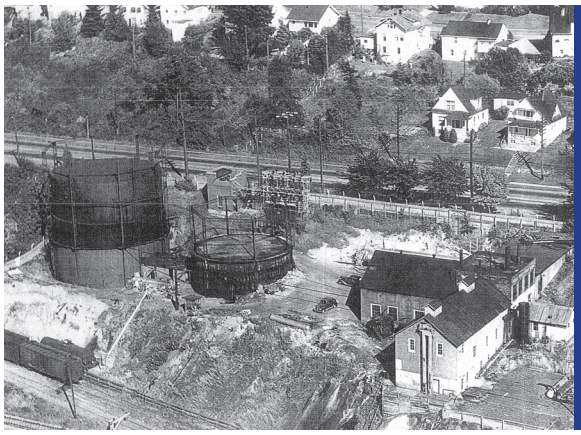

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY REPORT

South State Street Manufactured Gas Plant

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FINAL January 22, 2019

Final Remedial Investigation Report
South State Street Manufactured Gas Plant
Bellingham, Washington

January 22, 2019

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Final Remedial Investigation Report
South State Street Manufactured Gas Plant Site
Bellingham, Washington

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LIST OF ABBREVIATIONS AND ACRONYMS

µg/kg ..... micrograms per kilogram
µg/L ..... micrograms per liter
µg/m^3 ..... micrograms per cubic meter
AET ..... Apparent Effects Threshold
ARAR ..... Applicable or Relevant and Appropriate Requirements
BB&E ..... Bellingham Bay & Eastern Railroad
bgs ..... below ground surface
BNRC ..... Burlington Northern Railroad Company
BNSF ..... Burlington Northern Santa Fe Railway Corporation
BTEX ..... benzene, toluene, ethylbenzene, and xylenes
CERCLA ..... Comprehensive Environmental Response, Compensation, and Liability Act
City ..... City of Bellingham
CFR ..... Code of Federal Regulations
CGS ..... Coastal Geologic Services
CLARC ..... Cleanup Levels and Risk Calculations
cm/yr ..... centimeters per year
COC ..... chemical-of-concern
COPCs ..... constituents of potential concern
cPAH ..... carcinogenic polycyclic aromatic hydrocarbons
CSL ..... cleanup screening level
CWG ..... carbureted water gas
DNAPL ..... dense non-aqueous phase liquid
E&E ..... Ecology & Environment
Ecology ..... Washington State Department of Ecology
ELLW ..... extreme lower low water
EPA ..... US Environmental Protection Agency
ESA ..... Endangered Species Act
FS ..... feasibility study
ft ..... feet
ft^2 ..... square feet
GMD ..... Glaciomarine Drift
GRI ..... Gas Research Institute
HHRA ..... Human Health Risk Assessment
HPAH ..... high molecular weight PAH
IHS ..... indicator hazardous substance
LAET ..... lowest apparent effect threshold
LNAPL ..... light non-aqueous phase liquid
LPAHs ..... low molecular weight polycyclic aromatic hydrocarbon

2LAET ..... second lowest apparent effect threshold
m/sec ..... meters per second
mg/kg ..... milligrams per kilogram
mg/L ..... milligrams per liter
MGP ..... manufactured gas plant
MHHW ..... mean higher high water
MLLW ..... mean lower low water
mm ..... millimeter
MS/MSD ..... matrix spike/matrix spike duplicate
MTCA ..... Model Toxics Control Act
NAPL ..... non-aqueous phase liquid
ng/kg ..... nanograms per kilogram
NTU ..... nephelometric turbidity units
OHWM ..... ordinary high water mark
PAHs ..... polycyclic aromatic hydrocarbons
PCDDs ..... polychlorinated dibenzo-p-dioxins
PCDFs ..... polychlorinated dibenzo-p-furans
PLP ..... potentially liable party or person
ppt ..... parts per thousand
PSE ..... Puget Sound Energy
PSEP ..... Puget Sound Estuary Program
QAPP ..... quality assurance project plan
RCW ..... Revised Code of Washington
RI ..... remedial investigation
SAP ..... sampling and analysis plan
SCOs ..... sediment cleanup objectives
SCUM II ..... Sediment Cleanup User's Manual II
SHA ..... site hazard assessment
SMS ..... Washington State Sediment Management Standards
SQS ..... sediment quality standard
SSSMGP ..... South State Street Manufactured Gas Plant
TDS ..... total dissolved solids
TEQ ..... toxicity equivalency
TE ..... tidal efficiency
TEE ..... terrestrial ecological evaluation
TOC ..... total organic carbon
TPH ..... total petroleum hydrocarbons
TSS ..... total suspended solids
USACE ..... United States Army Corps of Engineers
UTL ..... upper tolerance limit

VAF.....vapor attenuation factor
VOC..... volatile organic compound
WAC..... Washington Administrative Code
WAD.....weak acid dissociable
WDNR..... Washington State Department of Natural Resources
WQC..... water quality criteria

1.0 INTRODUCTION

This remedial investigation (RI) report has been prepared under the Agreed Order negotiated between the City of Bellingham (City), Puget Sound Energy (PSE), and the Washington State Department of Ecology (Ecology) (Document No. 7655, Ecology 2010a). This report summarizes the findings of the RI conducted for the South State Street Manufactured Gas Plant (SSSMGP) cleanup site (Site) located in Bellingham, Washington (Figure 1). The RI was conducted to satisfy the requirements of the Model Toxics Control Cleanup Act (MTCA), Chapter 70.105D Revised Code of Washington (RCW), administered by Ecology under the MTCA Cleanup Regulation, Chapter 173-340-350 Washington Administrative Code (WAC) (Ecology 2007).

The RI report describes the history and environmental setting for the Site, a description of the releases of chemicals to the environment, potential receptors and Site screening levels that are protective of these potential receptors, and describes the nature and extent of chemicals exceeding screening levels for each affected media based on data collected during the RI. A feasibility study (FS) that develops and evaluates alternatives for conducting cleanup of the Site contamination described herein is provided at the conclusion of this RI report.

1.1 Site Description and Background

The Site is located in the general vicinity of Bayview Drive and South State Street as shown on Figure 1 in township T38 North, Range 2E, Section 36, occupying parcel numbers 380236245080, 380236237096, and 370201090495. The Site is situated on the northern portion of a City-managed park,[1] Boulevard Park, and includes nearshore uplands and adjacent aquatic lands located in Bellingham Bay.

