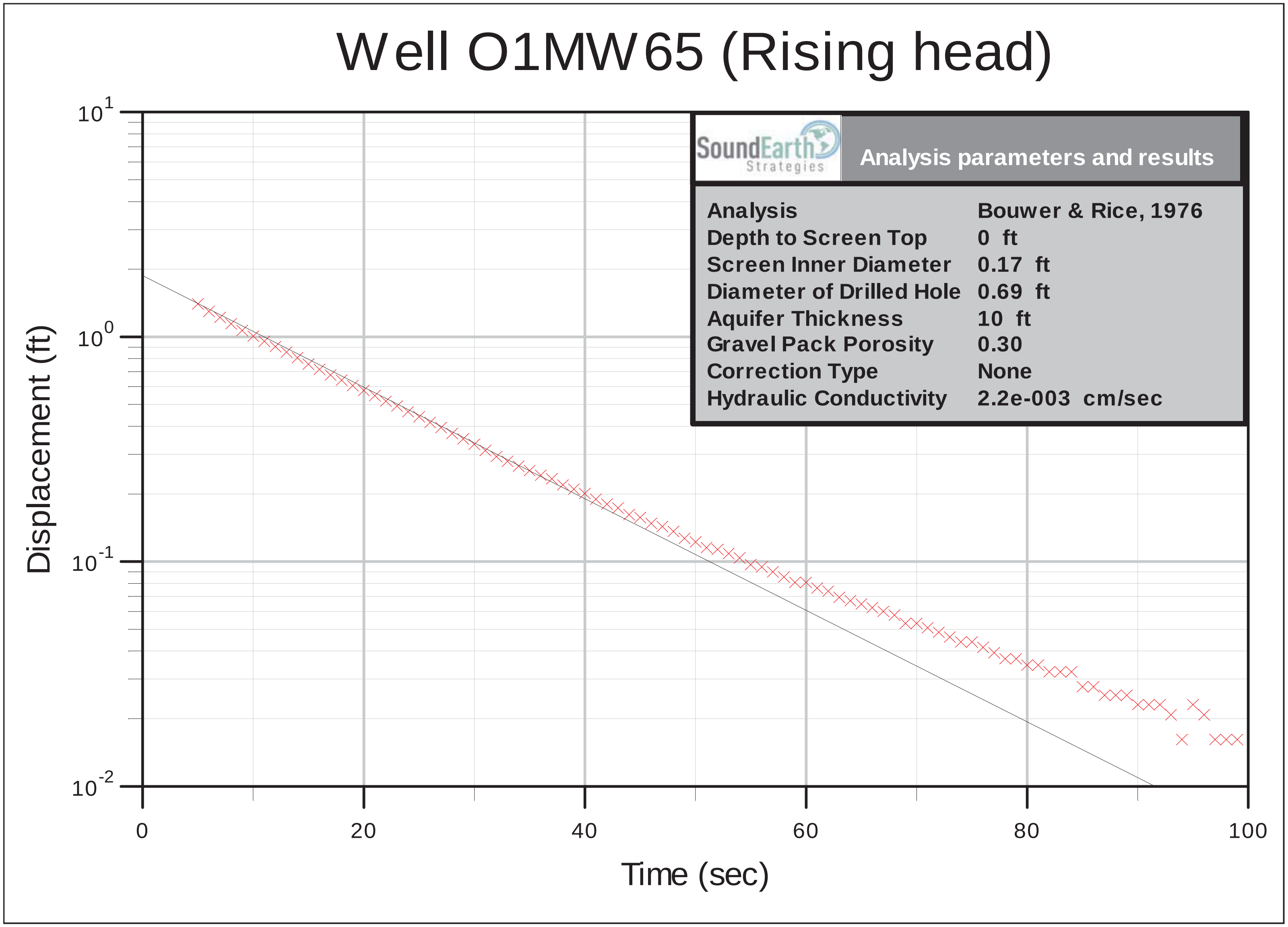

Well 01MW40 (Rising head)
Analysis parameters and results
Analysis Bouwer & Rice, 1976
Depth to Screen Top 0 ft
Screen Inner Diameter 0.17 ft
Diameter of Drilled Hole 0.69 ft
Aquifer Thickness 6.84 ft
Gravel Pack Porosity 0.30
Correction Type Recovery within Screen
Hydraulic Conductivity 1.3e-003 cm/sec
Displacement (ft)
10^1
10^0
10^-1
10^-2
0
60
120
180
240
300
Time (sec)

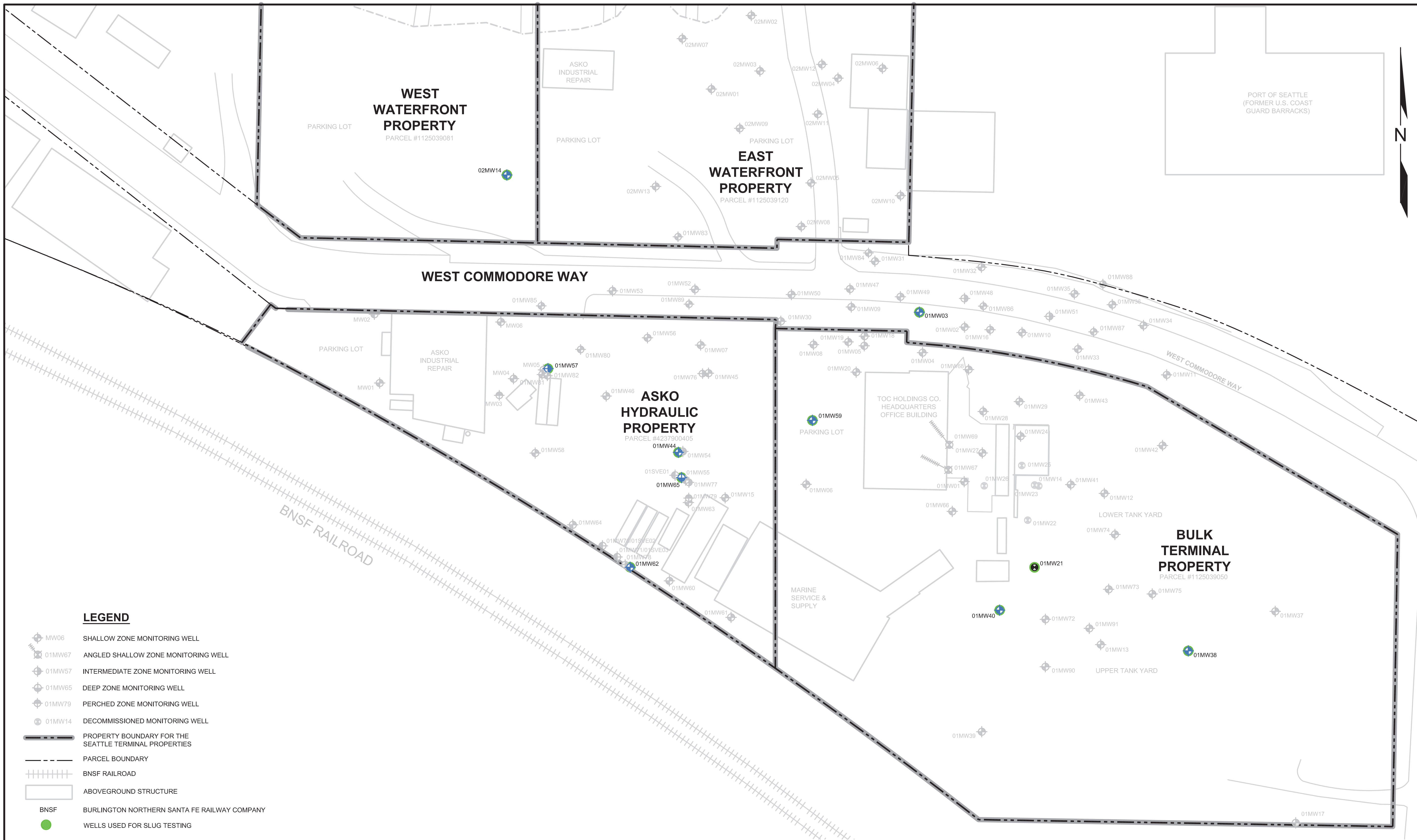

Well 01MW59 (Rising head)
Analysis parameters and results
Analysis Bouwer & Rice, 1976
Depth to Screen Top 0 ft
Screen Inner Diameter 0.17 ft
Diameter of Drilled Hole 0.69 ft
Aquifer Thickness 14.1 ft
Gravel Pack Porosity 0.30
Correction Type Recovery within Screen
Hydraulic Conductivity 9.1e-004 cm/sec
Displacement (ft)
Time (sec)
0
50
100
150
200
250

Slug Testing - Field Methods and Data Analysis
TOC Holdings Co. Facility No. 01-600
2737 W. Commodore Way
Seattle, Washington




Well 01MW57 (Rising head)
Displacement (ft)
10^1
10^0
10^{-1}
10^{-2}
0
90
180
270
360
450
Time (sec)
Analysis parameters and results
Analysis Bouwer & Rice, 1976
Depth to Screen Top 0 ft
Screen Inner Diameter 0.17 ft
Diameter of Drilled Hole 0.69 ft
Aquifer Thickness 5.5 ft
Gravel Pack Porosity 0.30
Correction Type None
Hydraulic Conductivity 1.0e-003 cm/sec


Well O1MW65 (Rising head)
Analysis parameters and results
Analysis Bouwer & Rice, 1976
Depth to Screen Top 0 ft
Screen Inner Diameter 0.17 ft
Diameter of Drilled Hole 0.69 ft
Aquifer Thickness 10 ft
Gravel Pack Porosity 0.30
Correction Type None
Hydraulic Conductivity 2.2e-003 cm/sec
Displacement (ft)
Time (sec)
0
20
40
60
80
100



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DATE: 06/25/13
DRAWN BY: NAC
CHECKED BY: PJK/TSB
CAD FILE: 01-600_2013FS_SLUG

