

DRAFT REMEDIAL INVESTIGATION REPORT

**CAPITAL INDUSTRIES, INC.
5801 3rd AVENUE SOUTH
SEATTLE, WASHINGTON
AGREED ORDER NO. DE 5348**

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

1,1-DCE	1,1-dichloroethene
ABP	Art Brass Plating
Agreed Order	Agreed Order No. DE 5348 entered into by Capital Industries, Inc. and the Washington State Department of Ecology on January 24, 2008
BDC	Blaser Die Casting
bgs	below ground surface
Capital	Capital Industries, Inc.
Capital Area of Investigation	the area south of South Mead Street, north of South Front Street, east of 1 st Avenue South, and west of 4 th Avenue South, and the property north of Mead Street and west of 4 th Avenue South
Capital Property	property owned by Capital Industries, Inc. at 5801 3 rd Avenue South in Seattle, Washington
Capital Site	area where concentrations of constituents of concern released from the Capital Property exceed applicable regulatory cleanup levels
CEFs	Cumulative Exceedance Factors
cis-1,2-DCE	cis-1,2-dichloroethene
COPCs	constituents of potential concern
Data Summary Report	<i>Data Summary Report, West Groundwater Investigation Area, Seattle, Washington</i> dated January 2008, prepared by Farallon, et al.
DNAPL	dense nonaqueous-phase liquid
Ecology	Washington State Department of Ecology
ECS	Environmental Consulting Services, Inc.
EPA	U.S. Environmental Protection Agency
Farallon	Farallon Consulting, L.L.C.
FSM	Floyd Snider McCarthy, Inc.
HVOCs	halogenated volatile organic compounds
Intermediate Zone	water-bearing zone from 40 to 70 feet below ground surface
IPIM	Inhalation Pathway Interim Measures
LDW	Lower Duwamish Waterway
mg/kg	milligrams per kilogram

µg/l	micrograms per liter
MTCA	Washington State Model Toxics Control Act Cleanup Regulation
OnSite	OnSite Environmental Inc. of Redmond, Washington
PCE	tetrachloroethene
PGG	Pacific Groundwater Group
PQLs	practical quantitation limits
PSC	Philip Services Corporation
PVC	polyvinyl chloride
RI	Remedial Investigation
RI Report	<i>Draft Remedial Investigation Report, Capital Industries, Inc., 5801 3rd Avenue South, Seattle, Washington</i> dated July 15, 2011, prepared by Farallon Consulting, L.L.C. (this report)
RI Work Plan	<i>Remedial Investigation Work Plan, Capital Industries, Inc., 5801 Third Avenue South, Seattle, Washington</i> dated September 16, 2008, prepared by Farallon Consulting, L.L.C.
SAP	Sampling and Analysis Plan
Shallow Zone	water-bearing zone from 20 to 40 feet below ground surface
TCE	trichloroethene
TOC	total organic compound
trans-1,2-DCE	trans-1,2-dichloroethene
VI	vapor intrusion
VOCs	volatile organic compounds
WAC	Washington Administrative Code
Water Table Zone	water-bearing zone from the surface to approximately 20 feet below ground surface

1.0 INTRODUCTION

This Draft Remedial Investigation Report (RI Report) has been prepared by Farallon Consulting, L.L.C. (Farallon) on behalf of Capital Industries, Inc. (Capital) to present the results of the Remedial Investigation (RI) of the Capital Area of Investigation (Figure 1). The RI has been conducted in accordance with the *Remedial Investigation Work Plan, Capital Industries, Inc., 5801 Third Avenue South, Seattle, Washington* dated September 16, 2008 prepared by Farallon (2008a) (RI Work Plan) that was reviewed and approved by the Washington State Department of Ecology (Ecology), and meets the requirements of Agreed Order No. DE 5348 entered into by Capital and Ecology on January 24, 2008 (Agreed Order).

The RI Work Plan defined the Capital Area of Investigation as the area south of South Mead Street, north of South Front Street, east of 1st Avenue South, and west of 4th Avenue South, and the property north of Mead Street and west of 4th Avenue South. The Capital Area of Investigation was modified based on the analytical results of groundwater samples collected during the RI field investigation as shown on Figure 1. In accordance with Exhibit B of the Agreed Order and with Section 200 of Chapter 173-340 of the Washington Administrative Code (WAC 173-340-200), the Capital Site is defined as the area where concentrations of constituents of potential concern (COPCs) released from the Capital Property, located at 5801 3rd Avenue South in Seattle, Washington, exceed applicable regulatory cleanup levels.

The RI Report is a deliverable required by the Agreed Order and was prepared in accordance with the Washington State Model Toxics Control Act Cleanup Regulation (MTCA), as established in WAC 173-340-350 and pursuant to the Agreed Order.

1.1 PURPOSE AND OBJECTIVES

The purpose of the RI is to collect sufficient information to enable development and evaluation of technically feasible cleanup alternatives in accordance with WAC 173-340-360 through 173-340-390. The objectives of the RI are to characterize the nature and extent of volatile organic compounds (VOCs) in groundwater, soil, and indoor ambient air exceeding the applicable screening levels. The screening levels used in the RI Report to delineate the nature and extent of VOCS are based on Philip Services Corporation (PSC) (2006b) and those

summarized in the *Data Summary Report, West Groundwater Investigation Area, Seattle, Washington* dated January 2008, prepared by Farallon, et al. (Farallon et al. 2008) (Data Summary Report). The RI provides sufficient data to develop a Conceptual Site Model for use in evaluating technically feasible cleanup alternatives for selection of a final cleanup action applicable to the Capital Site and to comply with the requirements of WAC 173-340-350 and the Agreed Order.

1.2 REPORT ORGANIZATION

The format of the RI Report is in accordance with WAC 173-340-810 through 173-340-840 and the Agreed Order. Section 2 of the RI Report provides a description of the Capital Area of Investigation and vicinity, a summary of background information, a description of the physical and environmental setting of the Capital Site, including geology and hydrogeology, and a summary of previous investigations conducted at the Capital Area of Investigation and surrounding properties. Section 3 describes the technical elements of the RI, including affected media, the COPCs, and applicable screening levels. Sections 4 and 5 present the RI Field Program and results, respectively. Section 6 provides the Conceptual Site Model developed for the Capital Site. Section 7 presents the RI conclusions and recommendations. The documents cited in the RI Report are listed in Section 8. Section 9 presents the standard limitations for the RI as performed by Farallon.

Figure 1 depicts the Capital Property and Figure 2 depicts the regional features near the Capital Property. Figure 3 shows historical and RI boring and monitoring well locations. Figure 4 depicts the Capital Area of Investigation. Figures 5 and 6 depict the historical and RI laboratory analytical data for soil samples collected at the Capital Area of Investigation. Figures 7 through 21 depict the laboratory analytical results for groundwater samples collected from the monitoring well network during the five quarterly monitoring events conducted from March 2010 through March 2011 for the Water Table Zone, the Shallow Zone, and the Intermediate Zone aquifers. Figures 22 through 25 provide cross-sections depicting subsurface lithology and distribution of COPCs. Figure 24 illustrates the reductive dehalogenation of chlorinated ethenes.

Tables 1 and 2 provide the screening levels for the COPCs in soil and groundwater, respectively. Table 3 provides a summary of groundwater elevations. Table 4 summarizes the analytical results for COPCs in soil samples collected during the RI. Table 5 provides the analytical results for total organic carbon in soil. Table 6 summarizes the laboratory analytical results for COPCs for reconnaissance groundwater samples collected during the RI. Table 7 provides the laboratory analytical results for groundwater samples collected from the monitoring well network during the five quarterly monitoring events conducted from March 2010 through March 2011 for the Water Table Zone, the Shallow Zone, and the Intermediate Zone aquifers at the Capital Property, and from the Blaser Die Casting (BDC) monitoring well network from February 2010 and March 2011 for the Water Table Zone, the Shallow Zone, and the Intermediate Zone aquifers. Table 8 provides the analytical results for total organic carbon in monitoring well groundwater samples. Table 9 provides the analytical results for 1,4-dioxane from groundwater samples collected from the Capital Property well network during June 2010 and March 2011, and from the BDC monitoring well network during June 2009 and March 2011. Table 10 provides the analytical results for monitored natural attenuation parameters from groundwater samples collected from the Capital Property monitoring well network during June and December 2010 and from the BDC monitoring well network during February 2008 and June and November 2009. Table 11 provides the water quality parameters collected during the monitoring well sampling events. Tables 12 and 13 provide fate and transport modeling input parameters and results, respectively, for the Capital Property BIOCHLOR Modeling study.

2.0 SITE BACKGROUND

This section provides a description and a summary of background information of the Capital Area of Investigation, the environmental setting, and the hydrogeologic setting. Sources of historical data include reports describing previous investigations conducted at the Capital Property by Floyd Snider McCarthy, Inc. (FSM) (2004); Environmental Consulting Services, Inc. (ECS) (2005); and Farallon. A more detailed discussion of background information is provided in the RI Work Plan.

The Capital Area of Investigation is located within the area defined in the Data Summary Report as the West of 4th Groundwater Investigation Area. Known sources of VOCs to groundwater in the West of 4th Groundwater Investigation Area defined in the Data Summary Report include the Capital Property, the PSC facility, the Art Brass Plating (ABP) facility, and the BDC facility (Figure 2).

The historical and background data for the Capital Property, PSC facility, ABP facility, and BDC facility are summarized in the Data Summary Report and discussed below. The screening levels defined by PSC (2006) and summarized in the Data Summary Report have been used to evaluate the data collected at each of the source areas. The definitions of the Water Table Zone, the Shallow Zone, and the Intermediate Zone used to describe the groundwater-bearing zones are consistent with the nomenclature adopted by PSC (2003) and discussed in Section 2.4.2 of this RI Report.

2.1 SITE DESCRIPTION

2.1.1 Capital Property

The Capital Property is defined as the property owned by Capital located at 5801 3rd Avenue South in Seattle, Washington (Figure 1). The Capital Property consists of four parcels totaling 182,468 square feet developed with five adjoining tilt-up slab-on-grade buildings designated as Capital Plant 1 through Capital Plant 5 and an open lot used for storage of finished products, including containers and dumpsters (Figure 2). Subsurface utilities that enter the Capital Property from the north and south include natural gas, sanitary sewer, and water services. A more detailed description of the Capital Property and facilities located within or adjacent to the

Capital Area of Investigation is provided in the RI Work Plan. A detailed description of facilities located within or near the Capital Area of Investigation is provided in the Data Summary Report.

2.1.2 Up-Gradient Source Areas

Known sources of VOCs to groundwater that may have been released or migrated in groundwater to the West of 4th Area include the BDC facility, the ABP facility, and the PSC facility (Figure 2). A discussion of each of these potential source areas is provided below and in the Data Summary Report.

2.1.2.1 Blaser Die Casting Facility

The BDC facility is located at the intersection of South Orcas Street and 3rd Avenue South, up-gradient and northeast of the Capital Property (Figure 2). Concentrations of halogenated volatile organic compounds (HVOCs) exceeding the screening levels have been detected in soil beneath a building addition and in groundwater down-gradient of the BDC facility to the south-southwest (Pacific Groundwater Group [PGG] 2006).

BDC completed an interim action at the BDC facility that consisted of excavation of soil with concentrations of HVOCs from the southwestern corner of the BDC facility to a depth of 8 feet below ground surface (bgs) in December 2007 and January 2008 (PGG 2007a; 2008). The excavation extended laterally until analytical results for HVOCs in soil were below the screening levels. However, soil containing concentrations of HVOCs exceeding the screening levels remains in-place (PGG 2008). A total of 1,000 tons of contaminated soil and construction debris were removed from the BDC facility.

2.1.2.2 Art Brass Plating Facility

A release of HVOCs to soil and groundwater has been confirmed at the ABP facility (Aspect Consulting 2005a; 2005b; 2007). Concentrations of HVOCs exceeding screening levels have been detected in groundwater down-gradient of the ABP facility (Aspect Consulting 2007).

2.1.2.3 Philip Services Corporation Facility

The PSC facility is a Resource Conservation and Recovery Act-permitted former hazardous waste treatment, storage, and disposal facility. Operations associated with the treatment and storage of materials at the PSC (2003) facility resulted in releases of contaminants to soil and groundwater. Concentrations of HVOCs and other contaminants exceeding screening levels have been detected in groundwater down-gradient of the PSC facility and in the West of 4th Area.

2.2 CAPITAL PROPERTY HISTORY

A history of the Capital Property operations and prior investigations is provided in the RI Work Plan, and is summarized below. Sampling locations from prior investigation are shown on Figure 3.

2.2.1 Capital Property

Capital has occupied the current location since 1965 and was developed in five phases: Capital Plant 2 was constructed in 1965, Capital Plant 3 in 1973, Capital Plant 4 in 1978, Capital Plant 1 in 1980, and Capital Plant 5 in 2005. The Capital Property has been operated exclusively for metal fabrication and related work such as painting since 1965.

Capital Plant 2 was destroyed by fire in January 2004 and was reconstructed later that year. Reconstruction of Capital Plant 2 included excavation of soil from within the building footprint to approximately 5 feet below the base of the slab elevation in some areas. Approximately 330 cubic yards of soil was removed during reconstruction.

A chemical and paint storage area existed in the Capital Plant 2 canopy area, and a paint station was located in the southwestern corner of Capital Plant 2 from 1968 to 1978. Solvents were used in a hot-solvent degreasing unit formerly located in an area between Capital Plant 3 and Capital Plant 4. A small quantity of a degreasing solvent reportedly was spilled onto the concrete floor in the area between Capital Plant 3 and Capital Plant 4 in 1988 during a refilling operation of the degreaser unit (ECS 2005).

2.2.2 Previous Investigations

Previous investigations conducted at the Capital Property by Farallon and others have detected concentrations of trichloroethene (TCE), tetrachloroethene (PCE), cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride (collectively referred to as HVOCs) exceeding the screening levels in groundwater in the Water Table Zone and the Shallow Zone at the Capital Property. Concentrations of PCE and TCE exceeding the screening levels were detected in soil at Capital Plant 4. Concentrations of TCE exceeding the screening levels were detected in soil at Capital Plant 2.

This section summarizes previous investigations conducted at the Capital Property and adjacent properties by Farallon and others. Investigations at the Capital Property were conducted between January 2004 and May 2007 and included sub-slab soil vapor sampling and analysis after Capital Plant 2 was destroyed by fire in January 2004; soil vapor, construction monitoring, and soil sampling during reconstruction of Capital Plant 2 (FSM 2004; ECS 2005); three phases of subsurface investigations conducted to evaluate the nature and extent of HVOCs in soil and groundwater at the Capital Property (ECS 2005); and subsurface investigations at the Capital Property to assess the nature and extent of HVOCs in groundwater up- and down-gradient of the Capital Property (Farallon et al. 2008). A more detailed summary of the previous investigations is presented in the Data Summary Report.

2.2.2.1 Floyd Snider McCarthy, Inc. 2004 Soil Vapor Monitoring

Soil vapor monitoring was conducted during the reconstruction of Capital Plant 2 after the plant was destroyed by fire in January 2004 (FSM 2004). Sub-slab soil vapor monitoring was conducted to assess whether HVOCs in groundwater beneath Capital Plant 2 posed a potential impact to indoor air quality in new Capital Plant 2. Concentrations of TCE above the laboratory detection limits were detected in 2 of the 12 soil vapor samples collected, and concentrations of PCE above the laboratory detection limits were detected in 10 of the 12 soil vapor samples collected (FSM 2004).

The analytical results of the sub-slab soil vapor samples were used to develop a vapor intrusion (VI) model using the Johnson & Ettinger Model for Surface Vapor Intrusion

into Buildings Guidance to evaluate the potential for sub-slab soil vapors beneath Capital Plant 2 to impact indoor ambient air quality in new Capital Plant 2 (Environmental Quality Management 2000; U.S. Environmental Protection Agency [EPA] 2002a; FSM 2004). Modeling results predicted that HVOCs and aromatic petroleum hydrocarbon concentrations in the new Capital Plant 2 office and shop areas would be below applicable MTCA Method B ambient cleanup levels (FSM 2004).

2.2.2.2 Floyd Snider McCarthy, Inc. 2004 Construction Monitoring

Reconstruction of Capital Plant 2 began in May 2004 and required removal of the concrete slab and excavation of soil to install a stormwater detention vault, footings, and utility trenches. A Soil Vapor and Construction Monitoring Report was prepared to govern the sampling proceedings associated with the Capital Plant 2 reconstruction excavation (ECS 2005). The soil excavated for Capital Plant 2 reconstruction was field-screened using a photoionization detector, and soil exhibiting elevated readings was segregated and stockpiled. Soil samples were collected and analyzed for HVOCs. Soil that did not contain HVOCs above laboratory practical quantitation limits (PQLs) was used as backfill or disposed of as nonhazardous/non-regulated waste, with approximately 330 cubic yards of soil exported from the Capital property (ESC 2005).

2.2.2.3 Environmental Consulting Services, Inc. 2004 Subsurface Investigation

ECS (2005) conducted a subsurface investigation of the Capital Property in November 2004 to evaluate the source of TCE detected in groundwater samples collected by PSC (2003) from monitoring wells CG-137-WT and CG-137-40 located proximate to Capital Plant 2 (Figure 3).

Concentration of TCE exceeding the screening level applicable at that time were detected in reconnaissance groundwater samples collected from the Water Table Zone in borings located adjacent to and up- and down-gradient of the Capital Property (Figure 3). Concentrations of PCE exceeding the screening level were detected in reconnaissance groundwater samples collected from the Water Table Zone in borings located adjacent to and down-gradient of Capital Plant 4.

Concentrations of TCE were detected in reconnaissance groundwater samples collected from the Shallow Zone in borings located adjacent to and up- and down-gradient of the Capital Property. Concentrations of TCE or PCE were not detected in the reconnaissance groundwater sample collected from the Shallow Zone in the boring located adjacent to and down-gradient of Capital Plant 4. Concentrations of vinyl chloride and other HVOCs were detected in reconnaissance groundwater samples collected from the Shallow Zone in borings advanced adjacent to and up- and down-gradient of the Capital Property.

Concentrations of HVOCs in soil samples were below the laboratory reporting limits or screening levels in all of the soil samples analyzed.

2.2.2.4 Environmental Consulting Services, Inc. 2005 Subsurface Investigations

A subsurface investigation was conducted in February 2005 using Gore Sorber passive soil vapor samplers at Capital Plant 2 and Capital Plant 4 (ECS 2005). A total of 19 soil vapor samplers were installed at Capital Plant 2, and 11 at Capital Plant 4. Concentrations of PCE and TCE were detected in the Gore Sorber passive soil vapor samples collected beneath the concrete slab at Capital Plant 2, with the highest concentrations detected at the southwestern corner of the Capital Plant 2 canopy area. Concentrations of TCE and PCE were detected in soil vapor samples collected beneath the concrete slab at Capital Plant 4, with the highest concentrations detected at the southwestern corner of Capital Plant 4 and in the Capital Plant 4 canopy area.