In accordance with MTCA, the Site boundary is defined by the extent of contamination caused by the release of hazardous substances from Site activities, and is not limited to a release area or property boundaries. Areas in which Site-related hazardous substances have been deposited, stored, disposed of, placed, or otherwise have come to be located, are included within the Site boundary in accordance with Chapter 173-340 WAC. The Site boundary as currently understood is shown on Figure 1 and other figures throughout this report. The development and refinement of this boundary based on RI findings is addressed in Section 5 of this report.

For clarity, the Site has been further divided into an upland area and marine area based on impacts to these two areas, which have different cleanup criteria under MTCA and Sediment Management Standards (SMS [2013]; Chapter 173-204 WAC) regulations.

The uplands area includes the upper and lower portion of the Site, which were developed into a public park by the City in the time period from the late 1970s to the mid-1980s and continue to be used for

[1] The marine portion of the Site includes aquatic lands managed by the Washington State Department of Natural Resources (WDNR).

this purpose. The upper and lower areas of the Site uplands are separated by a steep sloped area. As shown on Figure 1, active railroad tracks owned and managed by Burlington Northern Santa Fe Railway (BNSF) pass through the lower portion of the uplands, beneath the sloped area. For the purposes of clarity in describing areas of the Site, this text refers to three distinct upland areas of the Site, as shown on Figure 1: Lower Park Area, Upper Park Area, and Slope Area.

From approximately 1890 to the late 1940s, a coal gasification plant operated in the Upper Park Area, as shown on Figure 2. The facility manufactured gas from coal, supplying residents and local businesses of Bellingham with gas for heating, cooking, and lighting. The gas plant consisted of above-ground gas holder tanks, fuel oil tanks, a retort and purifying facility, coal tar separators, and sheds for coal and coke storage. Of the original gas plant structures, only a few remain: a concrete aboveground gas holder tank, a small brick utility building, remnants of concrete foundations, and likely some underground piping in the Upper Park Area and Slope Area. The coal gasification plant was originally operated by the Bellingham Bay Gas Company, a predecessor of PSE. Cascade Natural Gas and Bellingham Gas Company, a predecessor of Cascade Natural Gas, also owned and/or operated the facility for some time beginning in the late 1940s. Eventually, residential developers purchased the property in the 1960s. In 1975, the City acquired ownership of the majority of the gas plant property from a private owner and Burlington Northern Railroad Company (BNRC) (Griffin 2007) in order to establish Boulevard Park, which was dedicated by the City for public use in June 1980.

Between 1984 and 2009, a number of investigations (US Environmental Protection Agency [EPA] 1984, Ecology & Environment [E&E] 1991, Erickson and Cubbage 1998, Norton and Summers 1998, Integral 2007, Herrenkohl Consulting and Landau Associates 2009) were conducted to assess environmental concerns based on the Site's previous usage. The investigations found elevated concentrations of petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs; benzene, toluene, and xylene) in surface water, soil, and/or sediment. In 1991, Ecology conducted a Site Hazard Assessment (SHA) and placed the Site (then referred to as the Boulevard Park Site) on the Hazardous Sites List. In January 2004, the Boulevard Park Site was excluded by EPA from the "eligible response site" list under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) because of its preliminary hazard ranking score in their database (EPA 2004). Ecology concurred with EPA's decision, taking over jurisdiction of the Site (Ecology 2004).

On August 12, 2005, Ecology notified the City of potential liability for the Site and designated the City as a "Potential Liable Party" (PLP) under MTCA (Chapter 173-340 WAC) (Ecology 2005). Without admitting any liability, the City accepted its PLP status in an August 22, 2005 response letter (City of Bellingham 2005). On March 31, 2008, the City made a formal request to Ecology to initiate negotiations for an Agreed Order to complete an RI/FS for the Site (City of Bellingham 2008). In that letter to Ecology, the City also asked Ecology to designate PSE and BNSF as additional PLPs for the Boulevard Park Site. On December 31, 2008, Ecology notified PSE of potential liability for the Site and designated PSE as a PLP (Ecology 2008). Without admitting any liability, PSE accepted its PLP status in a January 7, 2009 response letter (PSE 2009). After public notice and opportunity to comment, an

Agreed Order for completing an RI/FS was signed between the City, PSE, and Ecology on April 30, 2010 (Document No. 7655). It was under the terms of this Agreed Order that the City and PSE conducted the RI, with Ecology oversight described in this report.

Work plans were developed to guide the remedial investigation efforts (Herrenkohl Consulting and Landau Associates 2010). The work plans included a sampling and analysis plan (SAP), quality assurance project plan (QAPP), and the project health and safety plan. Data collected in the 2010 field investigation were summarized in an Interim Data Report (Herrenkohl Consulting and Landau Associates 2011a), and the results incorporated herein. Additional field activities were completed from 2011 to 2016 based on review and evaluation of the RI data, in order to collect sufficient information to develop and evaluate cleanup alternatives for the Site, in accordance with WAC 173-340-350. Remedial investigation activities subsequent to the initial 2010 activities have been conducted in accordance with work plan addenda (Herrenkohl Consulting and Landau Associates 2011b, 2011c, 2012, 2013, and Landau Associates 2016), as approved by Ecology.

1.2 Regulatory Framework

The RI for the SSSMGP Site was conducted under MTCA (WAC 173-340), which regulates requirements for the identification and cleanup of contamination in soil, soil vapor, surface water, and groundwater. Contamination in sediments in Washington State is addressed through the SMS (WAC 173-204), which includes cleanup standards for marine surface sediments (Ecology 2013a).

Additional regulations that may be applicable or relevant and appropriate requirements (ARARs) include the following:[2]

- Federal Clean Water Act and National Toxics Rule (40 Code of Federal Regulations [CFR] 131), which provide water quality criteria (WQC) for protection of human health and aquatic organisms
- Water Quality Standards for Surface Water of the State of Washington (WAC 173-201A), which also provides WQC for protection of aquatic organisms
- Shoreline Management Act (RCW 90.58; WAC 173-14), which establishes requirements for substantial development in waters of the State of Washington
- Dredge and fill requirements under 33 CFR Part 320-330 and Washington State Hydraulics Projects Approval (RCW 77.55; WAC 220-110)
- Endangered Species Act (16 United States Code 1531 et seq.; 50 CFR Part 200; 50 CFR Part 402) because listed species are documented in Bellingham Bay (e.g., Bull Trout, Puget Sound Chinook).

[2] The Federal Safe Drinking Water Act (40 CFR 141) and the Washington State Department of Health rules for Public Water Supplies (WAC 246-290-310) are no longer considered ARARs because groundwater at the Site is not considered potable (refer to Section 3.6).