PROJECT NAME: TOC HOLDINGS CO. SEATTLE TERMINAL PROPERTIES
PROJECT NUMBER: 0440-004
STREET ADDRESS: 2737, 2750, 2800, AND 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

0 40 80 160
APPROXIMATE SCALE IN FEET

FIGURE 1 - APPENDIX A
LOCATION OF WELLS USED FOR SLUG TESTING (MARCH & AUGUST 2009)

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\DELIVERABLES\2013\ASKO\FS\APPENDIX A- AQUIFER TESTING DATA SUMMARY\01-600_2013FS_SLUG.DWG 3/20/2014

Radius of Influence Tracer Study Data

Table A2
Radius of Influence Tracer Study- Test Information
TOC Holdings Co. Facility No.01-600
Bulk Terminal Property
2805 West Commodore Way
Seattle, Washington

Well	Distance from Injection Well (feet)	Screen Top (feet below ground surface)	Screen Bottom (feet below ground surface)	Elapsed Time at First Detection of >1% Original Dye Concentration	Volume Injected at First Detection of >1% Tracer (gallons)	Elapsed Time at First Detection of >10% Original Dye Concentration	Volume injected at first detection of >10% tracer (gallons)
01MW81	0.0	19.5	28.5	Not Applicable	Not Applicable	Not Applicable	Not Applicable
01MW82	4.5	19	27	1:53	585	2:08	647.5
MW05	4.0	19	29	2:23	710	3:23	945

Table A3
Radius of Influence Tracer Study- Injection Flow Rate Measurements
TOC Holdings Co. Facility No. 01-600
Bulk Terminal Property
2805 West Commodore Way
Seattle, Washington

Date and Time	Elapsed Time	Volume Injected (gal)	Volume Injected (ft^3)	Change in Tank Volume Between Measurements (gal)	Time Between Measurements (min)	Flow Rate (gpm)	Estimated Radius of Influence (assuming strictly horizontal flow and an effective porosity of 0.2)	Estimated Radius of Influence (assuming strictly horizontal flow and an effective porosity of 0.3)
7/12/11 13:30	0d 00:00	0	--	--	--	--	--	--
7/12/11 13:52	0 d 00:00	0	0	--	--	--	--	--
7/12/11 14:00	0 d 00:08	150	20	150	8	18.7	1.88	1.54
7/12/11 14:15	0 d 00:23	200	27	50	15	3.3	2.17	1.78
7/12/11 14:30	0 d 00:38	--	--	--	--	--	--	--
7/12/11 14:45	0 d 00:53	335	45	135	30	4.5	2.81	2.30
7/12/11 15:00	0 d 01:08	--	--	--	--	--	--	--
7/12/11 15:15	0 d 01:23	430	57	95	30	3.2	3.19	2.60
7/12/11 15:30	0 d 01:38	--	--	--	--	--	--	--
7/12/11 15:45	0 d 01:53	585	78	155	30	5.2	3.72	3.04
7/12/11 16:00	0 d 02:08	--	--	--	--	--	--	--
7/12/11 16:15	0 d 02:23	710	95	125	30	4.2	4.10	3.35
7/12/11 16:45	0 d 02:53	825	110	115	30	3.8	4.42	3.61
7/12/11 17:15	0 d 03:23	945	126	120	30	4.0	4.73	3.86
7/12/11 17:45	0 d 03:53	1,090	146	145	30	4.8	5.08	4.14
7/12/11 18:15	0 d 04:23	1,185	158	95	30	3.2	5.29	4.32
7/12/11 18:45	0 d 04:53	1,305	174	120	30	4.0	5.55	4.54
7/12/11 19:15	0 d 05:23	1,440	193	135	30	4.5	5.83	4.76
7/12/11 19:45	0 d 05:53	1,550	207	110	30	3.7	6.05	4.94
7/12/11 20:15	0 d 06:23	1,675	224	125	30	4.2	6.29	5.14
7/12/11 20:45	0 d 06:53	1,800	241	125	30	4.2	6.52	5.33
7/12/11 21:15	0 d 07:23	1,900	254	100	30	3.3	6.70	5.47
7/12/11 21:45	0 d 07:53	--	--	--	--	--	--	--
7/12/11 22:15	0 d 08:23	2,150	287	250	60	4.2	7.13	5.82
7/12/11 22:45	0 d 08:53	2,290	306	140	30	4.7	7.36	6.01
7/12/11 23:15	0 d 09:23	2,340	313	50	30	1.7	7.44	6.07
7/12/11 23:45	0 d 09:53	--	--	--	--	--	--	--
7/13/11 0:15	0 d 10:23	2,500	334	160	60	2.7	7.69	6.28
Average Flow Rate for Test:						4.0 gpm		

NOTES:

The first flow rate of 18.7 gpm is artificially high, because of storage in the injection system piping and well bore.