Subsurface investigations were conducted in April and May 2005 that included collection of soil and reconnaissance groundwater samples from borings located in Plant 2 and Capital Plant 4 (ECS 2005). Concentrations of TCE exceeding screening levels were detected in the reconnaissance groundwater samples collected from the Water Table Zone beneath the Capital Plant 2 canopy area and beneath the southwestern corner of Capital Plant 2. Concentrations of HVOCs were not detected exceeding the screening level in soil samples collected at Capital Plant 2. Concentrations of PCE and TCE exceeding the screening level were detected in reconnaissance groundwater samples collected from the Water Table Zone beneath the southern portion of Capital Plant 4 and beneath the Capital

Plant 4 canopy area. Concentrations of TCE and PCE exceeding the screening level were detected in soil samples collected from borings located in Capital Plant 4 at depths ranging from 0.7 foot to 6.8 feet bgs.

2.2.2.5 Farallon 2006 Subsurface Investigations

Subsurface investigations were completed in January and February 2006 at Plant 2 and Capital Plant 4 to ascertain the groundwater flow direction proximate to the Capital Property, to assess the impact of an up-gradient source of TCE on groundwater at Capital Plant 2, and to assess the down-gradient extent of TCE and PCE in groundwater originating at Capital Plant 2 and Capital Plant 4 (Farallon et al. 2008). Concentrations of TCE exceeding the screening level were detected in reconnaissance groundwater samples and in groundwater samples collected from monitoring wells located in the Capital Plant 2 canopy area, and up- and down-gradient of Capital Plant 2. Concentrations of PCE and TCE exceeding the screening levels were detected in reconnaissance and monitoring well groundwater samples collected inside and down-gradient of Capital Plant 4 in the Water Table Zone and the Shallow Zone. Concentrations of PCE and TCE above laboratory practical quantitation limits (PQLs) were not detected in groundwater monitoring well samples collected up-gradient of Capital Plant 4.

Groundwater monitoring and sampling events were conducted by Farallon in February 2006 and by Farallon, Aspect Consulting, PGG, and PSC in May 2007 as part of the West of 4th Groundwater Investigation. Results from these groundwater monitoring and sampling events at monitoring wells screened in the Water Table Zone and the Shallow Zone at the Capital Property were summarized in the Data Summary Report.

2.2.2.6 Second Avenue South Redevelopment

Capital developed a vacated portion of 2nd Avenue South between South Mead Street and South Fidalgo Street between Capital Plant 1 and Capital Plant 2 in June 2008. Redevelopment included asphalt paving of soil. Sampling activities were conducted by Farallon at the 2nd Avenue South redevelopment area at opportune locations to confirm

the absence of HVOCs in soil. Concentrations of HVOCs exceeding soil-screening levels or laboratory PQLs were not detected in the 16 soil samples collected from test pits or the 1 soil sample collected from an electrical vault excavation area.

2.3 ENVIRONMENTAL SETTING

2.3.1 Land Use

The Capital Property is located within Seattle city limits in King County, Washington (Figure 1) and zoned as Industrial Light Manufacturing (King County, Washington 2007). Surrounding properties are a mixture of light industrial, commercial, and residential properties.

2.3.2 Demographics

The Capital Property is located south of downtown Seattle in the Georgetown neighborhood, which consists predominantly of industrial, commercial office, retail, and residential properties. The population of Seattle is approximately 668,660 (U.S. Census Bureau 2011).

2.3.3 Topography

The Capital Area of Investigation topography is relatively flat, sloping slightly toward the northeast. The ground surface elevation at the Capital Area of Investigation is approximately 15.5 to 20.5 feet above mean sea level (Alta/ACSM Title Land Survey 2004).

2.3.4 Meteorology

The climate of the Seattle area is maritime, characterized by cool summers and mild winters influenced by ocean air. The average annual minimum temperature is 45.1 degrees Fahrenheit, and the average annual maximum temperature is 61.5 degrees Fahrenheit. The average annual precipitation in Seattle is 36.22 inches, with over 4 inches of precipitation per month from November through March.

2.3.5 Groundwater Use

Potable water for the Capital Area of Investigation is supplied by the City of Seattle from the Cedar River and South Fork Tolt River watersheds. Use of groundwater as a drinking water source within Seattle city limits is prohibited by ordinance. There are no drinking water supply

wells within a 0.5-mile radius of the Capital Area of Investigation (Ecology 2007). Groundwater at the Capital Area of Investigation is not used as a drinking water source.

The determination of groundwater non-potability in the Georgetown neighborhood area is supported by Ecology, based on comments pertaining to the PSC (2003) Remedial Investigation Report. Ecology (2004) stated, “Nevertheless, the use of Georgetown groundwater in the future for drinking water seems remote and at this time Ecology does not believe it reasonable to require PSC to actively remediate groundwater to protect such a future use.” Therefore, groundwater at the Capital Area of Investigation is considered to be non-potable.

2.3.6 Surface Water

The Capital Area of Investigation is located within the floor of the north-south-trending Duwamish Valley, where the land surface is relatively level, with ground surface elevations ranging from approximately 15 to 25 feet above mean sea level (Farallon et al. 2008). The valley floor is approximately 6,000 feet wide in this area, and bounded to the east and west by steeply sloped uplands that rise to elevations of 300 to 500 feet above mean sea level. The Capital Area of Investigation is east-adjacent to the Lower Duwamish Waterway (LDW), approximately 2 miles upstream from the point of discharge to the marine waters of Elliott Bay. No other surface water bodies are known to be present in the Capital Area of Investigation.

The LDW was dredged and straightened in the early 1900s. Prior to that time, the Green-Duwamish River meandered as it flowed north through the Duwamish Valley toward Elliott Bay. Slip No. 2, approximately 1,000 feet southwest of the Capital Property (Figure 3), likely is an artifact of the original river course. The former river meander curved from the east, crossing the Duwamish Valley floor in the area south of the Capital Area of Investigation (Booth and Herman 1998). The abandoned meanders reportedly were filled with dredged material during the LDW straightening project.

The stretch of the LDW west of the Capital Area of Investigation is tidally influenced and has variable salinity concentrations. PSC (2003) compiled data showing that tidal fluctuations from -4.6 to +14.8 feet Mean Lower Low Water occur in the LDW, and that tide-induced flow reversals have been observed as far as 13 miles upstream from Elliott Bay. PSC (2003)

compiled depth-specific salinity data for sampling stations at the Spokane Street and 16th Avenue South bridges. The time-weighted average salinity at depth was 30.64 parts per thousand near Spokane Street, and 27.58 parts per thousand near 16th Avenue South.

2.4 HYDROGEOLOGIC SETTING

A summary of the regional geology and hydrology in the vicinity of the Capital Area of Investigation is provided below. The locations of the soil borings and monitoring wells proximate to the Capital Property are depicted on Figure 3. The boring and well logs are included in Appendix A.

2.4.1 Regional Geology

The regional geology in the vicinity of the Capital Property was defined by investigations conducted at the ABP facility, the BDC facility, and the Capital Property (PSC 2003) and summarized by Farallon in the Data Summary Report. The regional geology of the area has been described by Booth and Herman (1998), who defined two stratigraphic units: the Younger Alluvium and the Older Alluvium. The following geologic units have been identified within the Capital Area of Investigation, presented in order of increasing depth:

- Shallow Sand Unit;
- Intermediate Sand and Silt Unit;
- Silt Unit;
- Deep Sand and Silt Unit; and
- Bedrock.

The Shallow Sand Unit correlates to the Younger Alluvium defined by Booth and Herman (1998) and is described as soft, moderately sorted deposits of silt, sand, and sandy silt, and containing abundant wood and organics. The Shallow Sand Unit is found from a few feet above sea level to below current sea level and represents channel and overbank floodplain sediments deposited by the LDW in an estuarine and deltaic environment. The upper portion of the Shallow Sand Unit includes fill material in some areas, which is largely reworked native material

(Younger Alluvium) or imported soil for construction and grading purposes, which locally may contain woody debris or brick fragments.

The Intermediate Sand and Silt Unit correlates to the Older Alluvium defined by Booth and Herman (1998) and consists of interbedded sands and silts with discontinuous gravel lenses and trace amounts of shells and wood that is moderately dense to dense. It is considered to be of fluvial and marine origin.

The Silt Unit has been identified in deeper borings east of 4th Avenue South. PSC (2003) interpreted the Silt Unit as dipping to the west, beneath the Capital Area of Investigation. It is unclear whether this unit is present beneath the Capital Area of Investigation. If present, it likely is found at a depth greater than 75 feet bgs.

The Deep Sand and Silt Unit consists of sandy silt with fine sand and interbedded silty sand, with local gravel and cobbles. Wood fragments and shells are present in trace amounts. The Intermediate Sand and Silt Unit, the Silt Unit, and the Deep Sand and Silt Unit all likely are part of the Older Alluvium defined by Booth and Herman (1998).

Bedrock consists of marine and continental sedimentary rocks consisting of claystone, siltstone, sandstone, and some coal (PSC 2003). The estimated depth to bedrock ranges from 330 to 660 feet bgs near the LDW (U.S. Geological Survey 1991).

2.4.2 Hydrogeology

The regional hydrogeology of the Capital Area of Investigation summarized below is based on information from PSC (2003) and more-recent investigations conducted at the ABP facility, the BDC facility, and the Capital Property, as well as the results of the RI field investigation.

2.4.2.1 Zones

The following hydrogeologic units, presented in order of increasing depth, have been identified in the region:

- Shallow Aquifer Zone; and
- Intermediate Aquifer Zone.

These hydrogeologic units correlate with the geologic units described in Section 2.4.1, Regional Geology, and are consistent with the terminology used by PSC (2003). The Shallow Aquifer Zone corresponds to the Shallow Sand Unit, is continuous across the region, and extends to a depth of 40 feet bgs. Groundwater in the Shallow Aquifer Zone is unconfined and appears to be hydraulically connected to the underlying Intermediate Aquifer Zone.

The Intermediate Aquifer Zone corresponds to the Intermediate Sand and Silt Unit and is continuous across the region. The Intermediate Aquifer Zone is interpreted to extend from a depth of approximately 40 to 70 feet bgs beneath the Capital Area of Investigation. In the vicinity of the PSC facility, the top of the Silt Aquitard within the Silt Unit forms the base of the Intermediate Aquifer Zone. However, as noted above, the Silt Aquitard may not be present beneath the Capital Area of Investigation. The Intermediate Aquifer Zone was inferred by PSC (2003) to discharge to the LDW to the west. The overlying Water Table Zone and the Shallow Aquifer Zone also discharge to the LDW.

PSC (2003) adopted standardized nomenclature for groundwater monitoring and sampling intervals that was incorporated into the Data Summary Report and is used in this report. For sampling purposes, the water-bearing zones have been segregated into four depth intervals that generally correspond to the upper and lower portions of the Shallow Aquifer Zone, the Intermediate Aquifer Zone, and the Deep Aquifer Zone, although the actual depth of each aquifer zone may vary in some areas. Uniform interval nomenclature was selected based on depth rather than hydraulic characteristics. The general nomenclature for the groundwater monitoring and sampling intervals developed by PSC (2003) is used for the assessment of groundwater conditions at the Capital Property for the RI. The depth intervals are as follows:

- **Water Table Zone**—This zone corresponds to approximately the upper 10 feet of the Shallow Aquifer, from first-encountered groundwater to approximately 20 feet bgs;

- **Shallow Zone**—This zone is below 20 feet bgs and above 40 feet bgs, and generally within the Shallow Aquifer Zone;
- **Intermediate Zone**—This zone includes the water-bearing zone below 40 feet bgs extending to a depth of 70 feet bgs, and may lie above the Silt Aquitard (if present in the area); and
- **Deep Aquifer Zone**—No data have been collected from the Deep Aquifer Zone in the vicinity of the Capital Area of Investigation.

3.0 TECHNICAL ELEMENTS

This section summarizes the technical elements applicable to the Capital Area of Investigation that were considered in the RI. The technical elements were developed from the RI Work Plan and modified, as appropriate, based on field observations during the RI Field Investigation.

3.1 SCREENING LEVELS

Cleanup levels have not been established for the West of 4th Area or the Capital Area of Investigation. Therefore, screening levels used to identify the concentrations of contaminants of potential concern (COPCs) that present a potential risk to human health and the environment in groundwater and soil at the Capital Area of Investigation for this RI are consistent with the PSC (2006b) levels and those defined in the Data Summary Report. The screening levels were calculated by PSC (2006b) using MTCA Modified Method B groundwater cleanup levels, modified to include Asian Pacific Island Exposure scenarios for the consumption of fish for the groundwater-to-surface-water pathway, the Federal Clean Water Act Ambient Water Quality Criteria based on human health consumption of organisms for the groundwater-to-surface-water pathway, and the Residential Exposure Scenario for inhalation of indoor air exposure pathway (PSC 2006b). The screening levels for soil are presented in Table 1, and for groundwater in the Water Table Zone, the Shallow Zone, and the Intermediate Zone in Table 2.

3.2 CONTAMINANTS OF POTENTIAL CONCERN

The RI Work Plan identified COPCs for consideration for the RI that were based on the results of prior investigations and the Agreed Order. The groundwater samples collected for the RI in the Capital Area of Investigation were analyzed for all of the COPCs in at least two of the five monitoring events. The COPCS included:

- PCE;
- TCE;
- cis-1,2-DCE;
- trans-1,2-dichloroethene (trans-1,2-DCE);

- Vinyl chloride;
- 1,4-dioxane;
- Iron; and
- Manganese.

The COPCs that have retained for consideration in the Conceptual Site Model, as discussed in Section 6 of this RI Report, are based on the chemicals that present a potential risk to human health and the environment and have known or suspected sources that affect the Capital Area of Investigation. The Agreed Order includes 1,4-dioxane, iron, and manganese as COPCs for the Capital Area of Investigation. The COPCs detected at concentrations exceeding the screening levels in the Capital Area of Investigation that are addressed in the contaminant fate and transport discussion include PCE, TCE, cis-1,2-DCE, and vinyl chloride.

3.3 AFFECTED MEDIA

Groundwater, soil, and indoor air are the media of concern for the Capital Site. One or more of the COPCs were detected exceeding screening levels in soil and groundwater in the Water Table Zone, the Shallow Zone, and the Intermediate Zone at and up- and down-gradient of the Capital Property. COPCs have been detected in soil vapor and indoor air samples at facilities within the Capital Area of Investigation. These media represent the highest probable risk to human health and the environment based on the exposure pathway analysis performed, as described in Section 6, Conceptual Site Model.

4.0 REMEDIAL INVESTIGATION FIELD PROGRAM

This section describes the RI Field Program conducted within the Capital Area of Investigation to assess the nature and extent of the COPCs that may have been released at the Capital Property. The RI Field Program was conducted in accordance with the Ecology-approved RI Work Plan and included an assessment of soil quality to ascertain the lateral and vertical extent of HVOCs in soil proximate to Capital Plant 4, collection of Tier 1 reconnaissance groundwater samples from soil borings located immediately up- and down-gradient of Capital Plant 2 and Capital Plant 4, collection of Tier 2 reconnaissance groundwater samples to characterize the lateral and vertical extent of HVOCs not fully defined by the results of the Tier 1 reconnaissance groundwater sampling, and installation and sampling of monitoring wells to assess the lateral and vertical extent of COPCs in groundwater exceeding screening levels in the Water Table Zone, the Shallow Zone, and the Intermediate Zone down-gradient of Capital Plant 2 and Capital Plant 4. Groundwater elevations were measured to define flow direction during five groundwater monitoring events.

This section provides a discussion of the aquifer characterization, tidal investigation activities, and the vapor intrusion assessment activities conducted as part of the RI Field Program. The approach and scope of work for the RI Field Program were discussed in detail in the RI Work Plan and the Vapor Intrusion Assessment Work Plan (Farallon 2008b), both approved by Ecology.

The RI Field Program included collection of soil samples from three depth intervals at five boring locations in areas east and south of Capital Plant 4 for laboratory analysis for HVOCs, and laboratory analysis of soil samples collected from three depth intervals at four boring locations up- and down-gradient of Capital Plant 2 and Capital Plant 4 for total organic carbon (TOC) content. The groundwater characterization portion of the RI Field Program included reconnaissance groundwater sampling of the Water Table Zone, the Shallow Zone, and the Intermediate Zone from 21 boring locations, and installation and sampling of 5 monitoring wells in the Water Table Zone, 1 well cluster in the Shallow and Intermediate Zones, and an additional

11 well clusters composed of monitoring wells installed in the Water Table, Shallow, and Intermediate Zones.

The soil and reconnaissance groundwater borings and monitoring well locations are shown on Figure 3. Drilling was conducted by Cascade Drilling, Inc. of Woodinville, Washington. Boring logs pertaining to the RI Field Program are provided in Appendix A. Soil and groundwater samples were submitted to OnSite Environmental Inc. of Redmond, Washington (OnSite) for laboratory analysis.

4.1 SOIL SAMPLING

Borings B14, B15, and B18 were completed in December 2008 for the Tier 1 reconnaissance groundwater sampling of the RI Field Program in areas south and east of Capital Plant 4 (Figure 3). Soil samples were collected from borings B14, B15, and B18 at depths of 2, 5, and 7 feet bgs using EPA Method 5035 sampling protocols, and submitted to OnSite for analysis for HVOCs by EPA Method 8260B.

Borings B25 and B26 were completed as part of the Tier 2 reconnaissance groundwater sampling to delineate the nature and extent of concentrations of HVOCs in soil exceeding soil screening levels. Boring B25 is located south of South Fidalgo Street, southeast of Capital Plant 4 and east of prior boring location B15. Boring B26 is located in the area east of the Gull Industries Building and west of 4th Avenue South (Figure 3).

Soil samples were collected from borings B6, B9, B13, and B17 at three discrete depth intervals between 15 and 15.5 feet, 30 and 30.5 feet, and 60 and 60.5 feet bgs at each location and were submitted for laboratory analysis for TOC content. Borings B6, B9, and B13 were located in the areas south of South Fidalgo Street, and boring B17 was located in the building north of Capital Plant 4 in the Capital Area of Investigation (Figure 3). With the exception of the soil sample collected at boring B9 at 60 to 60.5 feet bgs, the soil samples collected for TOC were analyzed by EPA Method SW9060. The soil sample collected at boring location B9 at 60 to 60.5 feet bgs was analyzed using Plumb (1981) protocols.

4.2 RECONNAISSANCE GROUNDWATER SAMPLING

The reconnaissance groundwater sampling conducted for the RI Field Program was conducted in two phases. The first-phase Tier 1 reconnaissance groundwater sampling was conducted to assess the lateral and vertical nature and extent of HVOCs in groundwater at concentrations exceeding screening levels in Water Table Zone, Shallow Zone, and Intermediate Zone groundwater down-gradient of the Capital Property and migrating to the Capital Property from up-gradient source areas. The second-phase Tier 2 reconnaissance groundwater sampling was conducted to address data gaps identified from the analytical results of the Tier 1 groundwater reconnaissance sampling, and to support selection of appropriate locations for installation of monitoring wells. The reconnaissance groundwater sampling approach for the RI Field Program is presented in the following sections.

4.2.1 Tier 1 Reconnaissance Groundwater Sampling

Tier 1 reconnaissance groundwater sampling included advancing 13 soil borings located down-gradient of Capital Plant 2 and up-, cross-, and down-gradient of Capital Plant 4 to collect reconnaissance groundwater samples at variable depths in the water column for analysis for HVOCs (Borings B6 through B18 on Figure 3).