Additional ARARs that may apply to the Site because of its location or the nature of remedial actions will be discussed in the FS report.

MTCA regulations establish the process for managing upland contaminated sites, from the discovery phase through cleanup. The RI/FS process generates the data necessary to confirm whether the Site requires cleanup and to determine the most appropriate cleanup action (if necessary). If it is determined during the RI/FS that cleanup is warranted, the next step is to develop a cleanup action plan that must comply with several requirements, including protection of human health and the environment, cleanup standards and ARARs, and provisions for compliance monitoring. The cleanup phase involves design, construction, operation, and monitoring of cleanup activities.

The SMS establish standards for the quality of sediments, apply those standards as the basis for management and reduction of pollutant discharges, and provide a management and decision process for the cleanup of contaminated sediments. Part V of the SMS, Sediment Cleanup Standards, establishes procedures and criteria to identify, prioritize, and clean up contaminated sediment sites. Ecology published a guidance document to support application of the SMS: the Sediment Cleanup User's Manual II (SCUM II; Ecology 2017). The RI/FS is being conducted in accordance with both SMS and SCUM II guidance.

1.3 Project Objectives

The primary objective of the RI effort is to collect sufficient data to define chemicals of concern (COCs), to understand the nature and extent of contamination at the Site, to identify potential transport mechanisms that affect the migration potential of the contamination, to evaluate potential risks to human health and the environment by comparing the Site environmental data to screening levels, and to delineate the site boundary based on these findings. The objective of the FS is to use data evaluated in the RI to develop and evaluate cleanup alternatives, and to select an appropriate cleanup alternative for the Site.

1.4 Document Organization

The remaining sections of the RI report include:

- Section 2: Project Background—summarizes the Site history and previous investigations at the Site.
- Section 3: Environmental Setting—describes the physical and ecological setting of the Site and surrounding areas including Site geology, hydrogeology, topography, flora and fauna, historical and cultural resources, and land use.
- Section 4: Site Screening Levels—presents potentially applicable screening levels for each Site media based on applicable exposure pathways and receptors.
- Section 5: Nature and Extent of Contamination—describes the nature and extent of constituents of potential concern (COPCs) for each Site media.

- Section 6: Contaminant Fate and Transport—describes potential contaminant sources and transport mechanisms and the conceptual site model of migration and exposure pathways.
- Section 7: Emergency Interim Action—summarizes the stabilization efforts undertaken to prevent the erosion and migration of soil contamination along the shoreline
- Section 8: References—lists documents cited in the remedial investigation.

2.0 PROJECT BACKGROUND

This section summarizes the history and previous investigations at the Site. Information provided in this section includes excerpts from previous Site documents (Herrenkohl Consulting and Landau Associates 2010, 2011a).

2.1 Site History and Usage

The historical information presented below was obtained by reviewing aerial photographs, the Sanborn Fire Insurance Atlas for the Bellingham area (from 1890 to 1950); property maps (from the 1920s to 1940s); local historical reports (Griffin 2007; Herrenkohl Consulting and Landau Associates 2009); and personal communication with City and PSE personnel and representatives. Select photographs and maps are provided in Appendix A. The approximate locations of relevant historical features shown on Figure 2 are based on these sources. The following sections provide information on the historical activities at the Site, including the railway, lumber mill, manufactured gas plant (MGP), stormwater outfalls, which discharge rainwater collected in the nearby neighborhoods, and the current property usage as a public park.

The cleanup Site boundary is established based on contamination associated with operations of the manufactured gas plant. Other historical operations and property uses that may have caused Site contamination are discussed in the following sections.

2.1.1 Railroad (1890 to Present)

The mainline of the coastal railroad passes through the Site, as shown on Figure 2. The active rail line is currently owned and operated by BNSF, but this rail line began operation as the Fairhaven & Northern Railway in 1890. Additional railways historically crossed the Site adjacent to the current rail line. These rail operations included the Bellingham Bay & Eastern (BB&E)/Northern Pacific track connecting with Lake Whatcom and the Highway 9 corridor (originally transporting coal, logs, lumber, and passengers) and now serving as the South Bay Trail (a portion of which is located within the Site boundary); the Northern Pacific/Chicago Milwaukee log dump spur, a spur off of the main Northern Pacific line to State Street; and the State Street railway. Rail-carried timber was milled at E.K. Wood, which operated on the lower portion of the Site as discussed in Section 2.1.2 below. Rail-carried coal was exported across the Northern Pacific line and imported for use by the coal gas plant (Griffin 2007; Herrenkohl 2009). Historical transport or loading operations involving coal or treated lumbers could have released polycyclic aromatic hydrocarbons (PAHs), including carcinogenic PAHs (cPAHs), to soil near the railway.

2.1.2 Lumber Mill

A portion of the SSSMGP Site in the Lower Park Area partially overlaps with the footprint of a lumber mill constructed by Edward Eldridge and Erastus Bartlett in 1884 (Griffin 2007)(Figure 2). It does not appear that gas manufacturing activities were conducted in this area. The lumber mill changed

ownership several times through its history, but operated over most of its time as either the Bellingham Mill Company or the E.K. Wood Lumber Mill. The mill was located almost exclusively on a large wood dock/wharf supported by wood pilings that extended for approximately 1,200 feet (ft) along the shoreline and 400 ft out into Bellingham Bay (Appendix A; 1904 Sanborn map). The majority of logs were floated or rafted to the mill by way of Bellingham Bay and surrounding tributaries. The wood was then milled and sent to world markets on three- to five-mast sailing schooners. A 1913 Sanborn map (Appendix A) shows an oil house and a steam-generating house at the lumber mill. These features were likely used to power the equipment of the mill. The mill was closed after a fire burned it to the ground on September 30, 1925; the fire was believed to have been started by a hot box or gear box of a machine axle (Griffin 2007). Hundreds of wood pilings remained along the waterfront after the fire, as evidenced in the 1955 aerial photo in Appendix A. The mill was not rebuilt after the fire; though industrial activity continued in the area as several buildings are shown in the 1955 aerial photograph which appear be located just downhill from the MGP.

Over the next 50 years, most of the remaining pier and pilings were cut to the mudline or removed, and the area was filled from local sources (e.g., demolition materials from the Fairhaven Hotel, wood debris from the mill) and developed into the lower park area it is today (Griffin 2007).