-- = not measured

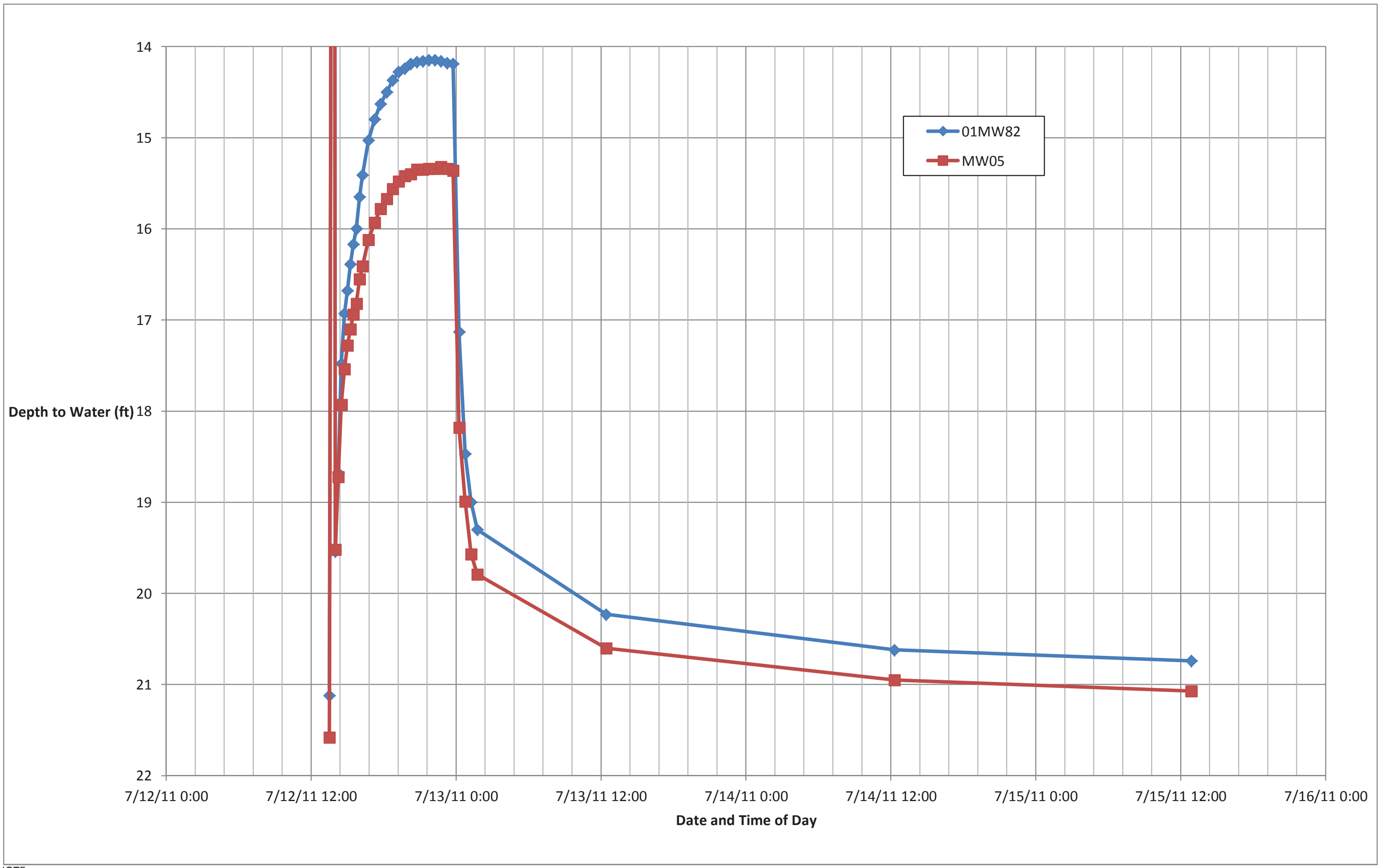
ft^3 = cubic feet

gal = gallons

gpm = gallons per minute

min = minutes

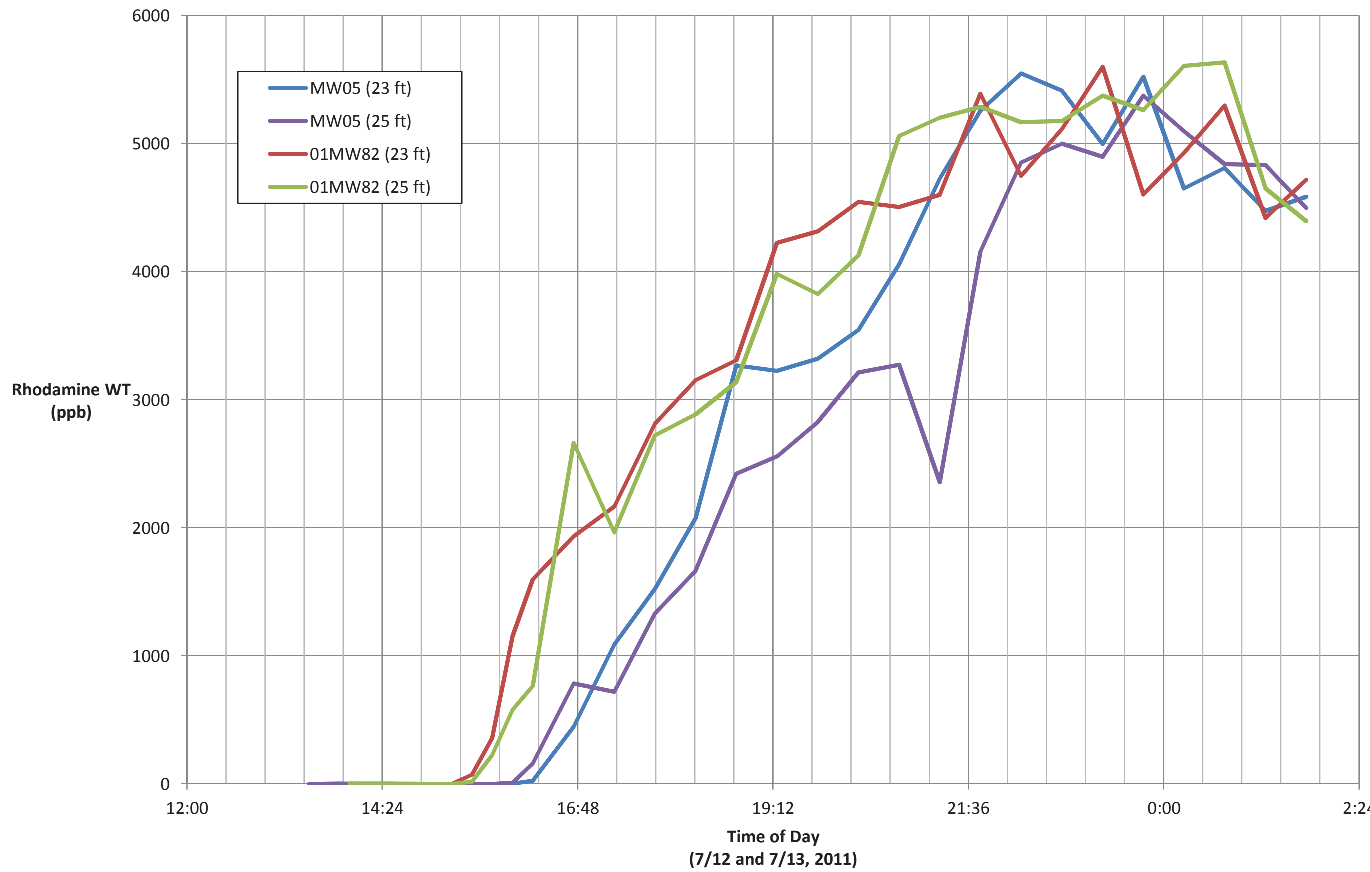
Chart A1
Depth to Water During the Radius of Influence Tracer Study
TOC Holdings Co., Facility No. 01-600
2737 West Commodore Way
Seattle, Washington



NOTE:
ft = feet

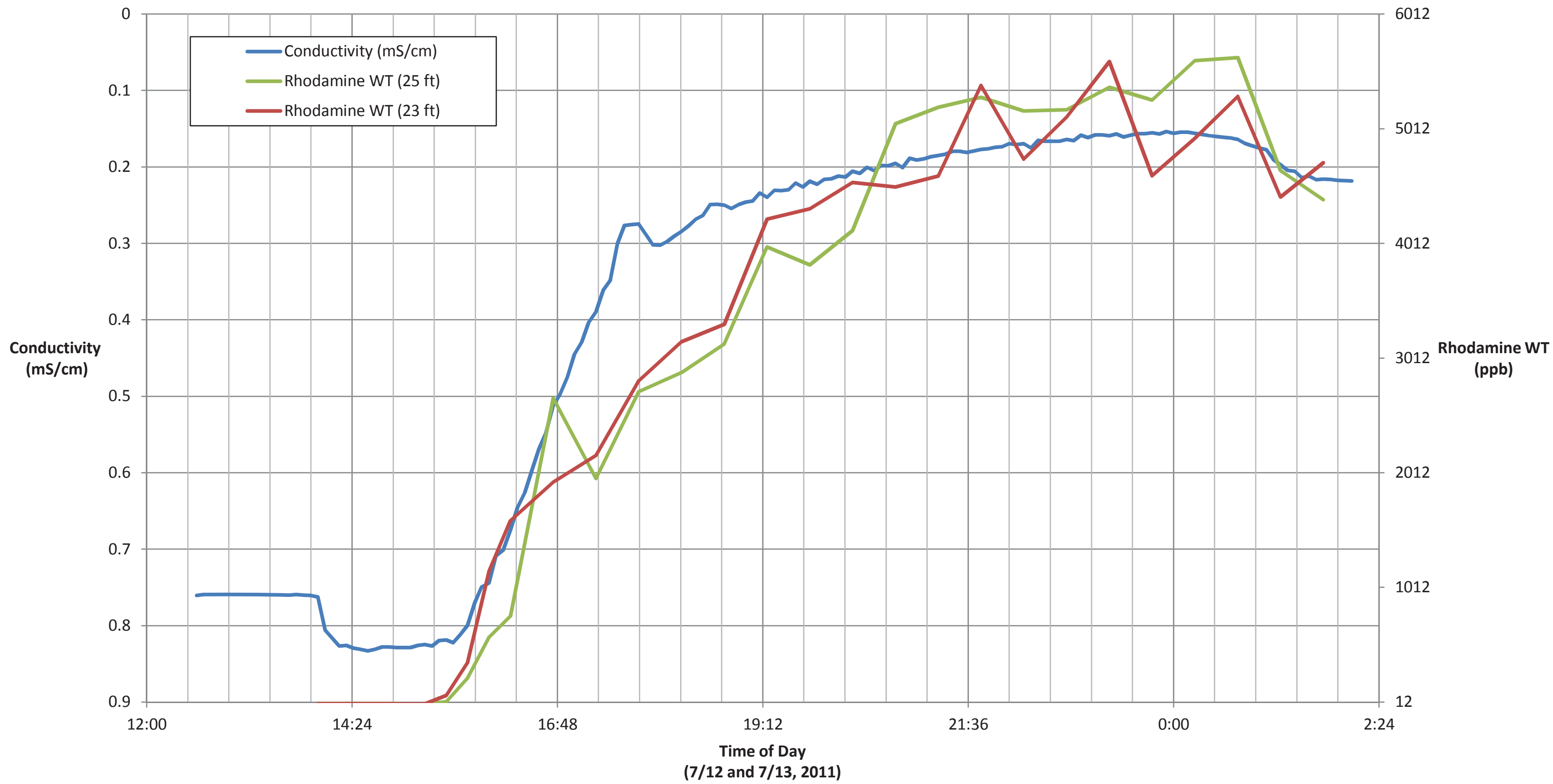
P:\0440 TOC Holdings Co\01-600 Seattle Terminal\Deliverables\2013\ASKO\FS\Appendix A- Aquifer testing data summary\ROI Results.xlsx

Chart A2
Monitoring Well Dye Concentrations during Radius of Influence Tracer Study
Toc Holdings Co., Facility No. 01-600
2737 West Commodore Way
Seattle, Washington



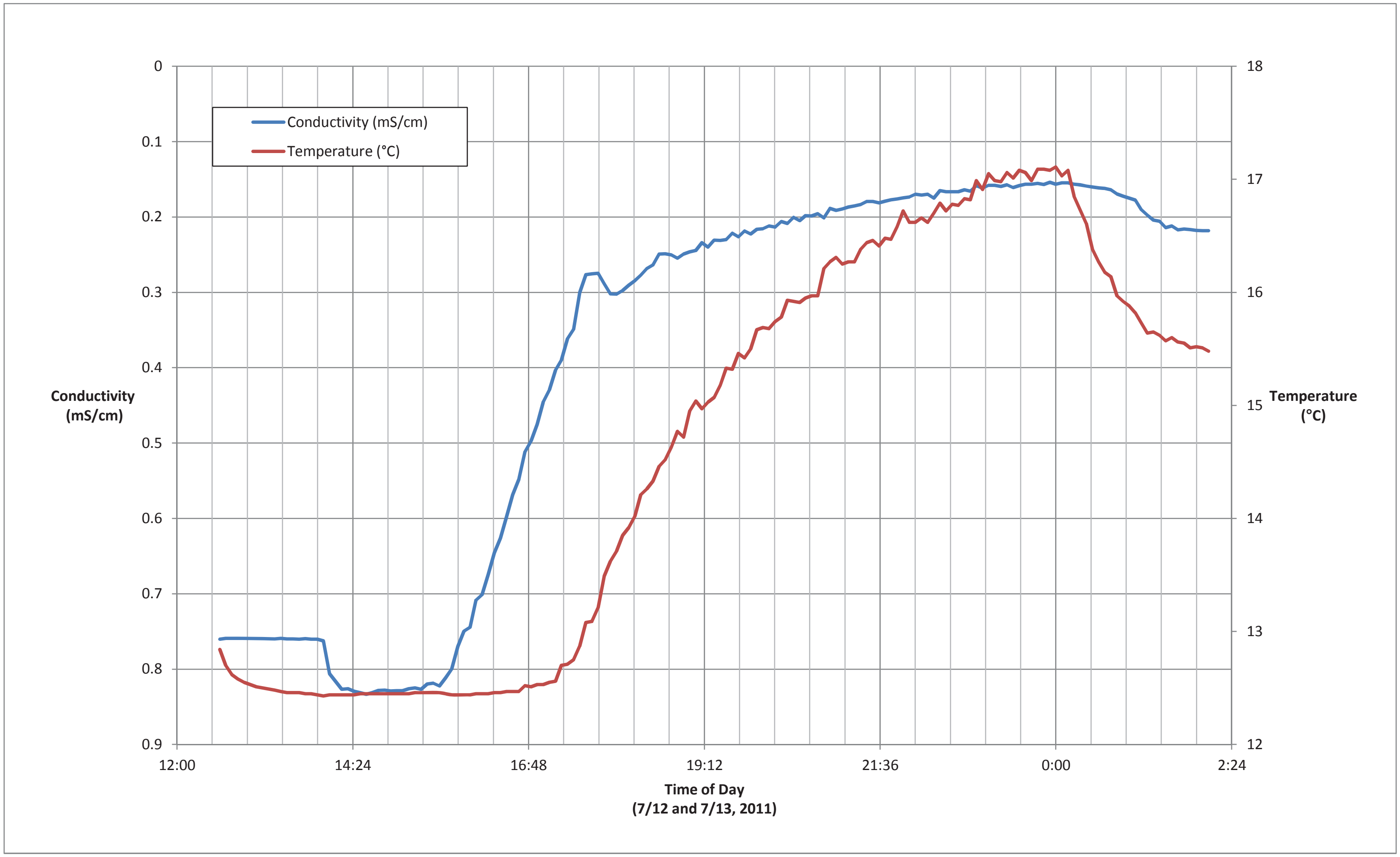
NOTES:
ft = feet
ppb = parts per billion