Borings B6 through B12 were located south and down-gradient of Capital Plant 2, and borings B13 through B18 were located up-, cross-, and down-gradient of Capital Plant 4 (Figure 3). Drilling for the Tier 1 reconnaissance sampling was completed between November 10 and December 16, 2008 using direct-push drilling methods. The soil borings were completed to depths ranging from 68 to 70 feet bgs, with the exception of boring B18, which was completed at a depth of 12 feet bgs (Appendix A).

4.2.2 Tier 2 Reconnaissance Groundwater Sampling

The scope of work for Tier 2 reconnaissance groundwater sampling was developed after review and evaluation of the analytical results of the reconnaissance groundwater samples collected from Tier 1, and included advancing one soil boring located south and down-gradient of Capital Plant 4 and seven soil borings located cross- and down-gradient of Capital Plant 2 to collect reconnaissance groundwater samples for analysis for HVOCs. Borings B19 and B21 were

located down-gradient of Capital Plant 4, and borings B20, B22 through B24, B27, and B28 were located cross- and down-gradient of Capital Plant 2 (Borings B19 through B28 on Figure 3). Drilling was completed between June 29 and July 9, 2009 using direct-push drilling methods. Borings were completed to depths ranging from 68 to 78 feet bgs (Appendix A).

Reconnaissance groundwater samples were collected from each boring in each of the water-bearing zones in accordance with the RI Work Plan. The reconnaissance groundwater sampling intervals were developed by Farallon and approved by Ecology to target the water-bearing zones that may contain concentrations of HVOCs exceeding the screening levels based on the vertical distribution of concentrations of HVOCs detected in the Tier 1 reconnaissance groundwater sampling. The Tier 2 reconnaissance groundwater samples were submitted to OnSite for analysis by EPA Method 8260B.

4.3 MONITORING WELL INSTALLATION

The monitoring well network includes 40 monitoring wells and was developed to facilitate monitoring of the three water-bearing zones described in the RI Work Plan. The monitoring well network is composed of wells MW-2 through MW-6 installed within the Water Table Zone; monitoring well cluster CI-15, which includes two monitoring wells installed within the Shallow and Intermediate Zones; and monitoring well clusters CI-1, CI-7 through CI-14, CI-137, and CI-141, each of which includes three monitoring wells installed within the Water Table, Shallow, and Intermediate Zones. The monitoring well network at the Capital Area of Investigation is shown on Figure 3. Monitoring well logs are included in Appendix A).

Monitoring wells MW-1 through MW-8 were installed in February 2006, each completed within the Water Table Zone. Monitoring well clusters CI-7, CI-8, CI-10, CG-137, and CG-141 were installed in February 2010, and monitoring well clusters CI-12 and CI-15 were installed in early March 2010 following completion of the Tier 1 and Tier 2 reconnaissance groundwater monitoring. Monitoring well clusters CI-11, CI-13, and CI-14 located in the down-gradient portion of the Capital Area of Investigation were completed in May and June 2010. The monitoring wells were constructed in accordance with the procedures outlined in the Ecology-

approved Sampling and Analysis Plan (SAP) provided in Appendix A of the Groundwater Monitoring Plan (Farallon 2010a).

With two exceptions, each monitoring well was constructed using 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) well casing. Monitoring wells MW-2 and MW-6 were constructed of 4-inch-diameter PVC. The monitoring wells were constructed with 10 feet of 0.010-inch machine-slotted screen, with the exception of monitoring well CI-10-65, which was constructed with a 15-foot screen interval. The construction details for the monitoring well network are provided in Appendix A and summarized in Table 3.

The screened intervals and total depth in each monitoring well were designed to screen a discrete depth range within the Water Table Zone, the Shallow Zone, or the Intermediate Zone. The specific screened interval of each monitoring well was selected based on the results of the Tier 1 and Tier 2 reconnaissance groundwater sampling conducted as part of the RI Field Program. Well development was conducted in accordance with the protocols outlined in Attachment 1 of the SAP provided with the Groundwater Monitoring Plan (Farallon 2010a). The locations and screened intervals of the monitoring wells installed in 2010 combined with the monitoring wells completed in the Capital Area of Investigation in 2006 allow a comprehensive evaluation of both vertical and horizontal groundwater gradients, as well as collection of groundwater samples for analysis for COPCs and natural attenuation parameters within each of the three water-bearing zones across the Capital Area of Investigation.

Following installation of the monitoring wells, the horizontal and vertical coordinates of each well and the top of the casing in each monitoring well were surveyed by Professional Land Surveyors, Inc. of Issaquah, Washington, a surveyor licensed in the state of Washington, relative to the NAVD88 vertical datum.

4.4 GROUNDWATER MONITORING AND SAMPLING

A total of five quarterly groundwater monitoring and sampling events were conducted at the Capital Area of Investigation between March 2010 and March 2011. The event conducted in March 2010 included monitoring and sampling of 28 individual monitoring wells. The June, September, and December 2010 and March 2011 monitoring and sampling events included all

40 monitoring wells in the Capital monitoring well network. The sampling protocols implemented during these events are discussed in detail in the Groundwater Monitoring Plan and the Addendum to Groundwater Monitoring Plan (Farallon 2010a, 2011c) and are summarized below.

The groundwater monitoring program included conducting monitoring well inspections prior to sampling, measuring groundwater levels at each monitoring well, and groundwater quality sampling. An inspection of the condition of each monitoring well was conducted concurrently with collection of water-level measurements. Field personnel noted the condition of the flush-mounted monument, monument seal, and casing to identify required maintenance activities. Water-level monitoring events were coordinated with ABP, BDC, and PSC to ensure that measurements were taken on approximately the same day. Water-level measurements were completed before each quarterly groundwater quality sampling event was initiated. Water-level measurements were collected in accordance with the procedure described in the SAP provided in Appendix A of the Groundwater Monitoring Plan (Farallon 2010a).

Each monitoring well was purged at a low-flow rate using a decontaminated bladder pump or dedicated down-hole submersible pump (monitoring well installations C1-M1, CI-137, and CG-141), with the intake placed at the approximate mid-point of the well screen interval or the mid-point between the water table and the bottom of the well screen if the water table was lower than the top of the well-screen interval. The parameters temperature, pH, conductivity, dissolved oxygen, and oxidation-reduction potential were monitored using a Yellow Springs Instruments multi-parameter water-quality meter equipped with a flow-through cell during purging to ascertain when stabilization of these parameters occurred. Following stabilization of the temperature, pH, conductivity, dissolved oxygen, and oxidation-reduction potential, groundwater samples were collected directly from the low-flow pump outlet.

The quarterly groundwater sampling and analysis program implemented as part of the RI Field Program included collecting groundwater samples for analysis for HVOCs during five quarterly events, and supplemental analyses as specified in the Ecology-approved Groundwater Monitoring Plan (Farallon 2010a). Because not all Capital Site groundwater monitoring well network wells had been installed at the time of the March 2010 quarterly event, monitoring and

sampling was conducted in March 2011 to provide four consecutive quarterly events for the entire well network. The quarterly groundwater monitoring and sampling program was implemented in accordance with the procedures described in the Ecology-approved Groundwater Monitoring Plan and SAP (Farallon 2010a). The laboratory analytical program for the five quarterly monitoring and sampling events is summarized below:

- **Quarter 1 2010 (March 2010)**—Analysis included HVOCs by EPA Method 8260B of groundwater samples collected from all monitoring wells installed at that time.
- **Quarter 2 2010 (June 2010)**—Analysis included HVOCs by EPA Method 8260B; 1,4-dioxane by EPA Method 8270C; total and dissolved manganese and iron by EPA Method 6010; and natural attenuation parameters, as discussed in the SAP (Farallon 2010a). Analysis for HVOCs; 1,4-dioxane; and total and dissolved manganese and iron was conducted at monitoring wells throughout the Capital Site monitoring well network. Analysis for natural attenuation parameters was conducted at monitoring well clusters MW-7/CI-7, CI-9, CI-10, CI-11, CI-13, and CG-137 in the Capital monitoring well network.
- **Quarter 3 2010 (September 2010)**—Analysis included HVOCs by EPA Method 8260B of groundwater samples collected from all monitoring wells in the Capital Site monitoring well network.
- **Quarter 4 2010 (December 2010)**—Analysis included HVOCs by EPA Method 8260B of groundwater samples collected from all monitoring wells in the Capital Site monitoring well network, and analysis for natural attenuation parameters at monitoring well clusters MW-7/CI-7, CI-9, CI-10, CI-11, CI-13, and CG-137 in the Capital Site monitoring well network.
- **Quarter 1 2011 (March 2011)**—Analysis included HVOCs by EPA Method 8260B of groundwater samples collected from all monitoring wells within the Capital Site monitoring well network and analysis for 1,4-dioxane by EPA Method 8270C at monitoring wells CI-7-40 and CI-7-60, CI-8-40 and CI-8-60, CI-9-40 and CI-9-70, CI-MW-1-40 and CI-MW-1-60, and CI-15-60.

4.5 AQUIFER CHARACTERIZATION—TIDAL STUDY AND SLUG TEST

A tidal study was performed to assess tidal influences on groundwater elevations and gradients near the LDW. The Tidal Study was conducted in accordance with the Ecology-approved Groundwater Monitoring Plan (Farallon 2010a). Field activities were conducted in July and August 2010 and consisted of a multi-well tidal study and aquifer characterization using slug tests in selected monitoring wells. The tidal study evaluated the effects of the inland propagation of the pressure wave caused by the rise in surface water in the LDW that can cause groundwater levels and both horizontal and vertical gradients to fluctuate. Filtering methods developed by Serfes (1991) were used to determine tidally averaged groundwater elevations. These data were then used to calculate the mean hydraulic gradients (horizontal and vertical) and the direction of groundwater flow at various times during the tidal cycle. Hydraulic conductivity also was estimated from the tidal data using the methods of Ferris (1963).

To further evaluate hydraulic conductivity in aquifer zones within the Capital Area of Investigation, slug tests were performed in a total of 12 monitoring wells. A detailed description of the tidal study and slug testing methods is provided in Appendix B.

4.6 VAPOR INTRUSION ASSESSMENT

The VI Assessment program was conducted to evaluate the VI exposure pathway for migration of VOCs to ambient indoor air of commercial and industrial buildings located within the Capital Area of Investigation, as defined in the Ecology-approved Vapor Intrusion Assessment Work Plan (Farallon 2008b).

The VI Assessment was conducted in accordance with the Revised Inhalation Pathway Interim Measures [IPIM] Work Plan prepared by PSC (2002), the Summary of Inhalation Pathway Interim Measure Approach prepared by PSC (2006a), and the Interim Vapor Intrusion Plan, West of 4th Avenue South Investigation Area, Seattle, Washington prepared by Arrow Environmental et al. (2007). A detailed scope of work is provided in the Vapor Intrusion Assessment Work Plan, Capital Industries, Inc. (Farallon 2008b) and the Addendum to the Vapor Intrusion Assessment Work Plan, Capital Industries, Inc. (Farallon 2011a), summarized below.

The IPIM Approach used for the VI Assessment program included four tiers of assessment:

- **Tier 1 and Tier 2 Assessments**—Concentrations of VOCs detected in reconnaissance groundwater samples collected from direct-push borings and in groundwater samples collected from monitoring wells in the Water Table Zone proximate to residential and commercial buildings were compared to the Groundwater IPIM Action Levels defined in the IPIM Approach (PSC 2002, 2006b). Tier 1 Assessments are conducted at target residences where concentrations of VOCs exceed the groundwater IPIM Action Levels; however, no residences are located within the Capital Area of Investigation. Tier 2 Assessments were conducted at commercial and industrial properties.
- **Tier 3 Assessment**—Commercial and industrial properties located within the Capital Area of Investigation and situated above groundwater in the Water Table Zone with concentrations of VOCs exceeding the Groundwater IPIM Action Levels defined by PSC (2006b) were identified under the Tier 2 Assessment as having a potential for a VI exposure pathway. A Tier 3 Assessment was conducted at these buildings, which included collection of co-located indoor ambient air, outdoor ambient air, and/or sub-slab soil vapor and groundwater samples and analysis for VOCs. Concentrations of VOCs in indoor ambient air relative to outdoor ambient air were evaluated and Noncarcinogenic and Carcinogenic Cumulative Exceedance Factors were calculated and compared to a benchmark of 10 in accordance with the IPIM Approach (PSC 2002, 2006a). The Tier 3 Assessment (sampling) for three remaining buildings is ongoing (Figure 4). The results of the Tier 3 Assessment are summarized in Section 5.4 of this report and will be reported under separate cover.
- **Tier 4 Assessment**—Commercial and industrial locations where concentrations of VOCs in indoor ambient air exceed the Exceedance Factors (PSC 2002, 2006a) require interim measures to mitigate or eliminate the VI exposure pathway from groundwater to indoor ambient air. Interim measures for commercial and industrial locations may include subsurface ventilation, as defined by PSC (2002, 2003, 2006a). A description of the design and implementation of mitigation systems for indoor ambient air that have been installed within the Capital Area of Investigation is summarized in Section 5.4 of this

report. A detailed summary of mitigation systems that may be necessary at buildings within the Capital Area of Investigation will be provided in the Vapor Intrusion Mitigation Work Plan that will be prepared specific to each building in accordance with the Agreed Order.

5.0 REMEDIAL INVESTIGATION RESULTS

The following section provides a summary of the results of the soil, reconnaissance groundwater, and monitoring well sampling and analyses pertaining to the RI Field Program. Figures 7 through 21 present the interpreted groundwater flow direction and the areal nature and extent of TCE, PCE, and vinyl chloride as isoconcentration lines for the Water Table Zone, the Shallow Zone, and the Intermediate Zone for each of the five groundwater monitoring events. The interpretation incorporates the data collected within the Capital Area of Investigation by Farallon as well as the data collected by PGG at the BDC facility located north and up-gradient of the Capital Property. The analytical data used to develop the interpretation of groundwater flow direction and the nature and extent of TCE, PCE, and vinyl chloride are summarized on Tables 3 and 7.

Interpretation of the subsurface soil stratigraphy and vertical nature and extent of TCE, PCE, and vinyl chloride as isoconcentration lines is shown on northeast-southwest cross-section A-A' that extends through the BDC facility-Capital Plant 4 to Slip 2 of the LDW (Figures 23 and 23a), east-west cross-section B-B' that extends from 1st Avenue South to 4th Avenue South through the southern portion of the Capital Property (Figures 24 and 24a), and northeast-southwest cross-section C-C' that extends from Capital Plant 4 to monitoring well CI-11 (Figures 25 and 25a). A detailed interpretation of the areal and vertical nature and extent of TCE, PCE, and vinyl chloride in a Conceptual Site Model is provided in Section 6.

5.1 SOIL SAMPLING RESULTS

The RI soil sampling program was conducted to address data gaps in the nature and extent of HVOCs in soil delineated by previous investigation, as defined in the RI Work Plan. Contamination detected during previous investigations. The following summarizes the results of soil investigations performed at the Capital Property prior to the RI, and the results of the RI field investigation.

A total of 41 soil samples were collected from 18 soil borings located in and around Capital Plant 2 and Capital Plant 4 in 2004 and 2005 (ECS 2005). The analytical data are presented on Figures 5 and 6 and in data tables in Appendix C. PCE and TCE were not detected exceeding

soil screening levels in soil samples collected in and around Capital Plant 2. PCE was detected exceeding the screening level in 10 soil samples collected from five locations at Capital Plant 4 where concentrations ranged from 0.0045 to 0.038 milligrams per kilogram (mg/kg). TCE was detected in 14 soil samples from six borings located in and around Capital Plant 4, with concentrations from 0.0024 to 0.14 mg/kg. Cis-1,2-DCE was detected exceeding screening levels in six soil samples collected from three borings located in and around Capital Plant 4.

FSM (2004) conducted soil vapor monitoring during the reconstruction of Capital Plant 2 after the plant was destroyed by fire in 2004. TCE was detected in 2 of 12 soil vapor samples collected, and PCE in 10 of 12 soil vapor samples collected during the reconstruction. Soil within the building footprint was excavated and removed to a depth of approximately 5 feet bgs. Approximately 330 cubic yards of soil was removed for disposal off the Site based on elevated photoionization detector field measurements.

Farallon (2009b) collected 36 soil samples from 13 borings (B1 to B5) and monitoring wells (MW-1 to MW-8) located on the Capital Property in 2006 (Figures 3 through 5). TCE was detected in soil samples collected from boring locations MW-1 and MW-2 at a depth of 15 to 16.5 and 8.5 to 9 feet bgs, respectively. The soil samples were collected below the depth at which groundwater was encountered at approximately 8 feet bgs; therefore, these results likely represent groundwater conditions. TCE was not detected in soil samples collected at shallower depths at these borings. Cis-1,2-DCE was detected exceeding the screening level in samples collected from MW-2, MW-3, and B3; however, the soil samples were collected from below groundwater and likely reflect groundwater conditions. Vinyl chloride was detected in soil samples collected from borings B1, B2, and B5 at depths ranging from 29.5 to 40 feet bgs, below groundwater and represents groundwater conditions. PCE, TCE, and/or cis-1,2-DCE were detected at concentrations exceeding screening levels in soil samples collected from above the Water Table in monitoring well borings MW-6 and MW-7, located in and down-gradient of Capital Plant 4. The data are presented on Figures 5 and 6, and summarized in Table 4.

Soil encountered in the borings completed for the RI within the Capital Area of Investigation consisted of poorly graded sand with lesser amounts of silty sand and silt (Appendix A). The upper 10 feet of soil that underlies the area consists of silt and sand with minor amounts of

poorly graded gravel. Poorly graded fine black sand was encountered in each of the borings from approximately 10 feet bgs to the total depth explored of 78 feet bgs. Thin discontinuous layers of silt and sandy silt ranging from approximately 0.3 foot to 9 feet in thickness were encountered at varied depths within the sand and were observed to increase in thickness and frequency between the depths of approximately 25 and 45 feet bgs. Increasing amounts of silt were noted in the sand at depths greater than 45 feet bgs, with frequent observations of silty sand and sandy silt.

Organic material consisting of woody debris was observed in soil samples collected from borings B8, B9, B14, B21, B24, and B26 at depths ranging from the ground surface to 56 feet bgs. Odor or sheen was not observed in the soil samples collected from the borings, with the exception of borings B17 and B25. A slight, “sweet” odor was noted in the soil sample collected from boring B17 at depths of 24 to 57 feet bgs within the Shallow Zone and the Intermediate Zone. Concentrations of VOCs were elevated in soil samples collected from boring B17 at depths of 7.5 to 57 feet bgs. An odor was noted in the soil sample collected from boring B25 at depths of 0.25 foot to 4.5 feet bgs. VOCs measured in the field were elevated in the soil sample collected from boring B25 at a depth of 2 feet bgs. Elevated VOCs were not measured in the field in soil samples collected from any other borings completed during the RI Field Program.

The soil sampling conducted during the RI Field Program focused on evaluating the lateral and vertical extent of HVOCs in soil proximate to Capital Plant 4. Concentrations of PCE and/or TCE exceeding applicable screening levels were detected in soil samples collected from above the Water Table in borings B14, B15, B18, and B25 (Table 4). Concentrations of PCE ranging from 0.0039 to 0.091 mg/kg were detected in soil samples collected at depths ranging from 2 to 7 feet bgs at borings B14, B15, B18, and B25. Concentrations of TCE ranging from 0.0035 to 0.024 mg/kg were detected in soil samples collected at depths ranging from 2 to 7 feet bgs at borings B14, B18, and B25. Borings B14, B15, and B25 are located south of Capital Plant 4. Boring B-18 is located east of Capital Plant 4 (Figure 6; Table 4). The HVOCs 1,1-dichloroethene (1,1-DCE), cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride were not detected at concentrations at or above the laboratory PQLs or exceeding applicable screening levels in any of the other soil samples analyzed.