Activities at the lumber mill may have included handling or storage of timbers treated with preservative (such as coal-tar creosote), which could have released cPAHs in the Lower Park Area. Additionally, the large number of timbers shown in the 1955 aerial photograph in Appendix A, many of which are still present today in the Lower Park Area and in the marine environment, may be have been treated with coal-tar creosote and could also be a source of cPAHs in the area of the Site.

Potential Wastes/By-Products

Sanborn maps (Appendix A) document the presence of numerous contamination sources at the former lumber mill, some of which are discussed above. Known and potential contamination sources include the following:

- Petroleum products associated with documented mill equipment such as boilers, engines, fuel tanks, and oil houses would be sources of petroleum hydrocarbons and their constituents, such as PAHs.
- Combustion of petroleum and/or wood waste in mill equipment and features such as engines, boilers, the slab/refuse fires and refuse dump, as well as the 1925 E.K. Wood Lumber Mill fire. These mill activities and the 1925 fire would be sources of cPAHs.
- Creosote-treated timbers would be sources of cPAHs.
- Site investigations indicate that wood debris and wood waste is present in Site sediment as a result of historic mill operations and log rafting. The anaerobic biodegradation of the wood waste in sediment can produce methylphenols and benzoic acid. 2,4-Dimethylphenol and benzoic acid were detected in Site sediment.

2.1.3 Manufactured Gas Plant

On December 18, 1890, the Bellingham Bay Gas Company began operation of an MGP in the Upper Park Area (Griffin 2007 and references therein). Gas production and storage occurred from 1890 until about 1956. The facility produced a gas used for heating and light (which was similar to natural gas but derived from coal) for use by local residents and businesses. Based on information from the 1891 and 1904 Sanborn Fire Insurance maps (Appendix A), the facility initially included a coal house bunker, retorts, purifier, barrel sheds, and two gas holders. The facility expanded over the following decades to include additional gas holders and other equipment as the demand for gas increased (Appendix A; Sanborn Fire Insurance maps 1913, 1930, and 1950). The ownership of the gas plant facility changed a number of times between the early 1900s and mid-1950s with Whatcom County Railway and Light Company having ownership in about 1904, and then Whatcom Fairhaven Gas Company, Puget Sound Traction & Light & Power Company, Puget Sound Power & Light, Bellingham Gas Company, and finally Cascade Natural Gas Corporation having ownership of the facility afterwards, until about 1956 (Griffin 2007 and Herrenkohl 2009). Details relating to demolition of the facilities, other than what is discussed below, are uncertain.

Gas Production Methods

Facility-specific operations methods were not available for review. However, it is reasonable to assume typical MGP practices were used until the late 1940s, when the facility was converted to a propane operation, as described below. Prior to that conversion, the facility likely used either coal carbonization, or the carbureted water gas (CWG) processes. These were the two main gas production processes used at gas works facilities like the former facility at the Site (Gas Research Institute [GRI] 1996, Griffin 2007). The older and simpler process was coal carbonization. In this process, coal was heated in closed retorts or ovens where the coal was kept from burning by limiting its contact with oxygen. Volatile constituents of the coal would be driven off as a gas, which was collected, cooled, and purified prior to being piped into gas holders for distribution. The solid portion of the coal would become a black, granular material called coke which may have been sold as a by-product of the gas operations for home or commercial use (GRI 1996, Griffin 2007).

The other common process for MGP was the CWG process, which produced a gas mixture that burned hotter and brighter than the coal carbonization process. In this process, coal or coke was heated in a closed vessel or retort into which steam was injected. A chemical reaction took place which produced a flammable gas mixture of methane and carbon monoxide. Petroleum products were then sprayed into the hot gas mixture, creating another chemical reaction in which petroleum constituents were "cracked" to form methane, which increased the heating and lighting value of the gas (GRI 1996).

Appendix A contains historical photographs that may help to illustrate the general construction details of the gas holder tanks. They appear to have been constructed in accordance with similar practices of the time, using cylindrical, telescoping vessels. The lower portions of the tanks, also referred to as the foundations, were constructed with concrete cylindrical walls and a metal plate bottom. The upper

portion of the tank could be raised or lowered to increase or decrease the tank's volume and moderate gas pressure. A lift-frame was constructed around the perimeter of the tank, resting on top of the foundation, which was used to raise or lower the upper portion of the tank as needed. It was common practice at the time to fill a portion of the foundation with water to create a seal between the upper portion of the tank and the foundation, thus gas contained inside would not escape.

Based on observations in Site explorations, it appears the metal plate bottom of the former northern gas holder remains in-place. Soil augers and direct-push drilling rigs are not capable of penetrating the steel, so conditions below the steel were not investigated as part of this RI. However, based on a photograph of the tank bottom construction circa 1910 (Appendix A), it appears the tanks were constructed directly on the Chuckanut bedrock.

The only above-grade remnant of the former MGP gas holders is the concrete cylindrical wall of the former central gas holder. The top of this structure is covered with a 2-inch-thick layer of asphalt to limit stormwater infiltration and prevent contact with oily residuals in the bottom of the gas holder, as discussed further below. It is assumed this gas holder also has a metal plate bottom, which is containing the oily material.

There appears to be no underground remnant of the former southern gas holder based on observations in two soil borings (GP-12 and GP-13). These borings met refusal on sandstone.

In the late 1940s, the SSSMGP facility was converted to a propane-air gas manufacturing process (Robinson 2010). Liquid propane tanks (2) are shown on a 1950 aerial photograph provided in Appendix A. In this revised manufacturing process, liquid propane is air-heated into gas which is then held in gas holders for distribution. There are no documented wastes or by-products from this process (Hatheway 2009).

Potential Wastes/By-Products

Manufactured gas plants have been known to create a number of different by-products and wastes, which could affect the environment. Coal tar is one of these wastes, which is a dense oily liquid by-product of production and storage, which could separate from the gas and be collected at various points in the process. It was reported in a Site status review report (E&E 1999) that the SSSMGP produced on average 39,000 gallons of coal tar per year as a by-product while manufacturing gas. The locations of several tar wells and a tar separator are shown on Figure 2 based on the historical Site information provided in Appendix A. Heavy fractions of oil that separate from coal tar as a dense non-aqueous phase liquid are referred to as coal tar creosote, which was likely a valuable commodity.

Other by-products include purifier waste and coke. Purifier wastes were typically lime or wood chips treated with iron oxides, which were used to remove cyanide and sulfur from the manufactured gas. Coke is the solid material remaining after the volatile components of coal are removed in the retort, and was a valuable industrial commodity, useful for its heating value. At the SSSMGP, coke may have

been temporarily stored in a shed or house until sale or used as feedstock in the CWG process. Coke sheds were identified at the Site on 1912, 1913, and 1930 Sanborn maps, as shown on (Figure 2).