Chart A3
Fluid Conductivity and Dye Concentrations in Well 01MW82 During Radius of Influence Tracer Study
TOC Holdings Co., Facility No. 01-600
2737 West Commodore Way
Seattle, Washington



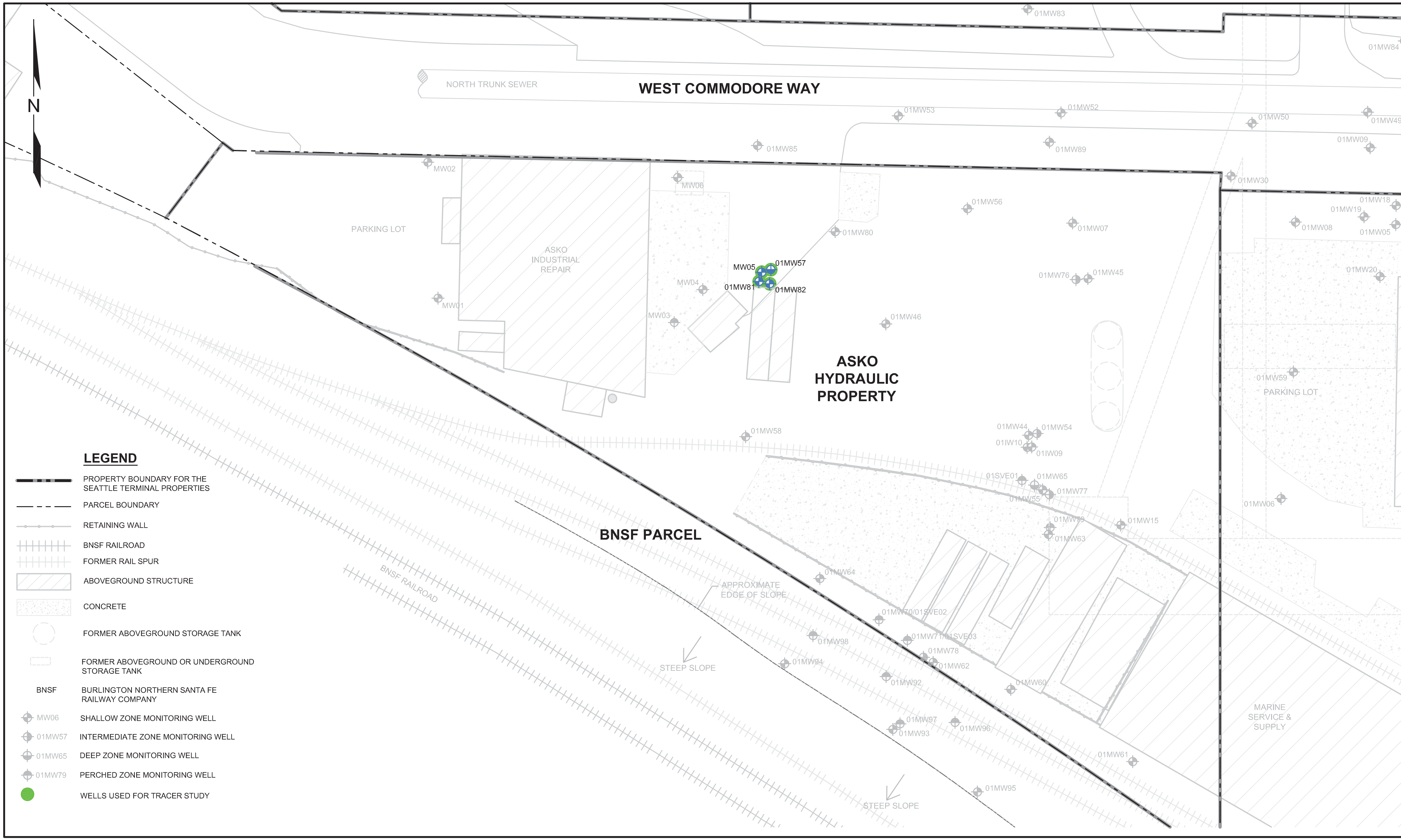
NOTES:
ft = feet
ppb = parts per billion
mS/cm = microsiemens per centimeter

Chart A4
Fluid Conductivity and Temperature in Well 01MW82 During Radius of Influence Tracer Study
TOC Holdings Co., Facility No. 01-600
2737 West Commodore Way
Seattle, Washington



NOTES:
°C = degrees celcius
mS/cm = microsiemens per centimeter

4/1/2014



SoundEarth Strategies
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DATE: 06/25/13
DRAWN BY: NAC
CHECKED BY: PJK/TSB
CAD FILE: 01-600_2013FS_TRACER

PROJECT NAME: TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
SES PROJECT NUMBER: 0440-004
STREET ADDRESS: 2805 WEST COMMODORE WAY
CITY, STATE: SEATTLE, WASHINGTON

REGION:

0 20 40 80
APPROXIMATE SCALE IN FEET

FIGURE 2 - APPENDIX A
LOCATION OF WELLS USED FOR TRACER STUDY

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\DELIVERABLES\2013\ASKO\FS\APPENDIX A- AQUIFER TESTING DATA SUMMARY\01-600_2013FS_TRACER.DWG

Laboratory Measurements of Soil Properties

Table A4
Results for Laboratory Analysis of Soil Properties
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

Well/Boring ID	Sample ID	Date Sampled	Analysis Depth (feet bgs)	Moisture Content[1][2] (% weight)	Density[1] (g/cc)		Porosity[1] (%Vb)		Porosity[3] (%Vb)		Total Pore Fluid Saturations[1] (% Pv)	Effective Permeability[1][4] to Water (millidarcy)	Hydraulic Conductivity[1][4] (cm/s)	Particle Size Distribution[5] (% by weight)							Fraction Organic Carbon[6] (g/g)	Total Organic Carbon[6] (mg/kg)
												25 psi Confining Stress			Sand Size							
					Bulk	Grain	Total	Air Filled	Total	Effective				Gravel	Coarse	Medium	Fine	Silt	Clay	Silt and Clay		
01MW76/B172	B172-23-23.5	3/1/2011	23.15	--	--	--	--	--	38.4	32.8	--	--	--	--	--	--	--	--	--	--	--	--
			23.3	20.7	1.43	2.72	47.5	18	--	--	62.2	1,082	1.07E-03	0.00	0.03	12.58	66.71	16.39	4.24	20.63	--	--
			23-23.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.20E-04	520
01MW85/B193	B193-25-25.5	04/20/11	25.1	--	--	--	--	--	--	--	--	--	--	0.00	0.00	32.65	58.34	7.18	1.83	9.01	--	--
	B193-26-26.5		26.1	--	--	--	--	--	38.8	33.8	--	--	--	--	--	--	--	--	--	--	--	--
			26.2	20.5	1.55	2.72	43.1	11.2	--	--	73.9	201	1.96E-03	--	--	--	--	--	--	--	--	--

NOTES:
Samples collected by SoundEarth Strategies, Inc.
All sample analyses conducted by PTS Laboratories, Inc. of Santa Fe Springs, California.
[1]Analyzed by American Petroleum Institute Recommended Practice 40.
[2]Analyzed by ASTM D2216.
[3]Analyzed by Modified ASTM D425.
[4]Analyzed by EPA Method 9100.
[5]Analyzed by ASTM D422/D4464M.
[6]Analyzed by Walkley-Black.

-- = not measured or not analyzed
% = percent
ASTM = ASTM International
bgs = below ground surface
cm/s = centimeters per second
EPA = U.S. Environmental Protection Agency
g/cc = grams per centimeter
g/g = gram per gram
mg/kg = milligrams per kilogram
psi = pounds per square inch
Pv = pore volume
Vb = bulk volume

APPENDIX B

SVE PILOT TEST DATA SUMMARY

SoundEarth Strategies

Appendix B
Soil Vapor Extraction Pilot Test
Step Test Operational Data for Test Well: 01SVE01
ASKO Hydraulic Property
TOC Holdings Co. Facility No. 01-600
2805 West Commodore Way
Seattle, Washington

							Suction Instrument Train								Bleed Air				Alternate Well Flow	
Date	Time	Barometric Pressure (psi)	Manual Dilution Valve (% open)	VFD Setting (Hz)	Wellhead Vacuum (in. H_2O)	KOT Vacuum (in. H_2O)	Static Pressure (in. H_2O)	Differential Pressure (in. H_2O)	Temp (°F)	VOC (ppmv)	LEL (%)	O_2 (%)	CO_2 (% / ppm)	Flow Rate* (scfm)	Static Pressure (in. H_2O)	Differential Pressure (in. H_2O)	Temp (°F)	Flow Rate (SCFM)	**total Flow (from baseline blower curve) SCFM	Alternate Well Flow Rate Estimate*
02/24/10	8:55	14.65	60	36	19	25	19.1	0.14	48	0.3	0	20.9	1140	43.9	1.5	6.5	48	130.4	135.2	4.8
	9:20	14.66	60	36	20	25	19.1	0.01	50	8.5	6	17.2	9400	11.7	1.5	6.5	50	130.1	135.2	5.1
	9:35	14.65	60	36	20	25	19.1	1.00	50	7.7	6	16.8	9100	117.1	2.0	6.5	50	130.0	135.2	5.2
	9:50	14.66	35	36	40	44	43.0	0.01	49	10.6	7	17.8	9300	11.4	1.0	5.5	49	119.9	135.2	15.3
	10:05	14.66	35	36	40	44	43.0	0.01	54	16	7	14.4	1.26%	11.3	1.0	6.6	50	131.2	135.2	4.0
	10:20	14.64	30	40	58	58	56.0	0.01	54	NM	4	18.7	8740	11.1	1.5	4.0	50	102.0	148.1	46.0
	10:35	14.66	30	40	55	58	56.0	0.01	54	20	6	16.1	1.10%	11.1	1.5	5.0	52	113.9	148.1	34.1
	10:50	14.66	30	40	55	58	56.0	0.01	56	11.5	2	19.5	4120	11.1	1.5	5.0	52	113.9	148.1	34.1
	11:15	Stop Test																		