The northern extent of HVOC concentrations exceeding the screening levels detected in soil is defined by boring ECS41 (Figure 5) in the area south of the northeast corner of Capital Plant 4, installed during a previous subsurface investigation (ECS 2005). The southern extent of HVOC concentrations exceeding the screening levels detected in soil is defined by boring B26 (Figure 4). The lateral extent of HVOCs exceeding the screening levels in soil east of the Capital Property has not been defined.

Soil samples were collected for TOC analysis within the Water Table Zone, the Shallow Zone, and the Intermediate Zone at boring locations B6, B9, B13, and B17. Concentrations of TOC ranging from 80 to 1,220 mg/kg were detected in soil samples collected from the Water Table Zone, with an average TOC concentration of 488 mg/kg; 380 to 2,100 mg/kg in soil samples collected from the Shallow Zone, with an average TOC concentration of 1,388 mg/kg; and 680 to 5,120 mg/kg in soil samples collected from the Intermediate Zone, with an average TOC concentration of 2,045 mg/kg (Table 5).

5.2 RECONNAISSANCE GROUNDWATER SAMPLING RESULTS

The observed groundwater conditions and analytical results for Tier 1 and Tier 2 reconnaissance groundwater samples collected during the RI Field Program are presented below. Groundwater was first encountered in the borings during drilling at depths ranging from 6 to 16 feet bgs. Saturated soils extended from first-encountered groundwater throughout the total depth of each boring.

The laboratory analytical results for the reconnaissance groundwater samples collected during the RI Field Program are summarized below for each of the three water-bearing zones. The laboratory analytical results are summarized in Table 6. The laboratory analytical reports and the data validation summary report are included in Appendix D.

5.2.1 Water Table Zone

The laboratory analytical results for the reconnaissance groundwater samples collected from the Water Table Zone are summarized as follows (Table 6):

- Concentrations of vinyl chloride exceeding the screening level were detected in the reconnaissance groundwater samples collected in boring B17 located north and up-gradient of the Capital Property, and in the reconnaissance groundwater samples collected in borings B6, B7, B21, and B22 located south and down-gradient of the Capital Property.
- Concentrations of PCE exceeding the screening level were detected in the reconnaissance groundwater samples collected in borings B13, B14, and B15 located down-gradient of Capital Plant 4, and in boring B18 located cross-gradient and east of Capital Plant 4.
- Concentrations of TCE exceeding the screening level were detected in the reconnaissance groundwater samples collected in borings B7 through B9, B12 through B15, B18, and B23.
- Concentrations of 1,1-dichloroethene 1,1-DCE and trans-1,2-DCE detected above the laboratory PQL were below screening levels.
- Concentrations of cis-1,2-DCE exceeding the screening level were detected in the reconnaissance groundwater samples collected in borings B8, B9, and B23.

5.2.2 Shallow Zone

The laboratory analytical results for the reconnaissance groundwater samples collected from the Shallow Zone are summarized as follows (Table 6):

- Concentrations of vinyl chloride exceeding the screening level were detected in reconnaissance groundwater samples collected in borings B17 and B28 located up-gradient of the Capital Property and in the reconnaissance groundwater samples collected in borings B6 through B13, B15, B16, B20 through B23, and B27 located down-gradient of the Capital Property.

- PCE was not detected at concentrations exceeding either the laboratory PQLs or the screening level in the reconnaissance groundwater samples analyzed.
- Concentrations of TCE exceeding the screening level were detected in the reconnaissance groundwater samples collected in borings B7, B8, B9, B12, and B23.
- Concentrations of 1,1-DCE and trans-1,2-DCE detected above the laboratory PQLs were below screening levels.
- Concentrations of cis-1,2-DCE exceeding the screening level were detected in the reconnaissance groundwater samples collected in borings B9 and B23.

5.2.3 Intermediate Zone

The laboratory analytical results for the reconnaissance groundwater samples collected from the Intermediate Zone are summarized as follows (Table 6):

- **Vinyl chloride** exceeded the screening level in the reconnaissance groundwater samples collected in borings B17 and B28 located up-gradient of the Capital Property and in the reconnaissance groundwater samples collected in borings B6 through B13, B15, B20, and B23 located down-gradient of the Capital Property.
- **PCE** did not exceed either the laboratory PQLs or the screening level.
- **TCE** exceeded the screening level in the reconnaissance groundwater samples collected in borings B8, B9, and B23. TCE was not detected at concentrations exceeding the screening level in reconnaissance groundwater samples collected from other borings.
- **1,1-DCE and trans-1,2-DCE** detected above the laboratory PQLs were below screening levels.
- **Cis-1,2-DCE** exceeded the screening level in the reconnaissance groundwater sample collected in boring B23.

5.2.4 Reconnaissance Groundwater Sampling Summary

PCE was detected at concentrations at or exceeding the screening levels in the reconnaissance groundwater samples collected from the Water Table Zone in borings B13, B14, and B16, located proximate to Capital Plant 4 (Table 6). PCE was not detected at concentrations at or

above the laboratory PQLs or exceeding the screening level in the reconnaissance groundwater samples collected from the Water Table Zone in any of the other borings or from the Shallow Zone or the Intermediate Zone.

TCE was detected at concentrations exceeding the screening level in reconnaissance groundwater samples collected from borings located up-gradient of the Capital Property in the Water Table Zone and the Shallow Zone, and in the Water Table Zone, the Shallow Zone, and the Intermediate Zone in borings located down-gradient of the Capital Property (Table 6). Concentrations of cis-1,2-DCE exceeding the screening level were detected in the reconnaissance groundwater samples collected from all three water-bearing zones in borings located down-gradient of the Capital Plan, co-located with concentrations of TCE, as characterized by the laboratory analytical results for the reconnaissance groundwater samples collected from borings B8, B9, and/or B23 (Table 6).

Vinyl chloride was detected at concentrations exceeding the screening level in reconnaissance groundwater samples collected from all of the water-bearing zones in borings located up- and down-gradient of the Capital Property (Table 6). Concentrations of vinyl chloride exceeding the screening level in the Shallow Zone east and southeast of the Capital Property is characterized by the laboratory analytical results for the reconnaissance groundwater samples collected from borings B19 and B24. The lateral and vertical extent of concentrations of vinyl chloride exceeding the screening level in the Intermediate Zone is characterized by the laboratory analytical results for the reconnaissance groundwater samples collected from borings B19, B21, B22, B24, and B27 (Table 6).

The results of the Tier 1 and Tier 2 reconnaissance groundwater sampling were evaluated to identify data gaps for selection of monitoring well locations and screening depths. Farallon (2009b) proposed monitoring well locations to Ecology in the Remedial Investigation Field Program First Phase Report, and met with Ecology to confirm approval of the final monitoring well locations presented in the Groundwater Monitoring Plan (Farallon 2010a).

5.3 MONITORING WELL SAMPLING RESULTS

The laboratory analytical results for the five quarterly groundwater monitoring and sampling events conducted during the RI Field Program are summarized below for each of the three water-bearing zones. Monitoring wells CI-9-WT, CI-9-40, CI-9-70, CI-11-WT, CI-11-30, CI-11-60, CI-13-WT, CI-13-30, CI-13-60, CI-14-WT, CI-14-35, and CI-14-70 were installed after the March 2010 monitoring event. All of the quarterly groundwater monitoring included analysis of groundwater samples for HVOCs. 1,4-dioxane was analyzed only in groundwater samples collected from select monitoring wells in the June 2010 and March 2011 monitoring events (Table 9). The laboratory analytical results for groundwater samples collected by Farallon from monitoring wells installed in the Capital Area of Investigation and by PGG installed at the BDC area are summarized in Tables 7, 8, and 9. Monitoring well locations are shown on Figure 3. The laboratory analytical reports and the data validation summary report for the monitoring well analyses are provided in Appendix D.

5.3.1 Water Table Zone

The laboratory analytical results for the groundwater samples collected from monitoring wells screened in the Water Table Zone are summarized as follows:

- **Vinyl chloride** exceeded the screening level in up-gradient monitoring well MW-5 and in down-gradient monitoring well CI-11-WT for four of the five quarterly monitoring events. Concentrations of vinyl chloride did not exceed the screening level in monitoring wells MW-5 or CI-11-WT in the March 2011 monitoring event. Vinyl chloride exceeded the screening level in down-gradient monitoring well CG-137-WT in all five quarterly monitoring events. A concentration of vinyl chloride exceeding the screening level was detected in monitoring well CI-14-WT in the December 2010 quarterly monitoring event only.
- **PCE** exceeded the screening level in up-gradient monitoring well CI-MW1-WT, down-gradient monitoring wells CI-9-WT and CI-14-WT, and monitoring wells MW-6 and MW-7, located proximate to Capital Plant 4, in all of the quarterly monitoring events.

- **TCE** exceeded the screening level in up-gradient monitoring wells MW-5 and CI-MW-1-WT and at down-gradient monitoring wells MW-2, MW-3, MW-4, MW-6, MW-7, CI-9-WT, CI-10-WT, CI-14-WT, and CG-137-WT in all of the quarterly monitoring events.
- **1,1-DCE and trans-1,2-DCE** did not exceed the screening levels in any of the groundwater samples analyzed.
- **cis-1,2-DCE** exceeded the screening level in monitoring well MW-5 in four of the five quarterly monitoring events. Concentrations of cis-1,2-DCE did not exceed the screening level in monitoring well MW-5 in the March 2011 monitoring event.
- **1,4-dioxane**—did not exceeded the screening level in any of the monitoring wells.

5.3.2 Shallow Zone

The laboratory analytical results for the groundwater samples collected from monitoring wells screened in the Shallow Zone are summarized as follows:

- **Vinyl chloride** exceeded the screening level in groundwater samples collected from all of the monitoring wells for all of the monitoring events, with the exception of the March 2011 monitoring event in monitoring wells CI-11-30 and CI-13-30, and all of the monitoring events in monitoring wells CI-9-40 and CI-MW-40.
- **PCE** was not detected at concentrations at or above the laboratory PQLs or exceeding the screening level in any of the monitoring wells in any of the monitoring events.
- **TCE** exceeded the screening level in groundwater samples collected from down-gradient monitoring wells CI-10-35 and CI-14-35 in all of the quarterly monitoring events.
- **1,1-DCE and trans-1,2-DCE** did not exceed the screening levels in any of the monitoring wells in any of the monitoring events.
- **cis-1,2-DCE** did not exceed the screening level in any of the monitoring wells in any of the monitoring events.
- **1,4-dioxane** exceeded the screening level in groundwater samples collected from monitoring well CI-8-40, located up-gradient of Capital Plant 4, and from monitoring well CI-7-40, located down-gradient of Capital Plant 4, in the June 2010 monitoring

event only. Concentrations of 1,4-dioxane exceeding the screening level were not detected at these two locations or in any of the other monitoring wells during the March 2011 monitoring event.

5.3.3 Intermediate Zone

The laboratory analytical results for the groundwater samples collected from monitoring wells screened in the Intermediate Zone are summarized as follows:

- **Vinyl chloride** exceeded the screening levels in groundwater samples collected from down-gradient monitoring wells CG-141-50 and CI-15-60 in all five quarterly monitoring events and from down-gradient monitoring well CI-137-50 in all of the monitoring events except the June 2010 monitoring event.
- **PCE** was not detected at concentrations at or above the laboratory PQLs or exceeding the screening level in any of the monitoring wells for any of the monitoring events.
- **TCE** exceeded the screening level in the groundwater samples collected from monitoring well CI-137-50 in the June 2010 monitoring event only.
- **1,1-DCE and trans-1,2-DCE** did not exceed the screening levels in any of the groundwater samples analyzed.
- **cis-1,2-DCE** did not exceed the screening levels in any of the groundwater samples analyzed.
- **1,4-dioxane** exceeded the screening level in groundwater samples collected from monitoring well CI-MW1-60, located up-gradient of Capital Plant 2, and at monitoring well CI-7-60, located down-gradient of Capital Plant 4, in the June 2010 monitoring event only. Concentrations of 1,4-dioxane exceeding the screening level were not detected at these two locations or in any of the other monitoring wells sampled for 1, 4-dioxane during the March 2011 monitoring event.

5.3.4 Iron and Manganese Groundwater Analytical Results

Groundwater samples were collected from select monitoring wells within the Capital Area of Investigation during the June and December 2010 monitoring events and analyzed for the

presence of ferric iron and manganese. Analyses for these constituents were conducted at 16 Water Table Zone monitoring wells, 12 Shallow Zone monitoring wells, and 12 Intermediate Zone monitoring wells in June 2010. Sampling and analysis activities included 8 Water Table Zone monitoring wells, 7 Shallow Zone monitoring wells, and 6 Intermediate Zone monitoring wells in December 2010 (Table 10).

Concentrations of ferric iron exceeding the screening level of 100 micrograms per liter ($\mu\text{g/l}$) were detected at all monitoring wells sampled during the two monitoring events. Ferric iron concentrations ranged from 380 to 58,000 $\mu\text{g/l}$ in the Water Table Zone, from 6,600 to 46,000 $\mu\text{g/l}$ in the Shallow Zone, and from 1,200 to 32,000 $\mu\text{g/l}$ in the Intermediate Zone.

Concentrations of manganese exceeding the screening level of 1,000 $\mu\text{g/l}$ were detected at monitoring well MW-4 in the Water Table Zone and at monitoring well CI-9-70 and up-gradient monitoring well CI-MW-1-60 in the Intermediate Zone. Manganese was not detected at concentrations exceeding the screening level in the groundwater monitoring wells sampled in the Shallow Zone within the Capital Area of Investigation.

5.3.5 Monitored Natural Attenuation Parameters Sampling Results

Groundwater samples collected during the June and December 2010 quarterly groundwater monitoring event were analyzed for natural attenuation parameters, including:

- Alkalinity by EPA Method 310.2;
- Sulfate by EPA Method 375.4;
- Sulfide by EPA Method 376.1;
- Nitrate and nitrite by EPA Method 353.2;
- Chloride by EPA Method 325.2/325.3; and
- Methane, ethane, and ethane by EPA Method 8015B.

The laboratory analytical results for the two quarterly groundwater monitoring and sampling events that included the monitored natural attenuation parameters conducted during the RI Field Program are summarized in Table 10 for each of the three water-bearing zones. Monitoring well locations are shown on Figure 3. The laboratory analytical reports and the data validation summary report for the monitoring well analyses are provided in Appendix D.

A discussion of these results and the potential for natural attenuation of COPCs is provided in Section 7.1.5, Monitored Natural Attenuation Data.

5.3.6 Groundwater Gradient and Flow Direction

Groundwater monitoring events were conducted by Capital, BDC, ABP, and PSC from February 2010 through January 2011 for monitoring wells screened in the Water Table Zone, the Shallow Zone, and the Intermediate Zone and located west of 4th Avenue South, as part of the RI for the Capital Area of Investigation. The groundwater elevation data for the 2010 and 2011 groundwater monitoring events are included in Table 3. The groundwater elevation contours for groundwater monitoring events conducted in February, May, August, and October 2010 and January 2011 are shown on Figures 7 through 21. The results of the 2010 and 2011 groundwater monitoring events indicate the following:

- The depth to groundwater ranged from 5.39 to 10.06 feet below the top of the monitoring well casings in the monitoring wells screened in the Water Table Zone, the Shallow Zone, and the Intermediate Zone.
- The potentiometric head differences for nested monitoring wells screened in the Water Table Zone, the Shallow Zone, and the Intermediate Zone for the Capital Area of Investigation were negligible, indicating that vertical hydraulic gradient is not a factor in vertical transport of contaminants.

Water Table Zone

- The approximate direction of groundwater flow in the Water Table Zone for the Capital Area of Investigation for all of the monitoring events was to the southwest, with very little deviation. A slight southerly deflection in the groundwater flow direction for the Water Table Zone was noted in the vicinity of the intersection of 1st Avenue South and East Marginal Way for the May 2010 monitoring event (Figure 7), and a slightly more westerly direction in the same area was noted for the December 2010 monitoring event (Figure 10). The cause of the shift in groundwater flow is not clear, but may be seasonal variations in groundwater elevations or other factors.

- The average horizontal hydraulic gradient for the Water Table Zone for the Capital Area of Investigation ranged from 0.002 to 0.003 foot per foot.

Shallow Zone

- The approximate direction of groundwater flow in the Shallow Zone for the Capital Area of Investigation was southwest. A slight southerly deflection in the groundwater flow direction for the Shallow Zone was noted in the vicinity of the intersection of 1st Avenue South and East Marginal Way for the June and September 2010 monitoring events (Figures 13 and 14, respectively).
- The average horizontal hydraulic gradient for the Shallow Zone in the Capital Area of Investigation ranged from 0.001 to 0.002 foot per foot.

Intermediate Zone

- The approximate direction of groundwater flow in the Intermediate Zone for the Capital Area of Investigation during the 2010 and 2011 groundwater monitoring events was southwest.
- The average horizontal hydraulic gradient for the Intermediate Zone in the Capital Area of Investigation was 0.002 foot per foot.

5.3.7 Tidal Study and Aquifer Characterization

A tidal study was conducted at the Capital Area of Investigation in July and August 2010 in accordance with the scope of work approved by Ecology in the Groundwater Monitoring Plan (Farallon 2010a). The tidal study was performed to assess tidal influences on groundwater elevations and gradients near Slip 2 of the LDW (Figure 3). The tidal study evaluated the effects of the inland propagation of the pressure wave caused by the rise in surface water in the LDW that can cause groundwater levels and horizontal and vertical gradients to fluctuate. Detailed results from the tidal study and aquifer characterization study are included in Appendix B.

The results of the tidal study show that the hydraulic gradient and groundwater flow direction in the three aquifer zones are relatively consistent during a tidal cycle and that tidal influence extends approximately 600 to 700 feet inland from the bank of Slip 2 of the LDW. Although

minor variations in flow direction occur as a result of tidal influence, the flow direction from the Capital Property remains predominantly southwest toward Slip 2 of the LDW during a tidal cycle.

Hydraulic conductivity estimates obtained using both tidal data and slug test results indicate relatively high hydraulic conductivity in the Water Table Zone and the Shallow Zone (approximately 100 to 200 feet per day). Hydraulic conductivity in the Intermediate Zone appears to be lower than that in the Water Table Zone based on slug test results (approximately 5 to 10 feet per day). The results of the slug test are included in Appendix B.

5.4 VAPOR INTRUSION ASSESSMENT RESULTS

5.4.1 Tier 1 and Tier 2 Assessments

The concentrations of VOCs detected in groundwater samples collected from the Water Table Zone were compared to groundwater IPIM Action Levels to determine whether the potential for VI exists in nearby buildings. The analytical results for groundwater samples that trigger Tier 3 Assessment in the buildings at and south of the Capital Property were reported in the letter regarding Vapor Intrusion Tier 2 Assessment (Farallon 2010b) and are summarized below.