Based on the study of 33 different MGP sites, the Gas Research Institute developed a list of 47 chemicals potentially associated with historical processes (GRI 1996). These can be divided into categories of inorganic and organic chemicals of interest, as follows:

Inorganics:

- Ammonia
- Cyanide
- Nitrate
- Sulfate
- Sulfide
- Thiocyanates
- Aluminum
- Antimony
- Arsenic
- Barium
- Cadmium
- Chromium
- Copper
- Iron
- Lead
- Manganese
- Mercury
- Nickel
- Selenium
- Silver
- Vanadium
- Zinc

Organics:

- Benzene
- Ethylbenzene
- Toluene
- Xylenes
- Polycyclic aromatic hydrocarbons
- Phenolics

As will be described in later sections of this report, each of the 25 organic chemicals and 15 of the 22 inorganic chemicals of interest were investigated. The investigation described later in this report included 70 individual chemicals in soil and groundwater, 185 chemicals in marine sediment, and 13 volatile chemicals in soil vapor in order to investigate a wide array of constituents of potential concern. Some inorganic compounds from the Gas Research Institute list, such as aluminum, iron, and manganese were not investigated based on their high prevalence in natural background soil and low risk of toxicity.

Dioxins / Furans

Based on a request from Ecology during the RI process, a literature review was conducted to determine if dioxins/furans should be considered for inclusion in the analytical suite for the investigation. It was not initially included because the MGP process is not a standard combustion process—coal and or petroleum is heated in the absence of oxygen and produces gas through pyrolysis, which differs from combustion and is not associated with dioxin/furan production due to the absence of oxygen.

Additionally, feedstocks at MGPs usually consisted of coal and range of petroleum materials. Oil-based gas processes typically used gas oil, fuel oil, cracked gas oil, heavy naphtha and heavy residuum as feedstock; petroleum-based feedstocks are composed of aromatics, olefins, naphthalenes, and

trace amounts of ash and sulfur (GRI 1996). In general coal is composed of fixed carbon, volatile material, moisture, ash, and trace sulfur (GRI 1996). These feedstock materials are unlikely to contain more than 1 percent chlorine. Experiments suggest that a chlorine content of 1 percent in the feedstock is the threshold for a direct relationship to dioxin formation from combustion sources—i.e., a chlorine content greater than or equal to 1 percent is strongly correlated to the amount of dioxin formed, but a chlorine content less than 1 percent is not (EPA 2006, Ecology 1998).

Various furans (e.g., dibenzofuran [CAS No. 132-64-9] and benzofuran [CAS No. 271-89-6]) are present in coal tar. These compounds, however, are not chlorinated, and they do not belong to the family of polychlorinated compounds (dibenzo-p-dioxins [PCDDs] and dibenzo-p-furans [PCDFs]) that Ecology suggests be considered as a site-related contaminant. Chlorinated dioxins and furans have not been identified as chemicals of interest at other MGP sites by federal or state agencies (in guidance or regulation), nor does literature suggest a relationship. The Gas Research Institute report noted above is considered the industry standard on the remediation of MGP sites, and does not list dioxins/furans as a typical MGP-related chemical.

Another major body of work reviewed was the *Remediation of Former Manufactured Gas Plants and Other Coal-Tar Sites*[3] written by Dr. Allen Hatheway, formerly with the Missouri University of Science and Technology. Dr. Hatheway spent his career searching for and compiling information regarding remediation of MGPs. His publication provides a comprehensive list of MGP COPCs; dioxins are not included on this list. The 2006 *Environmental Forensics Contaminant Specific Guide*[4] was also consulted and it does not identify MGPs as potential dioxin sources.

Federal and state regulatory websites were also reviewed. Neither the EPA's[5] or Ecology's website pages related to dioxin source control[6] and cleanup include MGPs as a source of these contaminants. A similar review of websites of other state agencies (Indiana, New York, New Hampshire) had the same result.

Inventories of dioxin sources by both state and federal agencies[7] revealed the following major sources of dioxins:

1. Incineration of municipal solid waste
2. Incineration of medical waste
3. Secondary copper smelting
4. Forest fires

[3] Hatheway, Allan W. Remediation of Former Manufactured Gas Plants and Other Coal-Tar Sites. 2012. CRC Press, Boca Raton, FL.
[4] Morrison, Robert and Brian Murphy (editors). 2006. *Environmental Forensics--Contaminant Specific Guide* Academic Press, Burlington, MA.
[5] http://www.epa.gov/region05/cleanup/mgp.htm; http://epa.gov/tio/download/misc/mgp/chap1-4a.pdf; http://www.epa.gov/pbt/pubs/dioxins.htm
[6] https://fortress.wa.gov/ecy/publications/publications/0003054.pdf;
[7] http://www.epa.gov/ncea/pdfs/dioxin/2006/dioxin.pdf; https://fortress.wa.gov/ecy/publications/publications/98320.pdf

5. Land application of sewage sludge
6. Cement kilns
7. Coal-fired power plants
8. Residential wood burning
9. Chlorine bleaching of wood pulp
10. Backyard burning of household waste
11. Hog fuel (wood waste) boilers
12. Activated carbon regeneration
13. Municipal wastewater treatment
14. Wood treatment
15. Oil refineries

Of the confirmed or suspected contaminated sites list maintained by Ecology[8], none of the sites where dioxin is a contaminant of concern is an MGP.

One New Zealand report[9] was reviewed that stated "recent industry studies have found that PCDDs and PCDFs may be present in coal tar and contaminated soil at gasworks sites." The paper explains that "studies undertaken at four gasworks sites [in New Zealand] have measured PCDDs and PCDFs in coal tar and contaminated soil in the range 1.13 to 13.1 nanograms per kilogram (ng/kg) I-TEQ."[10] Follow-up with the authors regarding these cited investigations was not successful. The references provided in that report were reviewed; however, no information was available on the referenced gasworks studies.

In reviewing the data provided in the New Zealand inventory, it was noted that the reported concentrations are low. As an example, the upper concentration listed for the coal tar and contaminated soil at gasworks sites cited in the New Zealand inventory (13.1 ng/kg I-TEQ) is well within the range of dioxin concentrations reported for urban background soil in Seattle (7.5 ng/kg TEQ to 36 ng/kg TEQ; average = 19 ng/kg TEQ). Given the relatively low concentrations of dioxin/furans measured in "coal tar and contaminated soil at gasworks sites," it appears this isolated connection between coal gasification and dioxins/furans is likely invalid, and the results were probably indicative of diffuse urban sources.