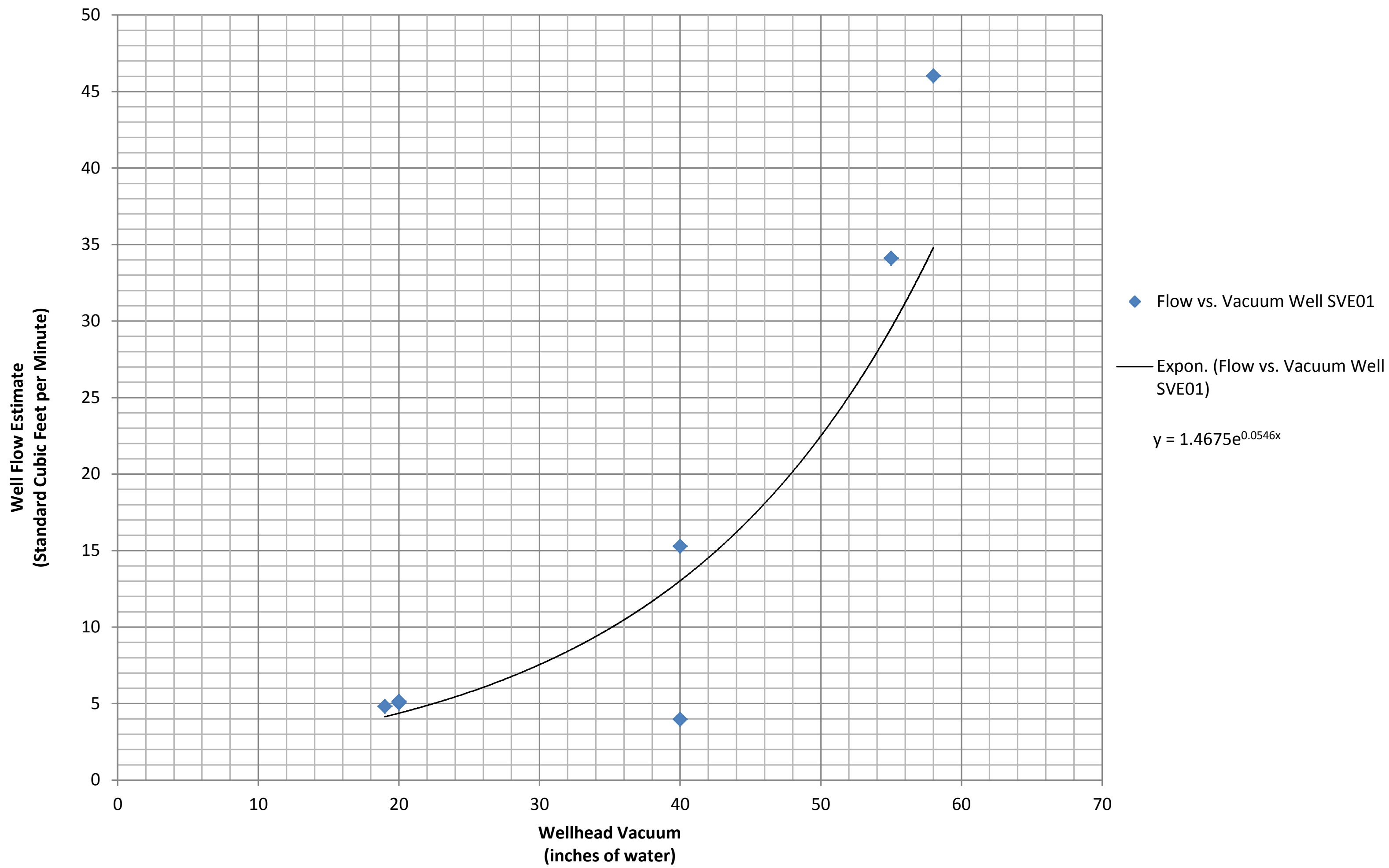
Comments:
*The suction instrument train flow rates are unreliable due to velocity levels below the recommended range for the averaging flow sensor. Alternatively, flow rates at various steps are estimated to be the difference between the total baseline flow rate and the flow rate calculated for the bleed air.
**The equation for the relationship of baseline flow to VFD setting is: y = 3.2137x + 19.507, where x = VFD setting in Hz.
NM= not measured

Appendix B
Soil Vapor Extraction Pilot Test
Observation Well Vacuums for Test Well: 01SVE01
ASKO Hydraulic Property
TOC Holdings Co. Facility No. 01-600
2805 West Commodore Way
Seattle, Washington

Date	Time	VFD Setting (Hz)	Manual Dilution Valve (% open)	Observation Well Head Vacuum (in. H_2O)						Notes	
				01MW44	01MW54	01MW65	01MW55	01MW15	01MW63		
Approximate distances from Test Well to Observation Well (ft)				20.6	22.1	6.8	10.8	47.3	25.6	--	--
02/24/10	9:10	36	60	1.2	0.12	0	0.16	2.3	0.3	Start Step 1	
	9:20	36	60	1.25	0.05	0	0.65	2.2	1.3	--	--
	9:35	36		1.21	0.1	0	0.45	2.2	1.3	--	--
	9:50	36	35	1.1	0.01	0.01	0.6	2.4	1.3	Start Step 2	
	10:05	36	35	1.1	0.1	0.05	0.55	2.1	1.2	--	--
	10:20	40	30	0.7	0.15	0.01	0.35	1.45	0.45	Start Step 3	
	10:35	40	30	0.9	0.15	0.05	0	1.95	1	--	--
	10:50	40	30	0.9	0.2	0.01	0.5	2	1.1	--	--

Comments:
(shaded cell) Indicates measurement is a pressure reading in inches of water.

Appendix B
Chart 1
Soil Vapor Extraction Pilot Test
Observation Well Measurements (Flow vs. Vacuum) for Test Well: 01SVE01
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, WA



Appendix B
Soil Vapor Extraction Pilot Test
Step Test Operational Data for Test Well: 01MW44
ASKO Hydraulic Property
TOC Holdings Co. Facility No. 01-600
2805 West Commodore Way
Seattle, Washington

							Suction Instrument Train								Bleed Air				Alternate Well Flow	
Date	Time	Barometric Pressure (psi)	Manual Dilution Valve (% open)	VFD Setting (Hz)	Wellhead Vacuum (in. H_2O)	KOT Vacuum (in. H_2O)	Static Pressure (in. H_2O)	Differential Pressure (in. H_2O)	Temp (°F)	VOC (ppmv)	LEL (%)	O_2 (%)	CO_2 (% / ppm)	Flow Rate* (scfm)	Static Pressure (in. H_2O)	Differential Pressure (in. H_2O)	Temp (°F)	Flow Rate (SCFM)	**total Flow (from baseline blower curve) SCFM	Alternate Well Flow Rate Estimate*
	Step 1																			
	11:50	14.86	50	42	19	24	26.0	0.05	54	136	13	1	>20,000	26.0	2.0	6.5	54	130.5	154	24.0
	12:05	14.87	50	42	20	27	26.0	0.05	60	9.8	0	20.9	460	25.9	1.5	6.5	54	130.6	154	23.9
	12:20	14.86	50	42	20	27	25.0	0.05	52	179	3	1.1	>20,000	26.1	1.5	6.5	52	130.8	154	23.7
	Step 2																			
02/24/10	12:30	14.86	25	42	38	44	42.0	0.05	54	186	16	1.2	>20,000	25.5	1.0	5.5	54	120.1	154	34.3
	12:45	14.86	25	42	40	44	43.0	0.02	56	191	3	1.2	>20,000	16.1	1.5	6.0	56	125.2	154	29.3
	13:00	14.86	25	42	40	44	43.0	0.01	54	184	1	1.1	>20,000	11.4	1.0	5.5	54	120.1	154	34.4
	Step 3																			
	13:15	14.86	22	43.5	58	62	60.0	0.01	53	191	4	1.3	>20,000	11.1	1.5	7.0	53	135.6	159	23.7
	13:30	14.86	22	43.5	60	63	61.0	0.01	52	197	5	1.5	>20,000	11.1	1.5	6.5	52	130.8	159	28.5