The analytical results for groundwater samples collected from the following monitoring wells identified these associated buildings for Tier 3 VI assessment (Figure 4):

- Monitoring well CI-MW-1-WT—Capital Plant 2;
- Monitoring well MW-2—Capital Plant 2 Canopy Area;
- Monitoring well MW-5—Capital Plant 1, Capital Plant 2, and Capital Plant 2 Canopy Area;
- Monitoring well CI-9-WT—Mobile Crane Office Building canopy structures;
- Monitoring well CI-10-WT—Beckwith and Kuffel Building; and
- Monitoring well CG-137-WT—Capital Plant 2 Canopy Area, Olympic Medical Building, and Mobile Crane Office Building.

Based on the IPIM Approach approved by Ecology, a Tier 3 Assessment of the commercial buildings located on the east side of Capital Plant 4 was not warranted. However, concentrations of VOCs were detected in soil samples collected between the east wall of Capital Plant 4 and the west wall of the commercial buildings to the east at 2 to 5 feet bgs (Figure 6). Based on the concentrations of VOCs detected in soil samples ECS-1, ESC-39, and ECS-40 (Figure 6), a Tier 3 Assessment was not warranted in the northernmost commercial building. The concentrations of VOCs detected in soil samples ESC-28 and ECS-38 located proximate to the three southernmost commercial buildings, indicated that a Tier 3 Assessment was warranted. The Gull Industries Building was included for Tier 3 Assessment based on concentrations of VOCs detected in reconnaissance groundwater samples (Farallon 2010c).

The buildings identified for Tier 3 Assessment included:

- Shipping office in Capital Plant 1;
- Laser QC office in Capital Plant 2;
- Mobile Crane Office Building;
- Beckwith and Kuffel Building;
- Olympic Medical Building;
- Commercial building east of Capital Plant 4 (Chinese Restaurant);
- Commercial building east of Capital Plant 4 (Pacific Food Systems, Northern Building);
- Commercial building east of Capital Plant 4 (Pacific Food Systems, Southern Building);
- and
- Gull Industries Building south of Capital Plant 4.

5.4.2 Tier 3 Assessment

A Tier 3 Assessment of the Olympic Medical Building was completed in 2008 (Farallon 2008b). The results of the Tier 3 Assessment indicated that Tier 4 Mitigation was required, as discussed below.

Inspections of all the buildings except the Gull Industries Building were completed in March 2011. Site-specific SAPs were prepared for each of the buildings identified for Tier 3 Assessment, with the exception of the Gull Industries Building. All of the prepared SAPs were approved by Ecology. Preparation of a SAP for the Gull Industries Building is pending receipt of access approval from the building tenants.

Tier 3 Assessments were conducted on April 13 and 14, 2011 at five of the buildings identified. Building-specific indoor air and/or sub-slab samples have been collected and analyzed and the data are being evaluated. The results of the Tier 3 Assessment will be provided in a Tier 3 Vapor Intrusion Assessment Report for each individual building under separate cover.

5.4.3 Tier 4 Mitigation

Tier 4 Mitigation has been instituted at the Olympic Medical Building. The need for VI mitigation was determined based on the evaluation of analytical results for ambient air samples collected from previous VI investigations. The evaluation was conducted in accordance with the Vapor Intrusion Assessment Work Plan (Farallon 2008b).

A Tier 3 Assessment was conducted at the Olympic Medical Building by PSC (2005) by sampling ambient indoor and outdoor air to determine whether commercial ambient air Cumulative Exceedance Factors (CEFs) and Noncancer Exceedance Factors exceeded the benchmark of 10 established by Ecology. Commercial indoor air CEFs calculated from concentrations of TCE detected in indoor ambient air samples collected at the Olympic Medical Building exceeded this benchmark (PSC 2006b). Based on the concentrations of TCE detected in indoor ambient air, a mitigation system was proposed by PSC for the warehouse area on the east side of the Olympic Medical Building.

A Sub-Slab Depressurization System was installed at the Olympic Medical Building on January 29, 2009 in accordance with the Vapor Intrusion Mitigation Work Plan, Olympic Medical Facility (Farallon 2009a). The Sub-Slab Depressurization System currently is operating in accordance with the Vapor Intrusion, Inspection, Monitoring, and Maintenance Work Plan, Olympic Medical Facility (Farallon 2009c).

5.5 DATA VALIDATION

Farallon performed data review and validation of analytical data received from the RI field investigation, including data reported for soil and groundwater, in accordance with the Quality Assurance Project Plan provided in Appendix B of the RI Work Plan. The following quality control information was reviewed during the data review and validation.

- Method deviations;
- Sample extraction and holding times;
- Method reporting limits;
- Blank samples;
- Field and laboratory duplicates;
- Surrogate recoveries; and
- Relative percent difference (precision).

The data validation reports are provided in Appendix D. The laboratory quality assurance/quality control data were within acceptable ranges of tolerance, and the analytical data are acceptable for use.

6.0 CONCEPTUAL SITE MODEL

The Conceptual Site Model has been developed to:

- Identify sources of COPCs to the soil or groundwater in the Capital Area of Investigation;
- Summarize the current understanding of the nature and extent and persistence of COPCs that exceed the screening levels in the subsurface at the Capital Area of Investigation;
- Identify the media of concern with concentrations of COPCs exceeding screening levels; and
- Determine potential migration and exposure pathways.

The sources of data used in developing the Conceptual Site Model were identified in the RI Work Plan and include the results of prior investigations conducted by others, the results of investigations conducted at the BDC facility by PGG, and the data collected in the RI field investigation. The Conceptual Site Model is a tool for identification, development, evaluation, and selection of technically feasible cleanup alternatives at the Capital Area of Investigation for the Feasibility Study.

The elements comprising the Conceptual Site Model include:

- Source(s) of COPCs;
- Affected media;
- Contaminant fate and transport; and
- Known or suspected human and environmental receptors and exposure pathways.

Each of these elements is summarized below.

6.1 SOURCE(S) OF COPCS

The following section describes sources of COPCs identified on the Capital Property and at up-gradient locations.

6.1.1 Capital Property Source Areas

Former operations at the Capital Property that may have resulted in releases of HVOCs to soil and groundwater include a vapor degreaser formerly located in Capital Plant 4 and a solvent-based parts cleaner formerly located in Capital Plant 2. There is no documented record of a significant release of solvents from either of these units.

6.1.1.1 Capital Plant 4 Source Area

PCE, TCE, and cis-1,2-DCE have been detected at concentrations exceeding screening levels in soil samples collected near the former degreasing unit that was located in Capital Plant 4 and at the east wall adjacent to the former ABP facility (Pacific Food Systems, Northern Building) (ECS 2005; Farallon 2009b). PCE and TCE were detected in the soil samples collected above the Water Table Zone from boring B-18 at 5 and 7 feet bgs. Boring B-18 is located cross-gradient to Capital Plant 4 and east of the Pacific Food Systems Northern Building (Figure 6).

The observed distribution of COPCs in soil suggests that releases may have occurred from the former degreasing operations in Capital Plant 4 and at a location east of Capital Plant 4 at the former ABP facility. PCE and TCE have been detected at concentrations exceeding screening levels in groundwater samples collected from monitoring wells MW-6 and MW-7, located in and down-gradient of Capital Plant 4; however, cis-1,2-DCE has not been detected exceeding screening levels in groundwater samples collected from these monitoring wells. The concentrations of PCE detected in soil above the water table range from 0.0039 to 0.091 mg/kg, and concentrations of TCE range from 0.0035 to 0.024 mg/kg. These concentrations of PCE and TCE are only slightly exceeding the screening levels and do not meet the threshold as a continuing source to groundwater. In addition, the area is covered by impermeable surfaces that preclude infiltration of surface water.

6.1.1.2 Capital Plant 2 Source Area

Concentrations of COPCs exceeding the screening levels have not been detected in shallow soil samples collected in Capital Plant 2 (ECS 2005). Soil samples with

concentrations of COPCs exceeding screening levels were collected from depths ranging from 8.5 to 34 feet bgs in boring locations B1, B2, B3, B5, MW1, and MW2. These samples were collected in the saturated Water Table Zone and are considered representative of groundwater conditions, not a soil source. Most of the soil beneath Capital Plant 2 was excavated during reconstruction after the fire, when approximately 330 cubic yards of soil with concentrations of VOCS was transported off-site for disposal.

COPCs exceeding the screening levels have been detected in groundwater in the Water Table Zone in and up- and down-gradient of Capital Plant 2. Concentrations of TCE in groundwater samples collected from the Water Table Zone are higher in samples down-gradient of Capital Plant 2 than in groundwater samples collected from the Water Table Zone up-gradient of Capital Plant 2. The observed distribution of COPCs in groundwater suggests that releases of COPCs may have occurred from the former parts cleaner operations located in Capital Plant 2 that have commingled with releases from sources at the BDC facility (See Section 2.1.2, Up-gradient Source Areas).

6.1.2 Up-gradient Source Areas

Known sources of COPCs up-gradient of the Capital Property include the BDC facility, the ABP facility, and the PSC facility (Figure 4). Releases of COPCs to groundwater at these up-gradient sources have migrated in groundwater in the Water Table Zone, the Shallow Zone, and the Intermediate Zone and have impacted groundwater within the Capital Area of Investigation. A detailed discussion of each of these potential source areas is provided in the Data Summary Report and the RI Work Plan.

Confirmed concentrations of COPCs exceeding screening levels are present in soil under the BDC facility, and concentrations of COPCs exceeding screening levels are present in groundwater in the Water Table Zone, the Shallow Zone, and the Intermediate Zone at and down-gradient of the BDC facility (PGG 2006, 2008). The COPCs released from the BDC facility have commingled with release(s) at the Capital Property and migrated in groundwater to the southwest.

Concentrations of COPCs exceeding screening levels have been detected in groundwater samples collected in the Water Table Zone, the Shallow Zone, and the Intermediate Zone from reconnaissance borings and monitoring wells at and down-gradient of the ABP facility (Aspect Consulting 2007). Based on recent data collected for the ABP facility RI and data collected at the Capital Property, a suspected source of vinyl chloride in the Intermediate Zone is located north of Capital Plant 5, at either the ABP facility or another location.

Operations associated with treatment and storage of materials at the PSC (2003) facility have resulted in releases of COPCs to soil and groundwater. Concentrations of COPCs exceeding screening levels have been detected in groundwater in the Water Table Zone, the Shallow Zone, and the Intermediate Zone down-gradient of the PSC facility and up-gradient of the Capital Property that has migrated west-southwest to the Capital Area of Investigation. These include 1,4-dioxane and vinyl chloride in the Shallow Zone and Intermediate Zone.

6.2 CONTAMINANT FATE AND TRANSPORT

This section presents the fate, transport, and potential migration pathways of the COPCs at the Capital Area of Investigation. The discussion is based on the hydrogeologic setting and the identification of contaminant source(s) to provide a framework for subsequent risk evaluations.

6.2.1 Contaminant Transport Processes

Subsurface contaminant movement depends on site environmental, physical, chemical, and biological characteristics and contaminant chemical properties. Migration pathway, mobility, and persistence are chemical-dependent and are affected by site environmental factors, including the concentration of other chemicals, oxidation-reduction potential, organic matter content, and the presence of microorganisms. Mobility is defined as the potential for a contaminant to migrate from a source. Persistence is a measure of how long a contaminant will remain in the environment.

The results of previous investigations confirm that PCE, TCE, and the associated degradation products are the primary COPCs at the Capital Area of Investigation. Concentrations of cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride, the typical degradation products of PCE and/or TCE, have been detected exceeding screening levels and are included as primary COPCs for the

Capital Area of Investigation. The Agreed Order includes 1,4-dioxane, iron, and manganese as COPCs for the Capital Site; however, there is no source of 1,4-dioxane at the Capital Area of Investigation, and iron and manganese are secondary COPCs. For purposes of the contaminant fate and transport discussion, only the primary COPCs impacting the Capital Area of Investigation (PCE, TCE, cis-1,2-DCE, and vinyl chloride) are included.

6.2.1.1 Aquifer Properties and Tidal Influence

Aquifer hydraulic properties, vertical gradients, and impacts of tidal influence from the LDW affect contaminant fate and transport within the Capital Area of Investigation. The hydrogeologic setting was discussed in Section 2.4. The results of the tidal investigation, which includes the results of aquifer slug testing performed across the Capital Area of Investigation, were provided in a letter report (Farallon 2011b; Appendix B). Aquifer properties calculated from the tidal study and from data from the BDC facility are included in subsequent modeling activities.

Vertical gradients are interpreted to be moderate and variable between aquifer zones and likely have little impact on contaminant migration. Tidal data indicate that horizontal gradients are relatively uniform within the area of tidal influence near the LDW, although some variation in flow direction and gradient was observed during a tidal cycle. Tidal mixing in the aquifers near the LDW likely affects contaminant concentrations near the shoreline.

6.2.1.2 Vadose Zone Processes

Contaminants occur in the vadose zone near the locations of the release (i.e., source areas). VOCs can volatilize from groundwater and vapors can migrate by diffusion from groundwater to the ground surface. Contaminants released at the Capital Property source area have infiltrated into the subsurface and migrated downward by gravity or vapor-phase transport through the vadose zone. When low-permeability soil is encountered, contaminants may migrate laterally along the permeability contrast.

Chlorinated VOCs are typically released as dense nonaqueous-phase liquids (DNAPLs) or dissolved in water. The relatively low concentrations of COPCs detected in

groundwater at the Capital Property do not suggest the presence of DNAPLs at the Capital Area of Investigation; however, COPCs are present in groundwater as dissolved phase. When the soil-moisture content is low, pore water movement becomes limited and contamination dissolved in pore water and sorbed to soil can remain in the vadose zone for long time periods. Therefore, contamination in the vadose zone can present a long-term source of COPCs to shallow groundwater. However, the shallow depth to the Water Table Zone at the Capital Area of Investigation limits the amount of vadose zone soil available as a potential source. In addition, COPCs have not been detected in soil within the vadose zone at Capital Plant 2 and are at relatively low concentrations in soil at the Capital Property.

VOCs with high vapor pressure may volatilize from shallow groundwater and migrate as vapors through the vadose zone, resulting in potential exposure to contaminant vapors in ambient indoor air. Elevated VOC vapor concentrations and contaminant mass flux into buildings would be expected in areas of shallow groundwater with high VOC concentrations. Groundwater with low VOC concentrations, and deep or confined groundwater is not expected to present a potential for substantial upward migration of VOC vapors. Volatilization from groundwater in areas away from the source(s) of contamination is expected to be limited by the rate of the contaminant diffusion from groundwater.

6.2.1.3 Saturated Zone Processes

The movement of contaminants dissolved in groundwater is controlled by the mechanisms of advection and hydrodynamic dispersion. Among these mechanisms, advection is the dominant factor that transports the plume in the direction of groundwater flow in the predominantly sandy aquifer zones present at the Capital Area of Investigation.

Advection and Dispersion

Advection is the transport of a solute (or dissolved contaminant) by groundwater flow at a rate equal to the velocity of the flowing groundwater. Advection is the dominant transport mechanism for the contaminants at the Capital Area of Investigation.

Hydrodynamic dispersion is a combination of mechanical dispersion and molecular diffusion. Dispersion is the effect of non-uniform distribution of flow velocities at the pore scale due to aquifer heterogeneities that results in the spreading of solute along (longitudinal dispersion) and perpendicular (transverse dispersion) to the direction of groundwater flow. Increased dispersion results in a larger volume of contaminated groundwater at lower concentrations. Longitudinal dispersion typically is one to two orders of magnitude greater than horizontal transverse dispersion, which in turn is one to two orders of magnitude greater than vertical transverse dispersion. Vertical dispersion may be important, depending on the vertical hydraulic gradients between aquifer zones. Vertical dispersion is expected to be minimal based on observed vertical gradients between zones at the Capital Area of Investigation.

Diffusion is driven by the solute concentration gradients according to Fick's Law. Diffusion is expected to be a very slow process relative to advection in the relatively permeable aquifers at the Capital Area of Investigation.

Sorption

Sorption is the tendency for a chemical to adsorb to the soil grains within the water-bearing zones. VOCs are known to adsorb to organic carbon, to mineral surfaces, and to the interface between air and water in the vadose zone. Because the phase partitioning is fast relative to the advective transport of VOCs, local equilibrium (i.e., instantaneous sorption and desorption) can be assumed. Sorption to organic carbon can be described by a linear partitioning coefficient, K_{oc} .

Sorption reduces the rate of contaminant migration as the solute continuously sorbs and desorbs to maintain local equilibrium. This reduction in migration rate is referred to as

retardation of contaminant in groundwater. Because VOCs also adsorb to mineral surfaces, some sorption is expected even if organic carbon content is low. For PCE, the threshold of organic carbon mass fraction is 0.0002 for surfaces of organic materials to be the primary sorption sites. However, sorption onto mineral surfaces is difficult to quantify (Fetter 1993).

The RI at the Capital Area of Investigation included collection of 12 samples for analysis for TOC. Four samples each were collected from the three aquifer zones (the Water Table, Shallow, and Intermediate Zones) (Table 5). TOC ranged from 80 to 5,120 mg/kg, with an average of 1,293 mg/kg (corresponding to mass fractions ranging from approximately 0.00008 to 0.005, with an average of 0.0013). The average TOC fractions in the Water Table Zone, the Shallow Zone, and the Intermediate Zone were approximately 0.00045, 0.0014, and 0.002, respectively. Organic carbon samples were collected at the BDC facility to the north, which indicated somewhat higher TOC values in soil (average mass fraction of 0.0029). These results indicate that VOC sorption to organic carbon occurs in groundwater at the Capital Area of Investigation; however, sorption is not a major factor controlling contaminant migration.

Degradation

Degradation of contaminants is a biochemical or chemical oxidation-reduction reaction within the subsurface. Naturally occurring bacteria in groundwater use organic chemicals as food sources and help break down contaminants into degradation products. Abiotic processes lead to degradation of chlorinated VOCs without the production of the daughter products associated with the biodegradation pathways. Reduced iron, for example, reacts with chlorinated VOCs. Depending on the types of organic compounds, degradation may occur under aerobic and anaerobic conditions. Oxygen is needed for aerobic organisms to degrade organic compounds. Under aerobic degradation processes, electrons will be transferred from organic material to oxygen (electron acceptor). This process reduces oxygen and transforms organic material to carbon dioxide and a new compound. The anaerobic degradation process is similar to the aerobic degradation process except that

other common electron acceptors such as nitrate, sulfate, and inorganic carbon are used instead of oxygen.

Figure 26 illustrates the biological degradation pathways for the chlorinated compounds present at the Capital Area of Investigation such as PCE, TCE, cis-1,2-DCE, and vinyl chloride. Reductive dechlorination is the primary biological degradation process for these COPCs, where the chlorinated compound is converted to another chemical by replacing chlorine atoms with hydrogen atoms. The sequential reduction of chlorinated VOCs eventually leads to production of innocuous end products such as ethene, ethane, and carbon dioxide. Reductive dechlorination occurs in anaerobic environments and is believed to be the primary degradation process occurring in the Capital Area of Investigation. The resulting daughter product of PCE dechlorination is TCE, which similarly may be reduced to cis-1,2-DCE, trans-1,2-DCE, and 1,1-DCE. These daughter products may be further reduced to vinyl chloride.