Finally, seven marine sediment samples were analyzed for dioxins/furans. Only two of the seven had detections above background conditions, and there was no spatial distribution indicating a gradient toward the Site, providing final confirmation that the Site was not a source of dioxin/furans.

[8] https://fortress.wa.gov/ecy/tcpwebreporting/report.aspx

[9] Simon J. Buckland, Howard K Ellis, and Patrick Dyke.2000. *New Zealand Inventory of Dioxin Emissions to Air, Land and Water, and Reservoir Sources,* Organochlorines Programme, Ministry for the Environment. March.

[10] I-TEQ is the international toxicity equivalency, based on older toxicity equivalency factors.

2.1.4 Stormwater Discharges

Two stormwater outfalls have been identified, located on the northeastern shoreline of the Site (Figure 2). One 18-inch corrugated metal outfall discharges untreated stormwater collected from South State Street and the surrounding South Hill Neighborhood (an approximate 122-acre area) into Bellingham Bay (Herrenkohl 2010). The other smaller 8-inch PVC pipe discharges untreated stormwater collected from three catch basins in the Boulevard Park parking lot and lower Site area.

2.2 Current Site Usage – Boulevard Park

Since 1980, the Site has been used solely as a public park. In 1975, the City acquired most of the gas plant property from a private owner and the BNRC for use as a park (Griffin 2007), which opened in June 1980 as previously noted. In early 1979, the City Parks and Recreation Department began development of the park, including construction of trails, parking lots, restrooms, and a picnic shelter. The redevelopment of the Site also included placement of fill with grading, landscaping, and shoreline improvements (e.g., erosion control).

As part of the park development, the City hired a geotechnical engineering firm to complete a soil and foundation investigation (Rittenhouse-Zeman 1979). Ten test pits and five borings were drilled in support of this investigation and included information on subsurface soil conditions such as thickness and type of fill materials and depth to bedrock (Herrenkohl Consulting and Landau Associates 2010). Soil in three test pits (TP-3, TP-5, and TP-10) and two borings (B-2, B-5) were observed to be saturated in oil with strong diesel odor; no chemical testing was conducted. Information from this study was used in designing a picnic shelter, restroom facility, pedestrian bridge, and parking areas.

The City pumped out an oil/water mixture that was remaining in the two gas holder tanks located in the upper portion of the Site. One of those tanks contained the oil/water that had been transferred from an older, larger tank (gas holder #3) previously removed from the park (City of Bellingham 1979a). The City had reportedly removed approximately two-thirds to three-quarters of the oil/water mixture by November 1979 and disposed the liquid in Albany, Oregon (Herrenkohl 2008). Because it was not possible to safely access the bottom of the tank, some of the mixture remained in the tank. The City filled the tank with sand and gravel and placed an asphalt cover over it before constructing a picnic shelter in its location in early 1980. The asphalt cover prevented direct contact with the tank and limited infiltration from precipitation; fencing and vegetation were used to prevent public access to the lower portion of the tank. At that time, the City also began construction on the pedestrian bridge over the railroad trestle, and renovation of the Pottery Studio (present day Woods Coffee Shop; City of Bellingham 1979b).

In January 1983, the landscape around the existing gas holder tank (gas holder #2) was modified by planting trees around the outside to prevent people from climbing the gas holder tank. City officials were concerned that coal tar residue remained on the outside of the tank and was observed (both visually and olfactory) in some surrounding soil (City of Bellingham 1983). Byron Elmendorf, Parks

Director at that time, contacted EPA officials in early 1984 and requested they conduct an investigation of the soil in the park. While waiting for a response from EPA, the City collected soil samples near the tank and submitted the samples to Ecology for analysis of PAHs (Ecology 1984). In a letter dated April 25, 1984, Ecology concluded the concentration of PAHs in these samples were not designated Extremely Hazardous Waste (<1 percent concentration) based on their evaluation of the State's Dangerous Waste Regulations (WAC 173-303). Approximately 55 gallons of soil and contaminated water was removed from the area adjacent to the tank and transported by a City contractor to a landfill for proper disposal (Uniform Hazardous Waste Manifest 1993).

On May 17 and 18, 1984, EPA collected soil samples (from 0 to 0.5 ft and 0 to 3 ft) in the upper (primarily) and lower portions of the Site (EPA 1984). Based on the findings, Park officials roped off the area of concern, the sloped area between the upper and lower portions of the Site. In addition, the City posted warning signs in the upper portion of the Site (City of Bellingham 1984a, b). On November 19, 1984, the US Department of Health and Human Services of the Centers for Disease Control provided review comments on EPA's study. They concluded the available data did not indicate a significant health risk to users of the park but recommended restrictions to public access in the upper portion of the Site (e.g., a fence around the existing gas holder tank), continued surveillance for new areas of contamination, and an assessment of the potential impact to marine surface water and marine ecology due to the PAHs. Subsequently, Ecology conducted a SHA a few years later and in 1991, placed the Site on the Washington State Hazardous Site list, as discussed in Section 1.1.

In the fall of 1984, the wharf along the northwest shoreline was refurbished with new decking and support stingers from a 3-ft high concrete retaining wall. Soon after, a public access pier was constructed that adjoined the wharf.

The next significant development for the northern portion of the park (within the Site boundaries, in the Lower Park Area; Figure 1) was the construction of a park shelter referred to as the "Porch" in 2009. The shelter is an approximately 30-ft by 30-ft wood structure built on a concrete foundation and used for musical concerts and theatrical productions during the warmer months of the year.

In the fall of 2013, approximately 1,000 ft of the shoreline in the Lower Park Area—extending from the Woods Coffee Shop to the western edge of the Site boundary—was improved, including stabilizing and protecting the shoreline, enhancing the intertidal zone and providing safe public access to the beach (City of Bellingham 2013). Construction activities included removal of undesirable material from the beach, such as concrete rubble, derelict iron machine parts, broken piling, and failing revetments. A portion of the beach was also excavated to provide sufficient depth for beach nourishment materials. Drift sills were constructed using large angular boulders that hold the enhanced beaches in place and beach fill material was composed of large and medium gravel.

The park is a well-utilized asset for the local community with an active trail system, over-water walkways, a pocket beach, picnic tables, barbeques, and an outdoor performance stage with events

throughout the summer. The park receives an estimated 1 million visitors per year, and is a popular meeting place for the public to enjoy scenic views of Puget Sound, exercise outdoors, and connect with others in the community throughout the year.