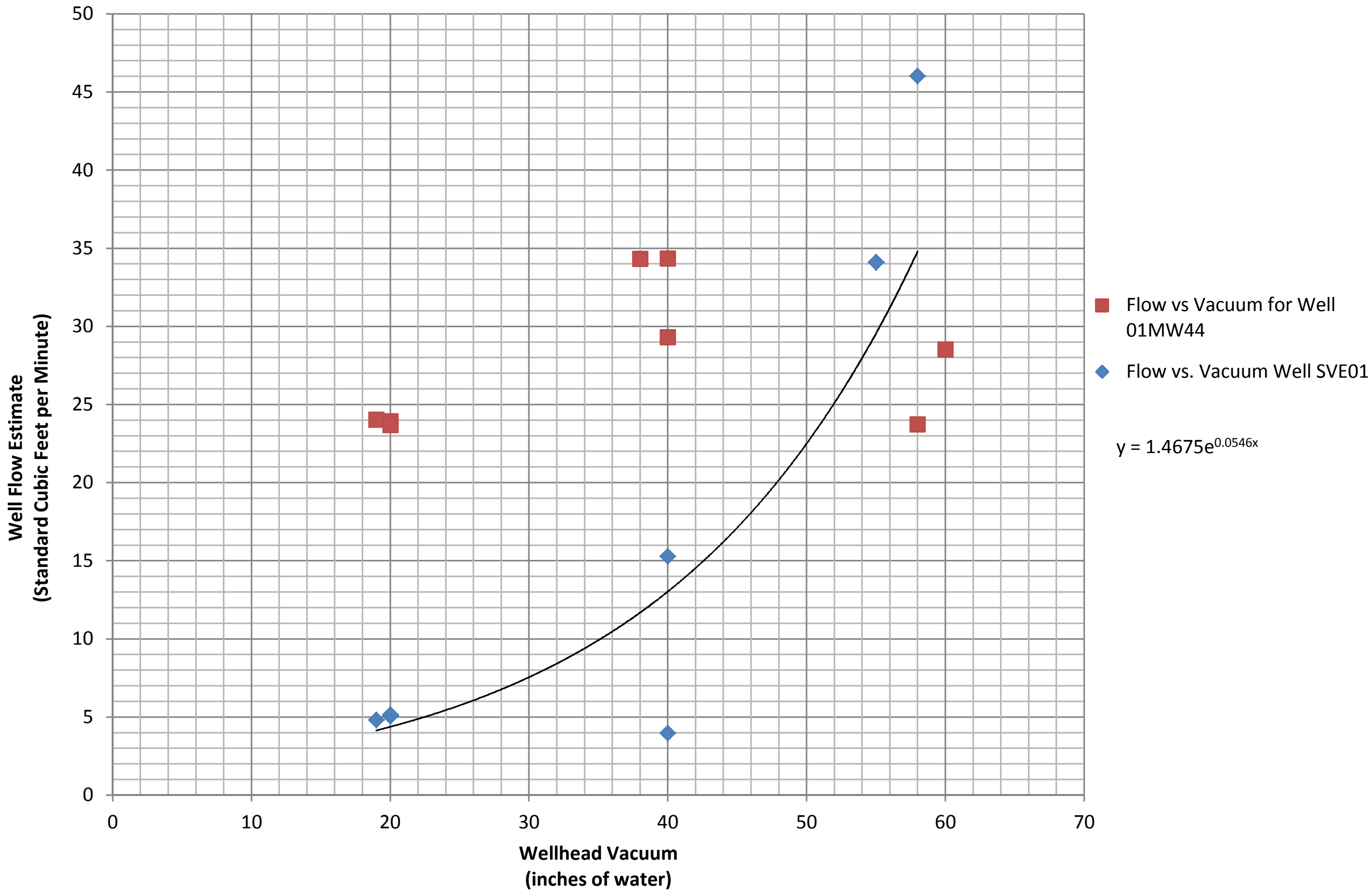
Comments:
*The suction instrument train flow rates are unreliable due to velocity levels below the recommended range for the averaging flow sensor. Alternatively, flow rates at various steps are estimated to be the difference between the total baseline flow rate and the flow rate calculated for the bleed air.
**The equation for the relationship of baseline flow to VFD setting is: $y = 3.2137x + 19.507$, where x = VFD setting in Hz.

Appendix B
Soil Vapor Extraction Pilot Test
Observation Well Vacuums for Test Well: 01MW44
ASKO Hydraulic Property
TOC Holdings Co. Facility No. 01-600
2805 West Commodore Way
Seattle, Washington

Date	Time	VFD Setting (Hz)	Manual Dilution Valve (% open)	Observation Well Head Vacuum (in. H_2O)						Notes	
				01MW54	01SVE01	01MW65	01MW55	01MW15	01MW63		
Approximate distances from Test Well to Observation Well (ft)				4.1	20.0	21.7	24.6	55.0	43.4	--	--
02/24/10	11:50	42	50	2.5	5.7	0	1.5	2	0.01	Start Step 1	
	12:05	42	50	0.3	5.0	0.01	1.65	1.85	0.2	--	--
	12:20	42	50	0.01	4.0	0	3.4	1.8	0.7	--	--
	12:30	42	25	0.05	3.7	0	4.1	1.7	1.6	Start Step 2	
	12:45	42	25	0.05	3.2	0.05	6.1	1.8	1.8	--	--
	13:00	42	25	0.01	2.6	0	7.4	1.45	1.7	--	--
	13:15	43.5	22	0.01	2.2	0	9.5	1.8	1.85	Start Step 3	
	13:30	43.5	22	0.01	2.0	0.1	13	1.0	2.2	--	--

Comments:
(grey shading) Indicates measurement is a pressure reading in inches of water.

Appendix B
Chart 2
Soil Vapor Extraction Pilot Test
Observation Well Measurements (Flow vs. Vacuum) for Test Well: 01MW44
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, WA



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Appendix B
Soil Vapor Extraction Pilot Test
Step Test Operational Data for Test Well: 01MW63
ASKO Hydraulic Property
TOC Holdings Co. Facility No. 01-600
2805 West Commodore Way
Seattle, Washington

							Suction Instrument Train								Bleed Air				Alternate Well Flow	
Date	Time	Barometric Pressure (psi)	Manual Dilution Valve (% open)	VFD Setting (Hz)	Wellhead Vacuum (in. H_2O)	KOT Vacuum (in. H_2O)	Static Pressure (in. H_2O)	Differential Pressure (in. H_2O)	Temp (°F)	VOC (ppmv)	LEL (%)	O_2 (%)	CO_2 (% / ppm)	Flow Rate (scfm)	Static Pressure (in. H_2O)	Differential Pressure (in. H_2O)	Temp (°F)	Flow Rate (SCFM)	**total Flow (from baseline blower curve) SCFM	Alternate Well Flow Rate Estimate*
02/24/10	Step 1																			
	14:20	14.69	40	30	18	22	21	0.04	53	118	0	20.9	490	23.3	0.5	4.5	53	108.2	116	7.684
	14:35	14.69	40	30	18	22	20	0.04	54	30	0	20.9	360	23.3	0.5	4.5	54	108.1	116	7.789
	Step 2																			
	14:50	14.69	30	36	32	38	36	0.05	60	117	5	18.1	9700	25.4	1.0	5.5	54	119.5	135	15.733
	15:05	14.69	30	36	32	38	36	0.05	68	115	15	11.6	>20,000	25.2	1.5	5.5	55	119.3	135	15.922
	Step 3																			
	15:25	14.69	20	39.5	60	63	60	0.05	68	144	13	11.4	>20,000	24.4	1.5	5.5	55	119.3	146	27.170
	15:40	14.69	20	39.5	60	63	61	0.04	68	146	13	11.4	>20,000	21.8	1.0	5.5	55	119.4	146	27.097
	15:55	14.69	20	39.5	60	64	61	0.04	62	133	5	12.5	>20,000	21.9	1.5	5.5	53	119.5	146	26.938

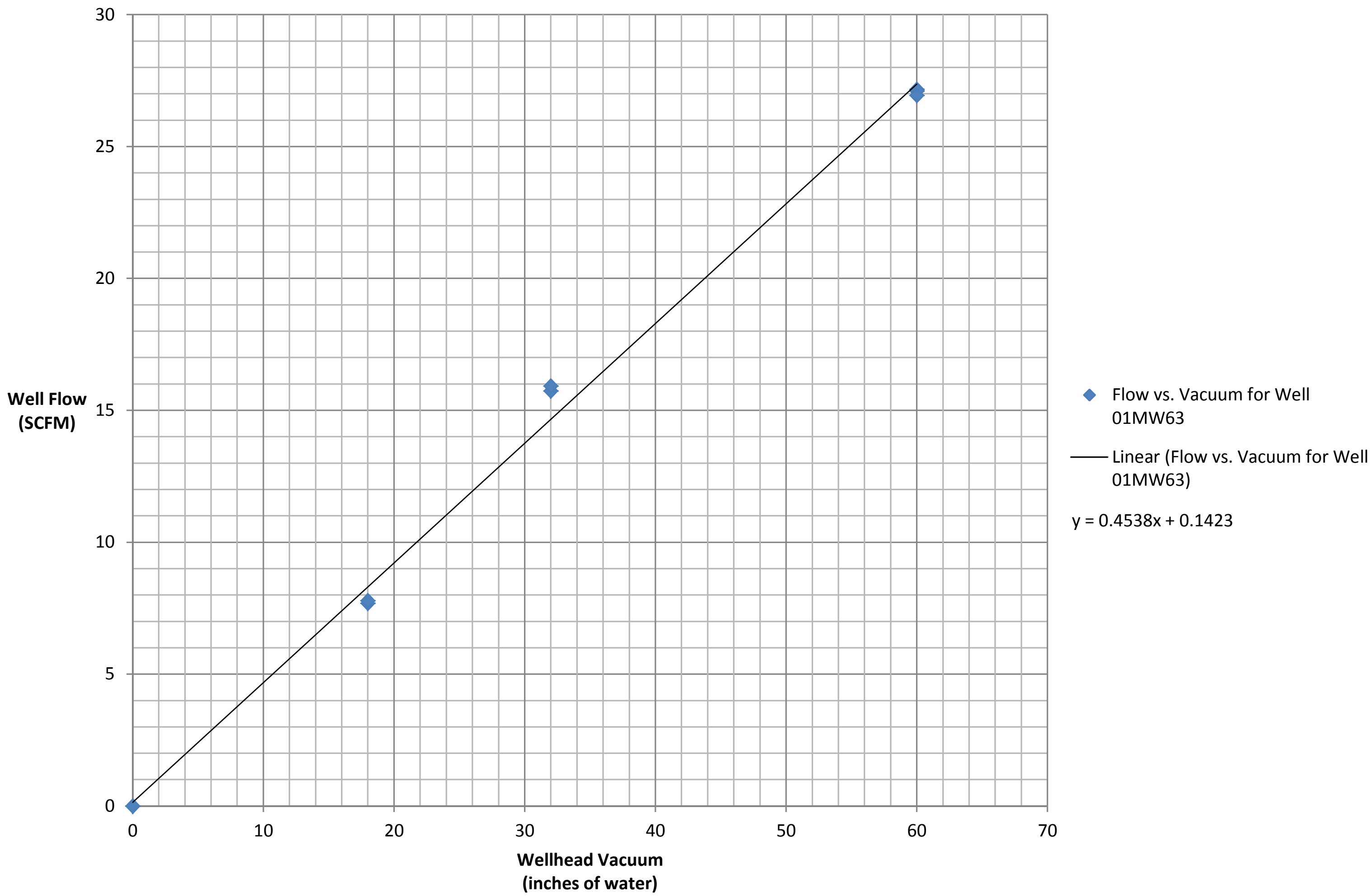
Comments:
*The suction instrument train flow rates are unreliable due to velocity levels below the recommended range for the averaging flow sensor. Alternatively, flow rates at various steps are estimated to be the difference between the total baseline flow rate and the flow rate calculated for the bleed air.
**The equation for the relationship of baseline flow to VFD setting is: $y = 3.2137x + 19.507$, where x = VFD setting in Hz.