PCE and TCE in groundwater extend from the Capital Property (and the up-gradient BDC, PSC, and ABP facilities) down-gradient toward the LDW. PCE, TCE, and cis-1,2-DCE have been detected with concentrations of vinyl chloride in groundwater. Detections of vinyl chloride are more widespread across the Capital Area of Investigation, with concentrations generally increasing to the west, suggesting a primary source of HVOCs other than the Capital Property. Detections of cis-1,2-DCE are commonly associated with detections of TCE and are believed to be a degradation product of TCE. Although the extent of cis-1,2-DCE is broadly similar to that of PCE and TCE, detected concentrations are below screening levels.

The presence of PCE and TCE daughter products indicates that reductive dechlorination is occurring in groundwater beneath the Capital Area of Investigation.

6.2.2 Natural Attenuation Parameters

Field water quality measurements and analyses for the parameters listed in Section 4.1.4 were conducted on groundwater samples collected from monitoring wells screened within the Water Table Zone, Shallow Zone, and Intermediate Zone. The field measurements and analytical

results have been used to assess groundwater geochemistry and the potential for natural attenuation as component of future remedial actions for the Site. The results are summarized in Table 10. Compounds indicative of biodegradation of PCE and/or TCE were detected, including DCE isomers and vinyl chloride, supporting the presence of anaerobic groundwater conditions capable of supporting reductive dechlorination. Groundwater geochemistry was further assessed for the degree of reducing conditions, including whether groundwater in each zone is sufficiently reducing to support complete biodegradation of PCE and TCE to carbon dioxide and chloride ions.

6.2.2.1 Water Table Zone

The results for the groundwater samples collected from monitoring wells screened in the Water Table Zone indicate that groundwater conditions are reducing. The degree of reducing conditions appears to vary within the plume area.

Dissolved oxygen measurements throughout the Site are typically less than 2.0 mg/l (Table 11), indicating depletion of oxygen and reducing conditions. Nitrate concentrations are low to below detection levels, indicating that nitrate is being used as an electron receptor in the biodegradation of PCE and/or TCE, and is being depleted. Nitrite, the reduced form of nitrate, was detected once at a very low concentration. The absence of nitrite is typical of most groundwater systems and may be indicative of bacteria using the available nitrogen from the reduction of nitrate rather than formation of nitrite.

Concentrations of the reduced states of iron and manganese, ferrous iron (Fe^{2+}) and manganese II (Mn^{2+}) have been detected, indicating that the oxidized states of these metals, ferric iron (Fe^{3+}), and manganese IV (Mn^{4+}) are also being used as electron receptors in the biodegradation of PCE and/or TCE, resulting in the production of Fe^{2+} and Mn^{2+} .

Sulfate is present in groundwater at most monitoring well locations at concentrations above 20 mg/l. Concentrations of sulfate less than 20 mg/l and decreasing trends in sulfate concentrations are typically desirable, indicating the presence of sulfate-reducing

conditions. Sulfate-reducing conditions are necessary for accelerated reduction of DCE isomers to vinyl chloride, and ethene to carbon dioxide and chloride. The available results are insufficient to evaluate whether there is a decreasing trend in sulfate concentrations to indicate that groundwater conditions are sufficiently reducing to support sufficient populations of bacteria capable of using sulfate as an electron receptor in the biodegradation of DCE isomers and vinyl chloride. Sulfide, the reduced form of sulfate, was also analyzed and was absent. The absence of sulfide is typical under sulfate-reducing conditions because the sulfide may be mineralized and not detected.

Methane, ethane, and ethene were analyzed. Ethane and ethene are degradation products of chlorinated ethenes and indicative of sulfate to methanogenic reducing conditions necessary for the complete reductive dechlorination of PCE and/or TCE. Methane is typically indicative of the presence of methanogenic bacteria under extreme reducing conditions, or the presence of decaying organic materials within the water-bearing zone associated with the soil matrix materials. Methane was detected at variable concentrations; however, concentrations were generally low, indicating that methanogenic reducing conditions are likely present but are not predominant. The absence of ethene and ethane at many of the monitoring well locations may be due to the relatively low concentrations of vinyl chloride available for biodegradation to ethane and ethene volatilization to the unsaturated soil zone or the rapid biodegradation of these gases, which are readily biodegraded in the absence of a continuing source of parent compounds.

Chloride is the ultimate breakdown product of PCE degradation and is typically higher in concentration at and down-gradient of the source area in comparison to up-gradient areas. Chloride was detected in monitoring wells where HVOCs were detected and in down-gradient wells, indicating the presence of chloride. The presence of chloride in these wells indicates that complete reductive dechlorination of PCE and/or TCE is occurring.

Alkalinity is used as an indicator of carbon dioxide production resulting from biodegradation or, where methanogenic conditions exist, the use of carbon dioxide by these bacteria. Typically, elevated alkalinity values within a source area and down-

gradient within a plume of HVOCs relative to areas where HVOCs are not present is indicative that biodegradation is likely occurring. Alkalinity concentrations were generally similar in all monitoring wells sampled.

6.2.2.2 Shallow Zone

Results for groundwater samples collected from monitoring wells screened in the Shallow Zone indicate that groundwater conditions are reducing. Groundwater geochemistry is similar to the overlying Water Table Zone but appears indicative of sulfate to methanogenic reducing conditions. Dissolved oxygen and nitrate are essentially depleted, as in the Water Table Zone. Fe^{2+} and Mn^{2+} are both present, supporting reduction of PCE and/or TCE to DCE isomers. Sulfate is present but generally at lower concentrations within the Capital Area of Investigation. Concentrations of sulfate in groundwater samples collected by PGG at the BDC facility are similar to the conditions in the Water Table Zone. Concentrations of methane are greater than in the Water Table Zone, indicating that stronger reducing conditions are likely present. Alkalinity values are also higher in the Water Table Zone, suggesting increased bacterial activity in this zone. The presence of chloride is indicative of the complete biodegradation of PCE and/or TCE.

6.2.2.3 Intermediate Zone

Results for groundwater samples collected from monitoring wells screened in the Intermediate Zone indicate that groundwater conditions are reducing. Groundwater geochemistry is similar to the overlying zones and, like the overlying Shallow Zone, also appears indicative of sulfate to methanogenic reducing conditions. The geochemical indicators are indicative that complete reductive dechlorination of PCE and/or TCE is occurring. This is supported by the presence of both chloride and/or ethene at multiple monitoring well locations. The BDC area appears particularly conducive to the reductive dechlorination process. Concentrations of ethane and ethene are greater at this area than at Capital. Further, sulfate concentrations are notably lower at most monitoring well locations within the Intermediate zone.

6.2.3 Physical and Chemical Properties of COPCs

The fate and transport of COPCs in the Capital Area of Investigation is affected by the physical, chemical, and biological processes of the compounds and subsurface conditions. A brief discussion of each property is provided below.

6.2.3.1 Water Solubility

Water solubility is the maximum quantity of a chemical that can dissolve in a fixed quantity of water at a given temperature and pH. Solubility is compound-dependent. PCE and TCE are less soluble in water than is cis-1,2-DCE or vinyl chloride, but all are soluble and can migrate in the dissolved phase in groundwater.

6.2.3.2 Pressure/Henry's Law Constant

Evaporation of a chemical can occur wherever a contaminant is exposed to the atmosphere, generally at the ground surface, in the vadose zone, and at the water table. Vapor pressure provides an indication of the rate at which a chemical volatilizes. Chemicals with higher vapor pressures are expected to enter the atmosphere much more readily than chemicals with lower vapor pressures. Henry's Law constant (H) is a conventional measure of volatility, and defines the potential for a dissolved contaminant to evaporate. H is more accurate than vapor pressure in estimating releases from water to air. Chemicals with H values higher than 10^{-3} atmosphere-cubic meter per mole indicate a greater tendency for a dissolved contaminant to partition into the vapor phase. PCE and TCE have relatively high H and low solubility and will readily volatilize from water to air.

6.2.3.3 Density and Viscosity

Most of the COPCs at the Capital Area of Investigation such as PCE, TCE, and cis-1,2-DCE are denser than water. When present in free phase, these compounds would form DNAPL, which has a potential for gravity-driven vertical migration through soil. However, as noted earlier, there are no data to suggest that DNAPL is present within the Capital Area of Investigation. The density of these compounds has a negligible effect when they are dissolved in groundwater. For example, PCE at its solubility (150,000 µg/l) increases the density of pure water by only approximately 0.0057 percent.

Naturally occurring dissolved inorganic compounds have much greater effect on the density of groundwater than dissolved PCE.

6.2.4 Fate and Transport in Groundwater

This section provides a discussion of the migration and transformation of PCE, TCE, cis-1,2-DCE, and vinyl chloride within the Capital Area of Investigation. These contaminants are present at higher concentrations and/or frequency at the Capital Area of Investigation than the remaining COPCs. The results of this assessment are used as initial input to the analytical flow and transport model described in Section 6.2.4.

As noted earlier, the confirmed and potential sources of the COPCs detected exceeding the screening levels at the Capital Area of Investigation include the ABP facility, the BDC facility, the PSC facility, and the Capital Property. Concentrations of COPCs have migrated down-gradient from each of these facilities in groundwater in the Water Table Zone, Shallow Zone, and Intermediate Zone that may have reached groundwater beneath and down-gradient of the Capital Property.

The sources for the concentrations of COPCs exceeding the screening level detected in groundwater at and down-gradient of Capital Plant 2 likely are the result of releases of HVOCs at the Capital Property, the ABP facility, the BDC facility, and the PSC facility. The sources of the concentrations of COPCs exceeding the screening levels detected in groundwater in the Water Table Zone at and down-gradient of Capital Plant 2 likely are the result of commingling of releases from the Capital Property and the BDC facility, while COPCs in the Shallow Zone and Intermediate Zone at and down-gradient of the Capital Property may be from releases at the Capital Property and other up-gradient sources, including the BDC facility, the PSC facility, and the ABP facility. The concentrations of COPCs detected in groundwater in the Water Table Zone at and down-gradient of Capital Plant 4 likely are the result of releases at the Capital Property. The source of COPCs in the Intermediate Zone at the Capital Property likely is from the PSC facility.

While multiple sources are contributing to the COPCs detected in groundwater at and down-gradient of the Capital Property, this discussion focuses on the fate and transport of

COPCs as currently identified in groundwater irrespective of the potential source. As discussed with and approved by Ecology, the purpose of the fate and transport analysis is to evaluate the migration and transformation of COPCs in groundwater and the potential impact to down-gradient receptors.

The extent of COPCs in groundwater in each of the three water-bearing zones was evaluated over five quarterly monitoring periods from March 2010 through March 2011. The interpreted COPC distribution in each water-bearing zone during each of the monitoring events is shown on Figures 7 through 21. These data were used to estimate the extent of dissolved COPCs. The COPC distribution in each aquifer zone is described below.

6.2.4.1 Water Table Zone

The interpreted lateral distribution of COPCs in the Water Table Zone is shown on Figures 7 through 11. These maps illustrate the TCE and vinyl chloride plumes at concentrations exceeding screening levels emanating from the vicinity of Capital Plant 2 and the up-gradient BDC facility, and the PCE plume originating near Capital Plant 4. The COPC distribution is shown in cross-section on Figures 23 through 25. As noted earlier, COPC data from ABP wells were not included in these interpretations in order to focus attention on the fate and transport within the Capital Area of Investigation.

The COPC data indicate that contaminant plumes have migrated down-gradient of the Capital Property in the Water Table Zone, but have not reached the LDW. The TCE plume extends approximately 900 feet down-gradient of the Capital Property between wells CI-14-WT and CI-13-WT. Well CI-13-WT is nearest the LDW (within approximately 200 feet) and acts as a “sentry” well to indicate potential further migration of COPCs in the Water Table Zone.

The distribution of vinyl chloride in the Water Table Zone is less extensive than that of TCE in the area directly down-gradient of the Capital Property. Low concentrations of vinyl chloride were detected in wells near Capital Plant 2 and sporadically in wells down-gradient of the Capital Property, including well CI-11-WT; however, vinyl chloride has not been detected in sentry well CI-13-WT. The PCE plume emanating from the Capital

Plant 4 area extends approximately 500 feet down-gradient of the Capital Property and does not approach the LDW.

The COPC maps indicate that the plumes are relatively stable and that COPC concentrations in the Water Table Zone have not increased significantly during the monitoring period. COPCs at concentrations exceeding screening levels have not reached beyond sentry well CI-13-WT, located proximate to and up-gradient of the LDW.

6.2.4.2 Shallow Zone

The interpreted distribution of COPCs in the Shallow Zone is shown in plan view on Figures 12 through 16. These maps illustrate the TCE and vinyl chloride plumes at concentrations exceeding screening levels emanating from the vicinity of Capital Plant 2 (and the up-gradient BDC and PSC facilities). PCE was not detected exceeding screening levels in the Shallow Zone in any of the monitoring wells during the five monitoring events. The COPC distribution in the Shallow Zone is shown also in cross-section on Figures 23 through 25.

The data indicate that contaminant plumes have migrated down-gradient of the Capital Property in the Shallow Zone, but have not reached the LDW. A TCE plume is evident up-gradient of the Capital Property at well BDC-6-30 and down-gradient of Capital Plant 2, encompassing wells CI-10-35 and CI-14-35. The plume is approximately 600 feet in length and extends to an area between wells CI-14-35 and CI-13-30. Well CI-13-30 is nearest the LDW (within approximately 200 feet) and acts as a “sentry” well to indicate potential further migration of COPCs in the Shallow Zone.

The distribution of vinyl chloride is more extensive in the Shallow Zone than in the Water Table Zone and likely reflects up-gradient contributions of degradation products from PSC or other sources. Although low concentrations of vinyl chloride have been detected down-gradient of the Capital Property, including in well CI-13-35, the highest vinyl chloride concentrations have been detected to the northwest in well CG-141-40, down-gradient of the ABP facility.

The COPC maps indicate that the plumes are relatively stable and that COPC concentrations in the Shallow Zone have not increased significantly during the monitoring period. Most COPCs have not reached beyond sentry well CI-13-30, located proximate to and up-gradient of the LDW, although low concentrations of vinyl chloride have consistently been detected in that monitoring well.

6.2.4.3 Intermediate Zone

The interpreted distribution of COPCs in the Intermediate Zone is shown in plan view on Figures 17 through 21. These maps illustrate the vinyl chloride plume at concentrations exceeding screening levels in the Intermediate Zone. PCE and TCE were not detected exceeding screening levels in the Intermediate Zone. The COPC distribution in the Intermediate Zone is shown in cross-section on Figures 23 through 25.

The vinyl chloride data indicate that a dissolved-phase plume is present in the Intermediate Zone down-gradient of the Capital Plant 1 and Capital Plant 5 area, with concentrations increasing laterally to the northwest, indicating a likely source up-gradient and to the northeast at the Capital Property. Vinyl chloride has migrated down-gradient of the Capital Property in the Intermediate Zone, but has not reached the LDW. The vinyl chloride plume extends approximately 600 feet from the Capital Property to an area between monitoring wells CI-15-60 and CI-12-60. Monitoring well CI-13-60 is located nearest the LDW (within approximately 200 feet) and acts as a “sentry” well to assess potential further migration of COPCs in the Intermediate Zone. Vinyl chloride has not been detected exceeding screening levels in the Intermediate Zone sentry well.

The COPC maps indicate that the vinyl chloride plume is relatively stable and that concentrations in the Intermediate Zone have not increased significantly during the monitoring period. COPCs exceeding screening levels have not reached beyond sentry well CI-13-60, located up-gradient of the LDW.

6.2.5 Groundwater Flow and Solute Transport Model Results

An analytical fate and transport model was developed with the objective of simulating contaminant migration at the Capital Area of Investigation. The model serves as a tool for

evaluation and development of technically feasible cleanup alternatives. The model development and results are summarized in the following sections.

6.2.5.1 Modeling Approach and Model Development

The EPA BIOCHLOR model was used to evaluate the fate and transport of dissolved contaminants in groundwater at the Capital Area of Investigation. BIOCHLOR is an analytical fate and transport model that simulates 1-dimensional advection, 3-dimensional dispersion, linear adsorption, and reductive dechlorination with or without decay.

Modeling Approach

The modeling approach for the RI was based on prior discussions with Ecology, who requested a modeling approach differing from traditional methods that include model calibration. Specifically, Ecology requested a simplified approach whereby a source term is assigned and the model is run forward to simulate future conditions without calibrating to existing data, rather than constructing a model and running simulations with a given set of input parameters for some length of time to simulate current conditions (the typical calibration method). The source term(s) would be representative of current HVOC concentrations in groundwater. It was understood that there may be more than one "source" spatially for a given COPC, depending on the interpreted plume configuration. In terms of model development, existing concentrations of HVOCs in groundwater would essentially be ignored other than to help establish source terms. A source term would reflect a relative "hot spot" of HVOC concentrations. If more than one source term was applied within an aquifer zone (i.e., multiple hot spots), separate models would be run for each source. Although the aquifer zones are hydraulically connected, the hydraulic properties and contaminant concentrations vary vertically; therefore, each water-bearing zone was modeled independently.

While this approach will not provide the typical initial "picture" of groundwater concentrations to use as a starting point for future simulations, it will simulate down-gradient concentrations at receptors (e.g., the LDW) over time based on current sources. Although this approach will not necessarily help to establish how the plumes

developed over time, it will reduce uncertainties associated with the history matching process. Uncertainty in the results will be assessed using sensitivity analysis. This approach is used for the Capital RI modeling discussed below.

Model Development

Model inputs were based on field measurements where available, or on literature values if site-specific data were unavailable. A summary of model inputs used in the BIOCHLOR modeling is provided in Table 12. The BIOCHLOR input screens for each modeled water-bearing zone are provided in Appendix E. These inputs were discussed in advance with consultants for BDC and ABP so that similar model inputs would be used for the modeling effort for each facility. Key model inputs are discussed below.

- **Source Concentrations**

As noted above, source concentrations were selected based on current HVOC concentrations detected in groundwater. The most recent data (March 2011) were used to select the “source” term in each aquifer zone. The sources were selected based on both HVOC concentrations and distance from the LDW. If multiple monitoring wells were present at roughly the same distance from the LDW, the greatest HVOC concentration in the group of monitoring wells was selected as the source. The specific HVOC source concentrations are listed in Table 12. The sources within each aquifer zone are identified as follows:

- **Water Table Zone**

- Source 1: Wells CI-12-WT and CI-14-WT, approximately 550 feet from the LDW
- Source 2: Well CI-10-WT, approximately 850 feet from the LDW
- Source 3: Wells MW-5, MW-6, and BDC-6-WT, approximately 1,500 feet from the LDW

- **Shallow Zone**

- Source 1: Wells CI-12-30 and CI-14-35, approximately 550 feet from the LDW

- Source 2: Well CI-14-40, approximately 1,050 feet from the LDW
- **Intermediate Zone**
 - Source 1: Well CI-15-60, approximately 850 feet from the LDW
- **Source Type and Simulation Time**

A continuous source was assumed for each source term. This is a conservative approach since the dissolved-phase “source” terms likely will decrease over time. Each model was run for a period of 500 years to ensure that steady-state conditions would be reached.