Park maintenance includes regular mowing and watering of the lawns, and occasional planting or replacing of trees as needed. Maintenance repair activities for the irrigation watering system and sewer system are relatively high in comparison to other City parks, due to the high park usage. Presently, the steeply sloped area of the park is overgrown with shrubs and trees. The City does not prune or mow in this area, preventing public access.

Future development in the lower portion of the park within the Site boundary includes shoreline restoration, maintenance and replacement of underground utilities, safety improvements at the railroad crossing, and the construction of a new over-water walkway.

2.3 Relationship to Other Nearby Cleanup Sites

There are three other MTCA cleanup sites under investigation near the SSSMGP Site, including the Whatcom Waterway, Cornwall Avenue Landfill, and R.G. Haley cleanup sites. Ecology is overseeing each of these cleanup efforts, which are being conducted under consent decrees between the entities noted below and the State of Washington. The Port of Bellingham is conducting the cleanup at the Whatcom Waterway and Cornwall Avenue Landfill sites, and the City is conducting the cleanup at the R.G. Haley site.

The Whatcom Waterway cleanup site overlaps with the sediments portion of the SSSMGP Site. The primary COC at the Whatcom Waterway site is mercury in sediments. The cleanup project is in the latter stages of designing and permitting the remedial action. The cleanup remedy includes monitoring of sediments within the SSSMGP Site boundary.

Along the shoreline of Bellingham Bay and approximately one-half mile to the northeast of the Site are the Cornwall Avenue Landfill and R.G. Haley cleanup sites. Contamination at these two sites consists primarily of municipal solid waste refuse, wood debris, and wood treatment chemicals associated with former operations at the R.G. Haley site. Both of these sites are in the preliminary design and permitting stages. It does not appear that these sites overlap with the SSSMGP Site boundary.

3.0 ENVIRONMENTAL SETTING

This section presents a summary of the environmental setting of the Site. This includes a discussion of relevant physical conditions, geology, hydrogeology which could affect the investigation, the contaminant fate and transport, or potential migration or exposure pathways. This section also includes a summary of natural and cultural resources, and land and navigation uses as they may be relevant to human or ecological receptors that could potentially be exposed to contamination, if present.

3.1 Physical Conditions

The sections below provide a summary of the physical conditions pertinent to understanding fate and transport, or chemical exposure scenarios. This evaluation considers Site structures, topography and bathymetry, drainage pathways and stormwater flow, shoreline features and erosion, sediment deposition, and surface water circulation patterns.

3.1.1 Site Structures

The Site has a number of structures within its boundaries, generally associated with the current land use as a public park. These structures are shown on Figure 1, and are summarized below by area:

Lower Park Area:

- Public pier (recently removed as discussed in Section 7, due to structural and safety concerns)
  - Timber construction, formerly located at the shoreline at the north end of grass lawn
  - Consisted of an approximately 100-ft wharf with retaining wall parallel to the shoreline, and an approximately 50-ft pier that extends into the bay
- Park shelter which functions as a covered stage
  - Constructed in 2009 in the eastern portion of the grass lawn
  - Approximately 900 square feet (ft^2)
- Restroom
  - Constructed in 1979 in the northern portion of the grass lawn
  - Approximately 700 ft^2
- Pedestrian bridge (currently closed to the public due to structural and safety concerns)
  - Built during park development to connect the upper and lower park areas that are separated by a steep slope
  - Approximately three stories high and spans the width of the railroad right-of-way

Upper Park Area:

- Gas holder # 2 (remnant from the MGP)
  - Concrete tank is approximately 50 ft in diameter and 20 ft high

  - Top is partially capped with asphalt and covered with two layers of 6-millimeter (mm) plastic and one layer of 20-mm plastic sheeting to prevent infiltration of precipitation
  - Security fence limits access to this feature
- Electric/generator building (remnant from the MGP)
  - Brick building along South State Street, approximately 425 ft^2.

3.1.2 Site Topography and Bathymetry

Figure 3 presents elevation contours for the Upland and Marine portions of the Site. As shown on the figure, the Lower Park Area is relatively flat, ranging from 10 ft to 20 ft above the mean lower low water (MLLW) elevation. The elevation along the uplands just above the mean higher high water (MHHW) is about 11 ft above MLLW, increasing in elevation to about 20 ft above MLLW near the railway. On the upland side of the railway, the elevation rises steeply in the Sloped Area of the Site from about 20 ft to 50 ft MLLW, generally mirroring the slope of the underlying shallow bedrock. The surface elevation in the Upper Park Area is varied, ranging from about 55 to 85 ft above MLLW. In the open grassy area southwest of Gas Holder Tank #2, the elevation is approximately 60 ft above MLLW, which is about 25 ft lower than the elevation of the adjacent South State Street. The elevation gradient between the Upper Park Area and South State Street is less uniform than other areas of the Site, apparently due to historical development activities.

Surface elevations in most areas of the Site uplands have been modified by development. In the Upper Park Area, the location of the former MGP facility, the surface has been modified by cutting into the sandstone bedrock to develop the access road to the plant and enhance the former gas plant's operating room and structures. Additionally, an unknown amount of fill and top soil was placed in this area to cover impacted soil and old concrete foundations, to flatten grades and enhance the functionality of the Park (Herrenkohl 2008, 2013).

The Lower Park Area has an elevation of approximately 10 to 15 ft above MLLW and is the former location of the lumber mill (refer to Section 2.2). The lower portion of the Site was created through filling the tidal flats and numerous derelict creosote pilings with wood chips/bark/dust and local fill materials of unknown source(s). Hummocky topography observed in this area is a result of settling of the fill material and degradation of organic materials.

As evidenced in the bathymetric contours, the intertidal zone in the marine portion of the Site slopes gently away from the uplands to a depth of about -4 ft MLLW, then strikes steeply in the subtidal zone to a depth of about -20 ft MLLW.

Based on bathymetry, the marine portion of the Site is divided into two areas for the purposes of discussion throughout this report:

Marine Portion of the Site:

- Intertidal Zone
- Subtidal Zone.

The intertidal and subtidal zones are further delineated in Section 3.4 based on habitat type and function.