Appendix B
Soil Vapor Extraction Pilot Test
Observation Well Vacuums for Test Well: 01MW63
ASKO Hydraulic Property
TOC Holdings Co. Facility No. 01-600
2805 West Commodore Way
Seattle, Washington

SVE Step Test Well: 01MW63											
Date	Time	VFD Setting (Hz)	Manual Dilution Valve (% open)	Observation Well Head Vacuum (in. H_2O) 01MW44	01MW54	01SVE01	01MW65	01MW55	01MW15	Notes	
Approximate distances from Test Well to Observation Well (ft)				43.2	43.4	25.5	21.8	19.1	31.2	--	--
02/24/10	14:20	30	40	12	0.01	0.05	0	4.0	0	Start Step 1	
	14:35	30	40	8.3	0.01	0.08	0	3.2	0	--	--
	14:50	36	30	6.9	0	0.08	0	1.8	0	Start Step 2	
	15:05	36	30	6.0	Flicker	0	0.03	1.4	0.01	--	--
	15:25	39.5	20	5.5	0.05	0	0.05	1.0	0.08	Start Step 3	
	15:40	39.5	20	5.2	0.08	0.04	0	1.0	0.1	--	--
	15:55	39.5	20	5.0	0.1	0.05	0	0.4	0.1	--	--

Comments:
(shaded) Indicates measurement is a pressure reading in inches of water.

Appendix B
Chart 3
Soil Vapor Extraction Pilot Test
Observation Well Measurements (Flow vs. Vacuum) for Test Well: 01MW63
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, WA



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Appendix B
Soil Vapor Extraction Pilot Test
Depth to Water Measurements
ASKO Hydraulic Property
TOC Holdings Co. Facility No. 01-600
2805 West Commodore Way
Seattle, Washington

Site: TOC Holdings Co., Seattle Terminal **Field Personnel: JAB/TGO**
Equipment: Krause DTW Meter - Blue

Pilot Test - Depth to Water Measurements

		Depth to Water (ft)										
Date	**Time**	**01SVE01**	**01SVE02**	**01SVE03**	**01MW15**	**01MW44**	**01MW54**	**01MW55**	**01MW62**	**01MW63**	**01MW64**	**01MW65**
02/23/10	09:45	--	--	--	22.61	21.42	29.83	22.63	--	26.54	--	33.91
02/24/10	07:36	--	--	--	22.57	22.38	29.75	22.69	--	26.54	--	33.75
	11:15	6.29	--	--	22.64	22.44	29.77	22.80	--	26.68	--	33.80
	13:54	--	--	--	22.86	22.66	29.82	23.15	--	27.23	--	33.80
	16:10	--	--	--	22.81	22.51	29.82	23.20		24.89		33.81

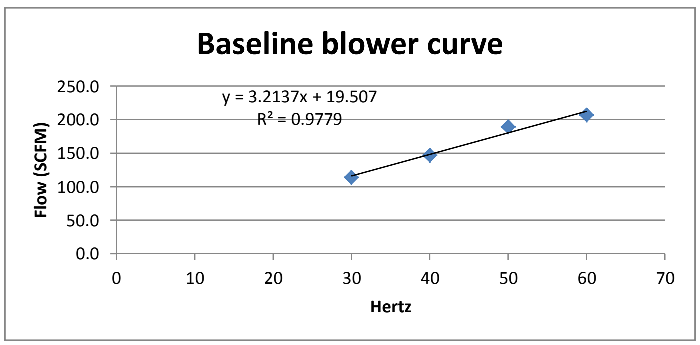
Comments:

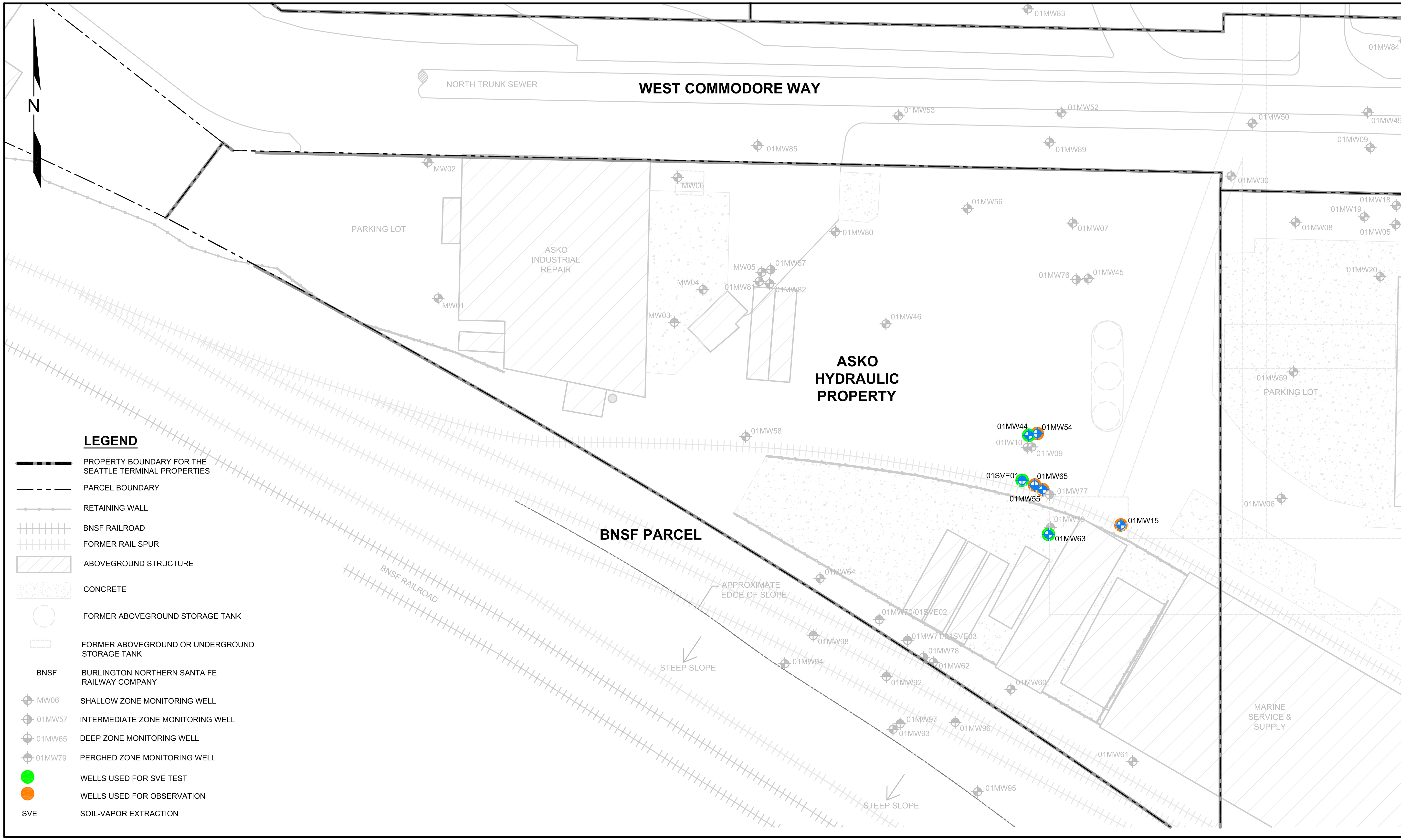
Appendix B
Soil Vapor Extraction Pilot Test
Baseline Blower Curve Data
ASKO Hydraulic Property
TOC Holdings Co. Facility No. 01-600
2805 West Commodore Way
Seattle, Washington

SVE Test Well: BASELINE

Date	Time	Barometric Pressure (psi)	Manual Dilution Valve (% open)	VFD Setting (Hz)	Wellhead Vacuum (in. H_2O)	KOT Vacuum (in. H_2O)	Suction Instrument Train (3" schedule 80 pvc): Static Pressure (in. H_2O)	Differential Pressure (in. H_2O)	Temp (°F)	VOC (ppmv)	LEL (%)	O_2 (%)	CO_2 (% / ppm)	Flow Rate (scfm)	Bleed Air (2" sch 80 PVC): Static Pressure (in. H_2O)	Differential Pressure (in. H_2O)	Temp (°F)	Flow Rate (SCFM)
02/24/10	8:30	14.65	0	60	N/A	16	5.5	3	48	N/A	N/A	N/A	N/A	206.8	N/A	N/A	N/A	N/A
		14.65	0	50	N/A	12	4.0	2.50	48	N/A	N/A	N/A	N/A	189.1	N/A	N/A	N/A	N/A
		14.65	0	40	N/A	8	3.0	1.50	48	N/A	N/A	N/A	N/A	146.7	N/A	N/A	N/A	N/A
		14.65	0	30	N/A	2	1.5	0.90	48	N/A	N/A	N/A	N/A	113.8	N/A	N/A	N/A	N/A

Comments:





4/1/2014

P:\0440 TOC HOLDINGS CO\01-600 SEATTLE TERMINAL\DELIVERABLES\2013\ASKO\FS\APPENDIX B- SVE PILOT TEST\01-600_2013FS_SVE.DWG

SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

DATE:	06/25/13
DRAWN BY:	NAC
CHECKED BY:	PJK/TSB
CAD FILE:	01-600_2013FS_SVE

PROJECT NAME:	TOC HOLDINGS CO. ASKO HYDRAULIC PROPERTY
SES PROJECT NUMBER:	0440-004
STREET ADDRESS:	2805 WEST COMMODORE WAY
CITY, STATE:	SEATTLE, WASHINGTON

REGION:

0 20 40 80
APPROXIMATE SCALE IN FEET

FIGURE 1 - APPENDIX B
LOCATION OF WELLS USED FOR SVE PILOT TEST (FEBRUARY 2010)

APPENDIX C

CHEMICAL OXIDANT DEMAND TEST SUMMARY

Table C1
Summary of Test Results
Permanganate Natural Oxidant Demand
and Klozur Demand
TOC Holdings Co. Facility No. 01-600
ASKO Hydraulic Property
2805 West Commodore Way
Seattle, Washington

48-Hour Permanganate Natural Oxidant Demand [1]				
Soil Sample ID	Average and Standard Deviation (g/kg)	Replicate 1 (g/kg)	Replicate 2 (g/kg)	Replicate 3 (g/kg)
B171-24 2/28/11 0940	1.6 ±0.3	1.6	1.5	1.7

NOTES:

[1]Demands were calculated on a weight $KMnO_4$/dry soil weight basis from an initial dose of 40.0 g/kg KMnO4 at a 1:2 soil to aqueous solution ratio.

g = grams

kg = kilograms

$KMnO_4$ = potassium permanganate

Klozur Demand								
Soil Sample ID	Run Number	Trial Activator	Soil Weight (g)	Groundwater Volume (ml)	Klozur Dosage (g/kg soil)	Groundwater pH	Klozur Demand (g/kg)	Klozur Demand (g/kg)
					t = 0 hours		t = 48 hours	t = 96 hours
B171-24 & 01MW45-20110307	1	NaOH	10	30	15	11.12-10.93	1.94	2.05
	2	NaOH	10	30	15	11.12-10.93	1.96	2.05

NOTES:

Soil Buffering Demand = 1.93 gallons 25% NaOH/2,000 lb of soil

Acid Generation Demand = 0.13 gallons 25% NaOH/lb of Klozur persulfate

g = grams

kg = kilograms

lb = pounds

ml = milliliters

NaOH = sodium hydroxide

t = time

Carus Remediation Technologies

Remediation Report

9 March 2011

CARUS®

Customer: SoundEarth Strategies
2811 Fairview Ave. E. Ste 2000
Seattle, WA 98102

Cc: K. Frasco

Attention: P. Kingston

From: L. Mueller

TECH # 11-039

Subject: RemOx® S ISCO Reagent Permanganate Natural Oxidant Demand

Summary

The average RemOx® S ISCO reagent permanganate natural oxidant demand (PNOD) for the soil sample at 48 hours was determined to be 1.6 g/kg potassium permanganate ($KMnO_4$) per dry weight of soil.

Background

One soil sample was received from SoundEarth Strategies from the TOC 01-600 project located in Seattle, Washington on March 2, 2011. The soil sample designation was B171-24. The sample was analyzed for permanganate natural oxidant demand following ASTM D7262-07 Test Method A. The measurement of the permanganate natural oxidant demand is used to estimate the concentration of permanganate that will be consumed by the natural reducing agents during a given time period of 48 hours.

Experimental

The sample was analyzed for permanganate natural oxidant demand following ASTM D7262-07 Test Method A. A brief summary is as follows:

To determine the PNOD, the soil was baked at 105°C for 24 hours then allowed to cool to room temperature. The soil was then blended and passed through a U.S. 10 sieve (2 mm). Reactors were loaded with 50 grams of soil and 100 mL of 20 g/L $KMnO_4$ for an initial dose of 40 g/kg $KMnO_4$ on a dry soil weight basis at a 1:2 soil to aqueous reagent ratio. Each soil dose was performed in triplicate. The reaction vessels were inverted once to mix the reagents. Residual permanganate (MnO_4^-) was determined at 48 hours. The demands were calculated on a dry weight basis.

Results

The permanganate demand is the amount of permanganate consumed in a given amount of time. It should be noted that in a soil or groundwater sample, the oxidation of any compound by permanganate is dependent on the initial dose of permanganate and the reaction time available. As the permanganate dose is increased, the reaction rate and oxidant consumption may also increase. Some compounds that are not typically oxidized by permanganate under low doses can become reactive with permanganate at higher concentrations.

The 48-hour PNOD results can be seen in Table 1 (on a dry soil basis).

Table 1: 48-Hour PNOD *

Soil Sample Identification	Average and Standard Deviation (g/kg)	Replicate 1 (g/kg)	Replicate 2 (g/kg)	Replicate 3 (g/kg)
B171-24 2/28/11 0940	1.6 ± 0.3	1.6	1.5	1.7

*Demands were calculated on a weight $KMnO_4$/dry soil weight basis from an initial dose of 40.0 g/kg $KMnO_4$ initial dose at a 1:2 soil to aqueous solution ratio.

Conclusions

For this application the amount of permanganate needed will be dependent on the reaction time allowed. The soil sample had a moderate demand with a 48-hour permanganate demand value of 1.6 g/kg. Generally, remediation sites with a soil demand of less than 20.0 g/kg at 48 hours are favorable for *in situ* chemical oxidation with permanganate (see Table 2 for additional information).

Table 2: Correlation of Permanganate Natural Oxidant Demand Results*

PNOD (g/kg)	**Rank**	Comment
<10	Low	ISCO with MnO_4^- is recommended. Soil contribution to MnO_4^- demand is low.
10-20	Moderate	ISCO with MnO_4^- is recommended. Soil contribution to MnO_4^- demand is moderate. Economics should be considered.
>20	High	ISCO with MnO_4^- is technically feasible. Other technologies may provide lower cost alternatives.

*Dry Weight Basis

Klozur® Persulfate Demand Test

Client:	Sound Earth Strategies 2811 Fairview Ave Suite 2000 Seattle, WA 98102 Phone: 206-436-5909 Pete Kingston
Performing Lab:	FMC Corporation Tonawanda, NY
Date	Mar. 15, 2011

I. Background

Klozur® activated persulfate is a strong oxidant capable of mineralizing a wide range of contaminants, including chlorinated solvents, petroleum hydrocarbons, polyaromatic hydrocarbons, gasoline additives, pesticides, and many others. Activation of the persulfate anion generates the sulfate radical, the primary species that drives the rapid destruction of the contaminants of concern. Activation can be accomplished by several methods[1]: heat, transition metals, addition of hydrogen peroxide, or utilizing high pH. Choice of the activation method will depend on the contaminant of concern and site characteristics.

A chemical oxidant is not specific as to what it will oxidize. As a result, activated persulfate will not only mineralize the contaminant of concern, but a portion of the oxidant will be used in oxidizing soil organics, reduced metals, and organic species that are not of concern. In addition, activated persulfate will undergo auto-decomposition, which will be a function of temperature, concentration and activation method. The demand upon the activated persulfate from all of these components is captured in a coarse screening test termed, “Klozur Demand Test”. It is dependent upon the site characteristics, such as the organic content of the soil, the mineral loading, and soil type and collectively must be considered for estimating the magnitude of oxidant dosing during field application.

The Klozur® Persulfate KDT test measures the loss of persulfate in the presence of soil, groundwater and activator over a period of 48 and 96 hours.

[1] FMC is the owner of licensee under various patent applications relating to the use of activation chemistries

The resulting KDT values can then be used as a guide to develop appropriate persulfate dosing for subsequent treatability testing and field applications.

II. Sample Handling for Sound Earth Strategies

Client Sample Identification

- Soil ID: B171-24; GW ID: 01MW45-20110307

Handling Procedures

- The samples were received on 03/09/2011.
- During the collection of the preliminary data, the soil was well mixed, used and put into its original container after its use.
- The groundwater sample was well mixed, used and put into its original container after its use.
- On 03/14/2011, multiple experimental samples were prepared according to the amounts shown in the results table below.
- The experimental samples were stored at room temperature and each sample was vigorously shaken once per day.
- About 1150 grams of the soil sample are left with us and about 500 milliliters of groundwater sample is left. The unused soil and groundwater samples will be disposed of responsibly after about one week.

III. Results

Sample ID	Run #	Trial Activator	Soil Wt. (g)	GW Water Vol. (mL)	Klozur Dosage (g/Kg Soil) t=0 hrs.	GW pH	t=48hr	t=96 hr
B171-24 & 01MW45-20110307	1	NaOH	10	30	15	11.12-10.93	1.94	2.05
	2	NaOH	10	30	15	11.12-10.93	1.96	2.05
	Soil Buffering Demand = 1.93 gallons 25% NaOH/ 2000 lb of Soil **Acid Generation Demand** = 0.13 gallons 25% NaOH/ lb of Klozur persulfate							

IV. Conclusions

The Klozur® Persulfate demand with NaOH activation for the soil and groundwater samples ranges from approximately 1.9 – 2.1 g persulfate / kg soil, which is considered average to moderate as compared to persulfate SOD for most soils.

Based on these values, an average of 2.0 g / kg should be used as a site-wide SOD for further refinement of the Klozur persulfate total demand.

V. Authorizing Signatures

This report contains the results as determined by FMC laboratory protocol and are accurately represented herein.

Stacey Telesz
FMC Technical Account Manager

Note: 1. FMC recommends performing suitable treatability testing and field pilot demonstration to determine the effectiveness of Klozur® activated persulfate on the contaminants of concern. KDT testing provides only an indication of the minimum amount of oxidant required to overcome the demands of soil, groundwater and other secondary species that contribute to the usage of the oxidant. The KDT results do not imply a guarantee of efficacy of the activated persulfate in actual field situations. 2. ANY SUCH QUANTITY OR WARRANTY IS EXPRESSLY DISCLAIMED.