- **Hydraulic Conductivity**

Hydraulic conductivity values were based on slug testing performed in Capital Site monitoring wells (Appendix B). Aquifer slug test data obtained from the nearby BDC facility were used to calculate average hydraulic conductivity values for modeling. The geometric mean of the available hydraulic conductivity estimates was selected. Hydraulic conductivity values for each zone were as follows:

- Water Table Zone 1.13E-02 centimeters per second
- Shallow Zone 9.99E-03 centimeters per second
- Intermediate Zone 2.13E-03 centimeters per second

- **Biotransformation rate (half-life)**

Rates were selected based on a review of literature values to obtain rates that would be realistic and representative of site conditions. The values selected were obtained from Newell et al. (2002) and represent the 25th percentile of biodegradation rates for COPCs based on a review of BIOCHLOR modeling studies. The selected half-lives represent relatively conservative values given the observed degradation of COPCs at the Capital Area of Investigation. The selected half-lives for BIOCHLOR modeling are as follows:

- PCE 1.2 years
- TCE 1.8 years

- cis-1,2-DCE 1.6 years
- Vinyl Chloride 1.7 years

- **Dispersion**

The modified Xu and Eckstein (1995) method was used to calculate the longitudinal dispersivity value used in the model. The Xu and Eckstein (1995) method provides lower range estimates of dispersivity, especially for large values of x , and was developed after weighing the reliability of the various field data compiled by Gelhar et al. (EPA 2000). Low-end estimates for transverse and vertical dispersivity ($0.10 * \alpha x$ and 0, respectively) were selected to be conservative and because these relations better fit high-reliability field data reported by Gelhar et al. (EPA 2000).

- **Model Area Width and Length**

The model width was set to 500 feet, which represents a reasonable width for centerline plume estimates. The model area length corresponds to the specific distance from each source to the LDW.

- **Source Area Thickness and Width**

The source area thickness was set to 20 feet, which represents the approximate thickness of each water-bearing zone. The source area width was set to 50 feet at each source, a reasonable and conservative estimate of the aquifer width likely to contain the maximum source concentration for each simulation. While the observed plumes are wider than 50 feet, the full width of each plume contains COPC concentrations at much lower concentrations than the maximum observed values used for each source term.

- **Effective Porosity, Bulk Density, and Fraction Organic Carbon**

Effective porosity and bulk density values were selected based on literature values for similar sediment types. Fraction organic carbon values were based on analytical results for soil samples collected within the Capital Area of Investigation and from the BDC facility.

○ **Retardation**

Adsorption to the soil matrix can reduce the concentration of dissolved contaminants moving through groundwater. The retardation factor is the ratio of the groundwater seepage velocity to the rate that organic chemicals migrate in the groundwater (EPA 2000). The degree of retardation depends on both aquifer and constituent properties. Retardation (R) is estimated from soil and chemical data using the following equation:

$$R = 1 + Kd \cdot \rho_b / n$$

Where: Kd = distribution coefficient

ρ_b = bulk density

n = effective porosity

The distribution coefficient (Kd) is calculated as follows:

$$Kd = Koc \cdot foc$$

Where: Koc = organic carbon-water partition coefficient

foc = fraction organic carbon on uncontaminated soil

Retardation factors were calculated for the COPCs included in the modeling analysis. The Kd value is dependent on both Koc and foc values. Koc values were obtained from the MTCA Cleanup Levels and Risk Calculations tables developed by Ecology. As noted above, fraction organic carbon (foc) was calculated based on data collected within the Capital Area of Investigation and the BDC facility.

The calculated retardation values ranged from 1.25 to 5. The retardation values used in each water-bearing zone are provided in the input screens for each model (Appendix E).

6.2.5.2 Solute Transport Modeling

Solute transport simulations were performed to evaluate the fate and transport of dissolved contaminants in groundwater within the Capital Area of Investigation. Specifically, the modeling objectives were to estimate:

- Which COPCs may reach the LDW as the plumes migrate down-gradient from each source area over time, and at what concentrations
- Peak concentrations of COPCs that may reach the LDW during plume migration

Using the model inputs described above, BIOCHLOR simulations were performed for each source area within each water-bearing zone. Each model was run for a period of 500 years to ensure that steady-state conditions were reached. Centerline plume analysis was performed to estimate the maximum COPC concentrations at the modeled end point.

After each simulation had been completed, the simulated COPC concentrations were evaluated, and both peak and long-term COPC concentrations were recorded. The BIOCHLOR model simulates the generation of daughter products, and these values were automatically incorporated into the BIOCHLOR results.

The centerline plume results for each BIOCHLOR simulation are presented graphically in Appendix E. The simulated peak and long-term COPC concentrations are presented also in Table 13. The simulation results indicate that neither peak nor long-term PCE, TCE, or cis-1,2-DCE concentrations reach the LDW exceeding screening levels in the Water Table, Shallow, or Intermediate Zones. Simulations show that vinyl chloride may reach the LDW at concentrations slightly exceeding screening levels in the Shallow Zone (2.9 µg/l) under long-term scenarios from Source Area 1 near wells CI-12-40 and CI-14-35. Peak concentrations of approximately 1.5 µg/l were simulated in the Water Table Zone after approximately 15 years from Source Area 2 near well CI-10-WT, with concentrations then decreasing in the long-term simulations. Vinyl chloride does not appear to reach the LDW at concentrations exceeding screening levels in the Intermediate Zone. These simulations are conservative (i.e., continuous source terms and long half-

lives) and do not account for tidal mixing that will dilute COPC concentrations before they enter the LDW.

For simulations that indicated the potential for vinyl chloride to reach the LDW at concentrations slightly exceeding the screening level, additional modeling was performed to assess the impact of a decaying source on model results. Although this approach is less conservative than the use of a continuous source term, it is more realistic because the modeled “source” represents dissolved-phase VOCs that will attenuate over time due to degradation and dispersion. As shown in Table 13 and noted above, two simulations indicated the potential for vinyl chloride to exceed screening levels at the LDW: one from Source Area 2 in the Water Table Zone, and one from Source Area 1 in the Shallow Zone. When a decaying source was used in the BIOCHLOR model (all other inputs remaining the same), the results indicated that both peak and long-term vinyl chloride concentrations would remain below screening levels at the LDW. A relatively low source decay rate (0.1 per year) was used in these simulations. The results indicate that screening levels are unlikely to be exceeded for any of the COPCs reaching the LDW.

Although the effects of tidal mixing cannot be incorporated into the BIOCHLOR model, tidal mixing will decrease the concentrations of COPCs reaching the LDW, as noted above. Tidally influenced dispersion and mixing have been recognized in groundwater for over 40 years (Cooper 1959; Kohout 1960). Dilution and dispersion associated with tidal mixing in groundwater have been found to decrease contaminant concentrations reaching surface water bodies by a factor of 3 to 10 or more in many coastal areas. Therefore, tidal influences would further decrease the simulated COPC concentrations potentially reaching the LDW.

Sensitivity analysis is performed to establish the effect of uncertainty on the calibrated model. In BIOCHLOR, sensitivity analysis is recommended when literature values are used or when there is uncertainty in model input parameters (EPA 2000). Sensitivity analysis is performed by varying one input parameter while holding the others constant and evaluating the effect of the parameter variation on the model results. For this modeling effort, a number of input parameters were tested for sensitivity, including

hydraulic conductivity, longitudinal dispersivity, solute half-life, retardation, hydraulic gradient, source thickness, and source width. These parameters are considered most likely to have a significant impact on model results. Sensitivity analysis was completed for each water-bearing zone. Model inputs were increased or decreased by a factor of 2 for the sensitivity analysis.

Sensitivity analysis indicates that the most-sensitive parameters are hydraulic conductivity, solute half-life, and hydraulic gradient, each resulting in a roughly 200 to 300 percent increase or decrease in simulated COPC concentrations over baseline conditions. Both hydraulic conductivity and gradient affect the results in similar ways because they impact groundwater velocity. Both of these parameters are well established by site-specific data. For solute half-life, relatively conservative baseline literature values were selected for the modeling.

6.3 PRELIMINARY EXPOSURE ASSESSMENT

This section presents the evaluation and conclusions pertaining to the potential human health risk from COPCs in the Capital Area of Investigation. Exposure scenarios are identified below that will be used to develop final cleanup levels, and to evaluate and select a final cleanup action alternative.

The evaluation of soil, groundwater, and soil vapor analytical data collected for the RI indicates that the COPCs that exceed screening levels and present a potential risk to human health and the environment include PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, vinyl chloride, and 1,4-dioxane. These compounds are present in soil and/or groundwater at concentrations that exceed the screening levels established for the Capital Area of Investigation. The nature and extent of the COPCs in the subsurface will determine the potential exposure scenarios for the human health effects applicable to the cleanup action. The following sections present the conclusions with respect to human health risk and the corresponding exposure pathways.

6.3.1 Vapor Pathway

Soil vapor is affected by volatilization directly from released contamination into unsaturated soil and by volatilization from soil and groundwater. Encountering contaminated soil and/or

groundwater by future construction workers could result in short-term exposure to vapors. Potential exposure could occur via the inhalation pathway from soil vapor to indoor ambient air where concentrations of PCE and TCE have been detected in soil and/or groundwater. The exposure risk posed by the vapor pathway in the Capital Area of Investigation is being evaluated under the Vapor Intrusion Assessment Work Plan (Farallon 2008b) and the Addendum to the Vapor Intrusion Assessment Work Plan (Farallon 2011a). The results of this evaluation will be reported under separate cover.

6.3.2 Soil Pathway

Potential exposure pathways for soil contamination include the direct contact pathway through dermal contact with and/or ingestion of soil. The limited area of soil with concentrations of COPCs exceeding the screening levels considered protective of the direct contact pathway for dermal contact and/or ingestion currently is covered with concrete, asphalt, and/or building structures, which minimizes the risk of direct contact. The Capital Area of Investigation is fully developed and currently there is no direct contact pathway for soil at the Capital Area of Investigation. Future development activities within the Vadose Zone could result in exposure to contaminated soil above direct contact levels; however, concentrations of COPCs detected in soil currently do not exceed the direct contact levels.

6.3.3 Groundwater Pathway

Groundwater is affected by releases directly into a groundwater-bearing zone or by desorption from soil particles by infiltrating surface water or seasonally high groundwater conditions. Potential exposure pathways for groundwater contamination include volatilization into soil vapor and subsequent exposure through the vapor pathway discussed in Section 6.3.1, Vapor Pathway, or via the direct contact pathway, which comprises both the dermal contact and ingestion pathways. No groundwater supply wells used for potable water supply are present at or in the vicinity of the Capital Area of Investigation. In addition, use of groundwater as a potable water supply is not permitted within the Seattle city limits. As discussed in Section 2.3.5, Groundwater Use, groundwater is considered a non-potable resource and cannot be used as a drinking water source at the Capital Area of Investigation or adjacent properties, and there is no practical use for groundwater in the Capital Area of Investigation. The ground surface is capped with concrete,

asphalt, or building structures; therefore, excavation activities would be required for direct contact with groundwater to become a potential risk to human health. There currently is no exposure pathway for groundwater at the Capital Area of Investigation. However, future development activities at the Capital Area of Investigation could result in short-term exposure of contaminated groundwater to construction workers.

6.3.4 Surface Water Pathway

The potential exposure risk associated with the surface water pathway includes discharge of potentially contaminated groundwater to the LDW. As the LDW is not a source of potable water, the potential exposure pathway would therefore be human consumption of fish from the LDW that has come into contact with contaminated surface water. The results of the RI confirm that concentrations of COPCs exceeding screening levels do not discharge to the LDW. Therefore, there currently is no exposure pathway for surface water.

The results of the conservative BIOCHLOR model indicate that concentrations of vinyl chloride exceeding the screening level may reach surface water of the LDW in 15 years. Although there may be a surface water exposure pathway in the future, the model parameters are extremely conservative, and the potential for contaminated groundwater to reach the LDW is low.

6.4 CONCEPTUAL SITE MODEL SUMMARY

This section summarizes the Conceptual Site Model, including the nature and extent of contamination, sources of contamination, contaminant fate and transport, and potential exposure and receptor pathways.

6.4.1 Nature and Extent of Contamination

The chlorinated solvents PCE, TCE, cis-1,2-DCE, and vinyl chloride have been detected in one or more of the water-bearing zones underlying the Capital Area of Investigation. The sources of the COPCs include the Capital Property, BDC, PSC, and ABP.

6.4.1.1 Water Table Zone

PCE, TCE, and vinyl chloride plumes are present beneath and down-gradient of the Capital Property in the Water Table Zone that originate from sources at the Capital

Property and from up-gradient sources, including BDC. The dissolved-phase TCE and vinyl chloride plumes in the Water Table Zone extend from beneath the Capital Plant 2 area and up-gradient of BDC to the southwest in the direction of groundwater flow toward the LDW. Monitoring well data indicate that COPCs have not reached the LDW from sources within the Capital Area of Investigation.

6.4.1.2 Shallow Zone

TCE and vinyl chloride plumes have been detected up- and down-gradient of the Capital Property in the Shallow Zone. A TCE plume is apparent in the Shallow Zone down-gradient of the Capital Plant 2 area. Vinyl chloride is widespread across the Capital Area of Investigation in the Shallow Zone, with concentrations increasing to the west, suggesting a primary parent product (TCE) source area up-gradient to the northeast. PCE was not detected exceeding screening levels in the Shallow Zone.

6.4.1.3 Intermediate Zone

Vinyl chloride is the only COPC detected exceeding screening levels in the Intermediate Zone. Vinyl chloride concentrations are not as widespread in the Intermediate Zone as in the Shallow Zone, and are greatest in the northwest portion of the Capital Area of Investigation. The data suggest a primary parent source area northeast of the Capital Property at the PSC facility.

The data indicate that COPCs are distributed differently within the three water-bearing zones. Although the Water Table Zone, the Shallow Zone, and the Intermediate Zone are hydraulically connected, there appears to be stratification of COPCs vertically. PCE, for example, is not detected exceeding the screening level in the Shallow or Intermediate Zones, but is present in the vicinity of Capital Plant 4 in the Water Table Zone. Similarly, TCE is not observed in the Intermediate Zone exceeding the screening level, but is present in the Water Table Zone and the Shallow Zone.

COPC concentrations decrease with depth within the Capital Area of Investigation. These data suggest that vertical flow of groundwater (and hence advective transport of COPCs) is limited

within the Capital Area of Investigation. Data from the tidal study performed by Capital confirm that vertical gradients are relatively small and variable between zones during a tidal cycle. The COPC plumes appear to be relatively stable over the five quarters of groundwater monitoring conducted between March 2010 and March 2011. The contaminant distribution in each zone follows the main direction of groundwater flow at the Capital Area of Investigation, to the southwest from the Capital Property, toward the LDW.

6.4.2 Sources of Contamination

Sources of contamination at the Capital Property include releases from a former vapor degreaser that was located in Capital Plant 4 and a solvent-based parts cleaner associated with painting operations in Capital Plant 2. PCE, TCE, and cis-1,2-DCE have been detected in soil at and east of Capital Plant 4, which may be a contributing source of PCE and TCE to the Water Table Zone near Capital Plant 4. Cis-1,2-DCE has not been detected in groundwater exceeding the screening level in monitoring wells near Capital Plant 4. COPCs have not been detected in soil elsewhere on the Capital Plant or within the Capital Area of Investigation.

Up-gradient sources of COPCs include the BDC, ABP, and PSC facilities. The data indicate that TCE and vinyl chloride in the Water Table Zone and the Shallow Zone are migrating in groundwater onto the Capital Area of Investigation from these up-gradient sources. Vinyl chloride detected in the Intermediate Zone at the northwestern portion of the Capital Property, at Capital Plant 5, suggests there may be an up-gradient source to the northeast in addition to the ABP and PSC facilities.

6.4.3 Contaminant Fate and Transport

The Conceptual Site Model summary relating to COPC fate and transport in groundwater is discussed below.

6.4.3.1 Groundwater

The fate and transport of COPCs in groundwater within the Capital Area of Investigation is affected by a variety of chemical, physical, and biological processes. Some of the chemical and biological processes are destructive and result in contaminant mass removal from groundwater. The presence of PCE and TCE daughter products throughout the

Capital Area of Investigation indicates that these compounds are undergoing degradation. The extent of PCE and TCE is less than that of the degradation products, particularly vinyl chloride. The greater extent of the daughter products may be an indication that PCE and TCE are degrading both at the source areas and farther down-gradient. These data suggest that natural attenuation is effectively limiting the down-gradient migration of the PCE and TCE plumes toward the LDW.

The modeling results indicate that PCE, TCE, and cis-1,2-DCE will not reach the LDW in any of the water-bearing zones based on the modeling approach stipulated by Ecology using current COPC concentrations to represent non-decaying source terms. This indication holds true for both peak and long-term scenarios. However, the very conservative modeling results suggest that vinyl chloride concentrations may slightly exceed the screening level in groundwater that discharges to the LDW from the Water Table Zone and the Shallow Zone over time. Peak concentrations at one of the modeled source areas in the Water Table Zone indicate a possible vinyl chloride concentration of approximately 1.5 µg/l roughly 15 to 20 years from the present, which is only slightly exceeding the screening level of 1.28 µg/l. Similarly, simulated vinyl chloride concentrations in the Shallow Zone indicate a potential vinyl chloride concentration of 2.9 µg/l under long-term scenarios (500 years), slightly exceeding the screening level of 1.69 µg/l. However, these simulations were run under very conservative assumptions, including a continuous source of COPCs for 500 years, which is highly unlikely given the dissolved-phase nature of the source. The simulations also assume relatively long half-lives and do not account for tidal mixing that will dilute COPC concentrations before they enter the LDW. As noted in Section 6.2.5, Groundwater Flow and Solute Transport Model Results, the use of a decaying source term, which is more realistic based on known source conditions, results in modeled concentrations that do not exceed screening levels at the LDW.

The site data and modeling results support consideration of monitored natural attenuation as a viable option for treatment of the COPCs present within the Capital Area of Investigation.

7.0 SUMMARY AND CONCLUSIONS

The RI Report has been prepared in accordance with the requirements of the Agreed Order and the Ecology-approved RI Work Plan. The results of the RI adequately characterize the nature and extent of contamination and subsurface conditions of the Capital Area of Investigation to evaluate technically feasible cleanup alternatives consistent with the requirements of WAC 173-340-350. This section presents a summary of the RI and conclusions.

7.1 CONCEPTUAL SITE MODEL SUMMARY

The following provides a summary of the Conceptual Site Model that identifies the COPCs and media of concern, the sources of COPCs, and the nature and extent of COPCs in soil and groundwater; and provides monitored natural attenuation data, groundwater flow direction, fate and transport modeling, and exposure pathway evaluation.

7.1.1 Constituents of Concern and Media of Concern

The COPCs defined by the Agreed Order for the Capital Area of Investigation include:

- PCE;
- TCE;
- cis-1,2-DCE;
- trans-1,2-DCE;
- Vinyl chloride;
- 1,4-dioxane;
- Iron; and
- Manganese.

Based on the results of the RI, the COPCs that exceed screening levels in soil and groundwater that have been retained based on known sources in the Capital Area of Investigation for evaluation by the Conceptual Site Model include:

- PCE;

- TCE;
- cis-1,2-DCE;
- trans-1,2-DCE; and
- Vinyl chloride.

7.1.2 Sources of COPCs

The known sources of COPCs to the Capital Area of Investigation include releases of solvents from former operations at Capital Plant 2 and Capital Plant 4, BDC, ABP, and PSC. There appears to be another source of COPCs north of Capital Plant 5 and possibly at the building adjacent to and east of Capital Plant 4. COPCs have migrated in groundwater to the Capital Area of Investigation from up-gradient sources at these facilities. PCE, TCE, and cis-1,2-DCE were detected at concentrations exceeding screening levels in soil samples collected from 2 to 7 feet bgs proximate to Capital Plant 4 that may be a limited source of COPCs to groundwater.

7.1.3 Nature and Extent of COPCs in Soil

The COPCs with detected concentrations exceeding the screening levels detected in soil at the Capital Area of Investigation include:

- PCE;
- TCE; and
- cis-1,2-DCE.

These COPCs exceed screening levels in soil in a limited area in the vicinity of Capital Plant 4 at depths of 2 to 7 feet bgs. These COPCs have not been detected exceeding screening levels in soil in any other areas within the Capital Area of Investigation.

The results of the RI have delineated the vertical and lateral extent of PCE and TCE in soil in the Plant 4 area, with the exception of the lateral extent in soil to the east. The known nature and extent of PCE and TCE in soil at the Capital Area of Investigation is sufficiently delineated to evaluate technically feasible cleanup alternatives.

7.1.4 Nature and Extent of COPCs in Groundwater

The RI used the nomenclature for three water-bearing zones that is consistent with the water-bearing zones defined by PSC (2003). The Water Table Zone corresponds to approximately the upper 10 feet of the Shallow Aquifer, from first-encountered groundwater to approximately 20 feet bgs; the Shallow Zone is below 20 feet bgs and above 40 feet bgs; and the Intermediate Zone includes the water-bearing zone below 40 feet bgs extending to a depth of 70 feet bgs. The groundwater flow direction in all of the water-bearing zones is toward the southwest. The chlorinated solvents PCE, TCE, cis-1,2-DCE, and vinyl chloride have been detected in one or more of the water bearing zones underlying the Capital Area of Investigation.

PCE, TCE, and vinyl chloride plumes are present up- and down-gradient of the Capital Property in the Water Table Zone. The dissolved-phase TCE and vinyl chloride plumes in the Water Table Zone extend from the BDC facility to beneath the Capital Plant 2 area to the southwest in the direction of groundwater flow toward Slip 2 of the LDW. Monitoring well data confirm that COPCs have not reached the LDW from sources within the Capital Area of Investigation.

TCE and vinyl chloride plumes are present up- and down-gradient of the Capital Property in the Shallow Zone. A detached TCE plume is apparent in the Shallow Zone down-gradient of Capital Plant 2. Vinyl chloride is widespread across the Capital Area of Investigation in the Shallow Zone, with concentrations increasing to the west, suggesting a primary parent product of TCE at a source area up-gradient to the northeast. PCE was not detected exceeding screening levels in the Shallow Zone.

Vinyl chloride is the only COPC detected exceeding screening levels in the Intermediate Zone. Vinyl chloride concentrations are not as widespread in the Intermediate Zone as in the Shallow Zone, and are greatest in the northwest portion of the Capital Area of Investigation. The data suggest a primary parent source area northeast of the Capital Property in the Shallow Zone.

Concentrations of 1,4-dioxane exceeding the screening level were detected at two monitoring wells up-and down-gradient of Capital Plant 4 during one sampling event. Concentrations of 1,4-dioxane exceeding the screening level were not detected at these two locations during the

March 2011 monitoring event. Based on the infrequent detection of 1,4-dioxane, it is not considered a COPC.

Concentrations of ferric iron exceeded the screening level at all monitoring wells sampled during the two monitoring events. Manganese exceeded the screening levels in one Water Table Zone well and one Intermediate Zone well. Neither iron nor manganese is considered a COPC for development of the Conceptual Site Model.

7.1.5 Monitored Natural Attenuation Data

The geochemical results for groundwater samples collected from the Water Table Zone support the chemical analytical data, indicating that PCE and/or TCE are being biodegraded through reductive dechlorination. The geochemical data indicate that groundwater conditions are sufficiently reducing to support the complete reduction of PCE and/or TCE to chloride and carbon dioxide. Natural attenuation or enhanced natural attenuation appears to be potentially viable remedial alternatives for the Water Table Zone.

Geochemical conditions in the Shallow Zone indicate that groundwater conditions are amenable to the complete reductive dechlorination of PCE and/or TCE. Natural attenuation or enhanced natural attenuation appears to be potentially viable remedial alternatives for the Shallow Zone.

Geochemical conditions in the Intermediate Zone indicate that groundwater conditions are amenable to the complete reductive dechlorination of PCE and/or TCE. Natural attenuation or enhanced natural attenuation appears to be potentially viable remedial alternatives for the Intermediate Zone.

7.1.6 Groundwater Flow Direction

Depth to groundwater ranged from 5.39 to 10.06 feet below the top of the monitoring well casings in the monitoring wells screened in the Water Table Zone, the Shallow Zone, and the Intermediate Zone. The approximate direction of groundwater flow in the Water Table Zone for the Capital Area of Investigation was southwest, with a slight southerly deflection in the groundwater flow direction for the Water Table Zone noted in the vicinity of the intersection of 1st Avenue South and East Marginal Way for the June 2010 monitoring event, and a slightly

more westerly direction in the same area noted for the December 2010 monitoring event. The average horizontal hydraulic gradient for the Water Table Zone for the Capital Area of Investigation ranged from 0.002 to 0.003 foot per foot.

The approximate direction of groundwater flow in the Shallow Zone was southwest, with a slight southerly deflection in the groundwater flow direction for the Shallow Zone noted in the vicinity of the intersection of 1st Avenue South and East Marginal Way for the June and September 2010 monitoring events. The average horizontal hydraulic gradient for the Shallow Zone ranged from 0.001 to 0.002 foot per foot.

The approximate direction of groundwater flow in the Intermediate Zone was southwest. The average horizontal hydraulic gradient for the Intermediate Zone in the Capital Area of Investigation was 0.002 foot per foot.

The potentiometric head differences for nested monitoring wells screened in the Water Table Zone, the Shallow Zone, and the Intermediate Zone for the Capital Area of Investigation were negligible, indicating that vertical hydraulic gradient is not a factor in vertical transport of contaminants.

Hydraulic conductivity estimates obtained using both tidal data and slug test results indicate relatively high hydraulic conductivity in the Water Table Zone and the Shallow Zone (approximately 100 to 200 feet per day). Hydraulic conductivity in the Intermediate Zone appears to be lower than that in the Water Table Zone based on slug test results (approximately 5 to 10 feet per day). The hydraulic gradient and groundwater flow direction in the three aquifer zones are relatively consistent during a tidal cycle, and that tidal influence extends approximately 600 to 700 feet inland from the LDW.

7.1.7 Fate and Transport Modeling

The fate and transport modeling using the BIOCHLOR model indicates that PCE, TCE, and cis-1,2-DCE are unlikely to reach the LDW in any of the water-bearing zones. The modeling suggests that vinyl chloride concentrations may slightly exceed screening levels in groundwater entering the LDW from the Water Table Zone and the Shallow Zone over time at peak

concentrations of approximately 1.5 µg/l, roughly 15 to 20 years from the present; vinyl chloride concentrations in the Shallow Zone indicate a potential concentration of 2.9 µg/l under long-term scenarios (500 years), slightly exceeding the screening level of 1.69 µg/l. These simulations are very conservative assumptions, including a continuous source of COPCs for 500 years, which is highly unlikely given the dissolved-phase nature of the source. The simulations assume relatively long half-lives and do not account for tidal mixing that likely will dilute COPC concentrations before they enter the LDW. Dilution and dispersion associated with tidal mixing in groundwater have been found to decrease contaminant concentrations reaching surface water bodies by a factor of 3 to 10 or more in many coastal areas. The use of a decaying source term, which is more realistic based on known source conditions, results in modeled concentrations that do not exceed screening levels at the LDW.

7.1.8 Exposure Pathways

The exposure pathways evaluated in the RI include direct contact with soil, direct contact with groundwater, vapor to ambient air, and groundwater discharge to surface water. Based on the results of the RI and the Conceptual Site Model, there is a minimal risk of direct contact with soil or groundwater other than during subsurface construction work. The exposure risk posed by the vapor pathway is being evaluated under the Vapor Intrusion Assessment Work Plan (Farallon 2008b) and the Addendum to the Vapor Intrusion Assessment Work Plan (Farallon 2011a). The results of the RI indicate that there is currently no exposure risk associated with the surface water pathway because groundwater with COPCs exceeding the screening levels currently does not discharge to the LDW.

7.2 CONCLUSIONS

The RI collected sufficient information to sufficiently characterize the Capital Area of Investigation, including development of a Conceptual Site Model that defines source areas, COPCs, media of concern, and the nature and extent of COPCs, and provides an exposure pathway analysis. Ecology has indicated that additional tidal studies are necessary to complete the RI. Tier 3 VI Assessments are ongoing pending access issues. No additional investigation is warranted to complete the RI and meet the requirements of the Agreed Order.

The results of the RI confirm that concentrations of one or more of the COPCs exceed screening levels and MTCA cleanup levels that may be applicable to the Site. There is sufficient information to evaluate and select a technically feasible cleanup alternative.

8.0 REFERENCES

- Alta/ACSM Title Land Survey. 2004. Capital Industries Seattle Site. March.
- Arrow Environmental, Aspect Consulting, Farallon Consulting L.L.C., and Pacific Groundwater Group (Arrow et al.). 2007. *Interim Vapor Intrusion Plan*. July 20.
- Aspect Consulting. 2005a. *Preliminary Site Investigation Results, Art Brass Plating, Inc., 5516 Third Avenue South, Seattle, Washington*. December 1.
- . 2005b. *Follow-up Site Investigation Results, Art Brass Plating, Inc., 5516 Third Avenue South, Seattle, Washington*. July 19.
- . 2007. *Interim Cleanup Action Plan, Art Brass Plating, Inc., 5516 Third Avenue South, Seattle, Washington*. February 26.
- Booth, D. B., and L. Herman. 1998. *Duwamish Basin Groundwater Pathways Conceptual Model Report*. City of Seattle, Office of Economic Development.
- Cooper, H. H., Jr. 1959. “A Hypothesis Concerning the Dynamic Balance of Fresh Water and Salt Water in a Coastal Aquifer.” *Journal Of Geophysical Research*. 64 (no. 4): 461-467.
- Environmental Consulting Services, Inc. (ECS). 2005. *Draft Remedial Investigation Report, Capital Industries Site, Seattle, Washington*. Prepared for Capital Industries, Inc., Seattle, Washington. June.
- Environmental Data Resources, Inc. 2004. *Capital Industries, 5801 Third Avenue South, Seattle, Washington. Inquiry Number 01249156r*. August 12.
- Environmental Quality Management. 2000. *Users Guide for the Johnson & Ettinger Model for Subsurface Vapor Intrusion into Buildings*. (Revised.) December.

- Farallon Consulting, L.L.C. (Farallon). 2008a. *Remedial Investigation Work Plan, Capital Industries, Inc., 5801 Third Avenue South, Seattle, Washington*. Prepared for Capital Industries, Inc., Seattle, Washington. September 16.
- . 2008b. *Vapor Intrusion Assessment Work Plan, Capital Industries, Inc., 5801 Third Avenue South, Seattle, Washington*. Prepared for Capital Industries, Inc., Seattle, Washington. September 16.
- . 2009a. *Vapor Intrusion Mitigation Work Plan, Olympic Medical Facility, Capital Industries, Inc. 5801 Third Avenue South, Seattle, Washington*. Prepared for Capital Industries, Inc., Seattle, Washington. March 9.
- . 2009b. *Remedial Investigation Field Program, First Phase Report, Capital Industries, Inc., 5801 Third Avenue South, Seattle, Washington*. Prepared for Capital Industries, Inc., Seattle, Washington. September 18.
- . 2009c. *Vapor Intrusion, Inspection, Monitoring, and Maintenance Work Plan, Olympic Medical Facility, 5900 First Avenue South, Seattle, Washington*. Prepared for Capital Industries, Inc., Seattle, Washington. November 2.
- . 2010a. *Groundwater Monitoring Plan, Capital Industries, Inc., 5801 3rd Avenue South, Seattle, Washington*. Prepared for Capital Industries, Inc., Seattle, Washington. May 19.
- . 2010b. Letter Regarding Vapor Intrusion Tier 2 Assessment, Capital Industries, 5801 3rd Avenue South, Seattle, Washington. From Daniel Caputo, Project Chemist, and Peter Jewett, L.G., L.E.G., Principal Engineering Geologist. To Mr. Ed Jones, State of Washington Department of Ecology, Northwest Regional Office. November 1.
- . 2010c. Letter Regarding Response to Ecology Letter Dated November 3, 2010, Vapor Intrusion Assessment, Capital Industries, 5801 Third Avenue South, Seattle, Washington. From Daniel Caputo, Project Chemist, and Peter Jewett, L.G., L.E.G., Principal

Engineering Geologist. To Mr. Ed Jones, State of Washington Department of Ecology, Northwest Regional Office. December 2.

———. 2011a. *Addendum to the Vapor Intrusion Assessment Work Plan, Capital Industries, Inc., 5801 Third Avenue South, Seattle, Washington*. Prepared for Capital Industries, Inc., Seattle, Washington. January 18.

———. 2011b. Letter Report Regarding Tidal Study and Aquifer Characterization Results, Capital Industries, Inc., 5801 Third Avenue South, Seattle, Washington. From Norm Colby, Senior Hydrogeologist, and Peter Jewett, Principal. To Mr. Ed Jones, Washington State Department of Ecology. March 3.

———. 2011c. *Addendum to Groundwater Monitoring Plan, Capital Industries, Inc., 5801 3rd Avenue South, Seattle, Washington*. Prepared for Capital Industries, Inc., Seattle, Washington. March 4.

Farallon Consulting L.L.C. (Farallon), Aspect Consulting, Arrow Environmental, and Pacific Groundwater Group (Farallon et al.). 2008. *Data Summary Report, West Groundwater Investigation Area, Seattle, Washington*. January.

Ferris, J. G. 1963. “Cyclic Water-Level Fluctuations as a Basis for Determining Aquifer Transmissibility.” *Methods of Determining Permeability, Transmissibility and Drawdown*. U.S. Geological Survey Water-Supply Paper 1536-I. pp. 305–318.

Fetter, C.W. 1993. *Contaminant Hydrogeology*. Macmillan Publishing Co., New York.

Floyd Snider McCarthy, Inc. (FSM). 2004. *Capital Industries, Inc. Soil Vapor and Construction Monitoring Report*. Prepared for Capital Industries, Inc., Seattle, Washington. July 6.

King County, Washington. 2007. *GIS Center, Parcel Viewer*. No date.

http://www.metrokc.gov/gis/mappointal/PViewer_main.htm#newsHead.

(December 31, 2007.)

- Kohout, F. A. 1960. “Cyclic Flow of Salt Water in the Biscayne Aquifer of Southeastern Florida.” *Journal Of Geophysical Research*. 60 (no. 7): 3133-2144.
- Newell, C., et al. 2002. *Calculation and Use of First-Order Rate Constants for EPA Studies*. U.S. Environmental Protection Agency Groundwater Issue. November.
- Pacific Groundwater Group (PGG). 2006. *Blaser Die Casting Soil and Groundwater Investigation Report*. October 30.
- . 2007a. *Blaser Die Casting Pilot Source Control Action Plan*. April 10.
- . 2007b. *Indoor Air Mitigation, 5700 Third Avenue South, Seattle, Washington*. June.
- . 2008. *Current Status Report, Blaser Die Casting, 5700 Third Avenue South, Seattle, Washington*. June.
- Philip Services Corporation (PSC). 2002. *Revised Inhalation Pathway Interim Measures Work Plan*. August.
- . 2003. *Final Comprehensive Remedial Investigation Report*. November.
- . 2005. *Tier 3 Sampling Report for Inhalation Pathway Interim Measures, 5900 1st Avenue South, Seattle, Washington*. January.
- . 2006a. *Summary of the Inhalation Pathways Interim Measure Approach, Seattle, WA*. October.
- . 2006b. *Revised Technical Memorandum No. 1, Modeling, Cleanup Levels, Constituents of Concern, Remediation Levels, Conditional Points of Compliance, and Corrective Action Schedule, Seattle, WA*. June.
- Philip Services Corporation (PSC) and Pioneer Technologies Corporation. 2005. *Tier 3 Sampling Report for Inhalation Pathway Interim Measures, 5801 Third Avenue South, Seattle, Washington*. January.

- Plumb, R. H. 1981. *Procedures for Handling and Chemical Analysis of Sediment and Water Samples*. Technical Report EPA/CE-81-1, U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
- Serfes, M.E.. 1991. “Determining the Mean Hydraulic Gradient of Ground Water Affected by Tidal Fluctuations.” *Ground Water* 29 (no.4): 549-555.
- U.S. Census Bureau. 2011. U.S. Census Bureau News Release: “U.S. Census Bureau Delivers Washington's 2010 Census Population Totals, Including First Look at Race and Hispanic Origin Data for Legislative Redistricting.” February 23. <<http://2010.census.gov/news/releases/operations/cb11-cn45.html>.> (June 9, 2011.)
- U.S. Environmental Protection Agency (EPA). 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. October.
- . 1998. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water*. Technical Report EPA/600/R-98/128, Office of Research and Development. September
- . 2000. BIOCHLOR Natural Attenuation Decision Support System, User’s Manual Version 1.0. January.
- . 2002a. *Johnson & Ettinger Model Spreadsheets*. SL.ADV.xls and SG.ADV.xls.
- . 2002b. *BIOCHLOR Natural Attenuation Support System Version 2.2*. March.
- U.S. Geological Survey. 1983. *7.5-Minute Quadrangle Seattle South, Washington*.
- . 1991. *Bedrock Geological Map of the Seattle 30’ by 60’ Quadrangle, Washington*. Open-File Report OF-91-147, scale 1:100000.

Washington State Department of Ecology (Ecology). 2001a. *Guidelines for Preparation of Quality Assurance Project Plans for Environmental Studies*. Publication No. 01-03-003. February.

———. 2001b. *Model Toxics Control Act Cleanup Levels & Risk Calculations Version 3.1*. Publication No. 94-145. Revised November.

———. 2004. *Philip Services Corporation – Georgetown Facility Remedial Investigation Report Ecology/EPA ID#: WAD 00081 2909*. February 9.

———. 2005. *Capital Industries Plan 4 Vapor Intrusion Assessments*. 2005.

———. Well Logs. No Date.

<http://apps.ecy.wa.gov/welllog/MapSearch/viewer.htm?&FASTSTART=YES&SESSIONID=651490206> (December 2007.)

Western Regional Climate Center. *Seattle University of Washington (457478), Period of Record Monthly Climate Summary, 1971 to 2000 Monthly Climate Summary*. No date. <http://www.wrcc.dri.edu/CLIMATEDATA.html>.

Xu, M., and Y. Eckstein. 1995. “Use of Weighted Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Scale.” *Journal of Ground Water* 33 (no. 6): 905-908.

9.0 LIMITATIONS

The conclusions and recommendations contained in this report/assessment are based on professional opinions with regard to the subject matter. These opinions have been arrived at in accordance with currently accepted hydrogeologic and engineering standards and practices applicable to this location and are subject to the following inherent limitations:

- **Accuracy of Information.** Certain information used by Farallon in this report/assessment has been obtained, reviewed, and evaluated from various sources believed to be reliable. Although Farallon’s conclusions, opinions, and recommendations are based in part on such information, Farallon’s services did not include verification of its accuracy or authenticity. Should such information prove to be inaccurate or unreliable, Farallon reserves the right to amend or revise its conclusions, opinions, and/or recommendations.