3.1.3 Drainage and Stormwater

The overall movement of stormwater at the Site is toward Bellingham Bay, following the topographic contours shown on Figure 3. Approximately 5 to 10 percent of the surface area of the Site is covered by impermeable surfaces, including buildings, paved walkways, compacted gravel walkways, and covered structures. Two stormwater outfalls discharge onto the beach above MHHW. The two outfalls are located in the northeastern portion the Lower Park Area. Samples collected from these locations use designated sampling points SW-01 and SW-02, shown on Figure 3. The surface water drainage from the surrounding South Hill neighborhood discharges into Bellingham Bay; a significant portion of this is routed through the outfall represented by sample location SW-01.

The majority of the precipitation on the Site infiltrates into the soil through the permeable and semi-permeable (grass-covered) areas to join the groundwater flow. The drainage from the parking lot system in lower Boulevard Park captured by the park stormwater system is discharged through the outfall represented by sample location SW-02.

3.1.4 Shoreline Features and Erosion

The existing conditions along the shoreline at the Site generally consist of a level low-bank approximately 9 to 11 ft above MLLW. The upland area along most of the shoreline is vegetated with grass and the bank slope is armored with rock (cobbles and boulders ranging from about 12 to 18 inches in diameter). Until the fall of 2017, a portion of the north-facing shoreline consisted of a timber pile-supported timber wharf with a concrete bulkhead. These features were removed as part of an Interim Cleanup Action at the Site, as described further in Section 7. The shoreline directly to the south of the Site is improved with recently engineered and built shoreline protection. The City completed shoreline restoration of the western shoreline south of the Site, between the Woods Coffee Shop and near the Site boundary. Implementing the protection system generally included excavation of rip-rap and concrete materials, and the installation of beach nourishment and drift sills.

The small pocket beach that occupies the central portion of the Site is in a low wave energy environment and is protected from winds from all directions except from the north. The pocket beach area appears to be relatively stable with accretion visible in some areas.

The primary erosional force along the Site's shoreline is wave action generated by winds. The predominant winds for Bellingham Bay are from the south-southwest, which provides the Site with a

degree of protection due to the sheltered headlands to the south (Coast and Harbor Engineering 2010). However, the outer shoreline of the Site does experience a moderate amount of erosional stress, including periodic flooding during extreme high tides.

A storm, which produced relatively high winds, surf, and precipitation, occurred on February 10, 2017 and resulted in bank erosion and damage to the existing wharf. The storm appears to have removed soil and fill debris previously located behind the rock armor. The storm also appears to have damaged the existing concrete bulkhead adjacent to the wharf on the upland side. The damage was evidenced by visible settlement and cracking in the concrete bulkhead as well as sinkholes or eroded channels behind the bulkhead. An emergency interim action is underway to prevent erosion of potentially contaminated soil, described later in Section 7.

3.1.5 Sediment Deposition

There is no sedimentation rate information for sediments within the Site boundary. However, sedimentation rates have been evaluated for other parts of Bellingham Bay as part of the Whatcom Waterway Site RI/FS (RETEC 2006 and references therein). Data collected in support of the Whatcom Waterway RI/FS indicates much of the inner Bellingham Bay area, including the area between Boulevard Park and Cornwall Avenue Landfill, is depositional with the Nooksack River as a primary sediment source. Sedimentation rates were calculated for the Whatcom Waterway Site using four estimation methods including the onset of Cs-137 activity, peak of Cs-137 activity, Pb-210 decay, and peak mercury concentration (RETEC 2006). The average net sedimentation rate calculated for inner Bellingham Bay was 1.6 centimeters per year (cm/yr; range from approximately 1.5 to 1.8 cm/yr). A similar sedimentation rate is expected for aquatic lands within the Site boundary, especially within and adjacent to the pocket beach. This was confirmed in the field where a 0.5- to 3-ft layer of fine-grained sediment was observed above a wood debris layer in many of the sampling locations within the Site boundary (refer to Appendix B boring logs). The surficial sediments were likely deposited over the wood debris layer in the last 50–60 years since log rafting ceased in this portion of the bay.

As with any shoreline that has undergone modifications, sedimentation rates along the Site's shoreline have likely varied significantly over the years with the construction then demolition of the lumber mill, and shoreline protection projects including drift sill construction and the latest interim action to protect the shoreline from erosion. Based on empirical evidence of shoreline erosion during significant storm events, and the distribution of cPAHs confirmed during this RI, there has been some degree of sediment transport away from the shoreline, even if only under ephemeral conditions, such as storm events. Chemical testing was used in this RI to evaluate the extent of contaminant transport, rather than relying on models to predict where potentially contaminated materials may have been deposited. Further evaluation of sediment transport may be required during remedial design to enhance long-term effectiveness. An interim action was conducted at this Site, as described in Section 7 of this RI report to protect the shoreline from continued erosion until a cleanup action can be developed and implemented for the Site.

3.1.6 Surface Water and Circulation Patterns

The sediment and water dynamics in the vicinity of the Site are driven by a complex interplay of forces including deep water currents, tides, river discharges, and wind. The Site is located on the boundary of what has been called the upper Bellingham Bay area and the Inner Harbor. The currents in this area are generally powered by a fairly steady deep water current (greater than 20 meters) that brings Pacific Ocean water from Rosario Strait in through the south end of Bellingham Bay and westward. The westward moving deep current eventually encounters the powerful discharge of the Nooksack River located in the northwest corner of the bay and mixing ensues (US Army Corps of Engineers [USACE] 1977). The bottom currents of Bellingham Bay have a typical velocity range from 0.2 to 0.3 meters per second (m/sec) with deep current velocities ranging between 0.04 to 0.18 m/sec (Colyer 1998). Re-suspension of fine grained sediments can occur at velocities above 0.3 to 0.4 m/sec; however, the bottom currents near the Site fall in the lower velocity range and are considered a net depositional environment (RETEC 2006).

The currents on the surface of the bay are highly influenced by the winds and the discharge rates of the Nooksack River, which have a velocity range between 0.02 to 0.06 m/sec with a maximum of about 0.36 m/sec (Colyer 1998 and Shea et al. 1981). The primary surface currents of the bay spin clockwise in nature, but counter-clockwise rotations can occur depending on the wind direction. Several studies have suggested that an eddy may form north of the Site near the mouth of Whatcom Waterway (Collias et al. 1966, USACE 1977, Colyer 1998). This eddy generally functions in a clockwise rotation and its location is dependent on the tide level as well as the discharge rates of the Nooksack River and Whatcom Creek (Colyer 1998). As a result of this eddy, surface water at the Site is generally flowing in a southwestern direction and a depositional environment is created along its shoreline. The longshore drift near the Site can vary with the wind and does not have a dominant direction (Ecology 2010b).

The mean tidal range in Bellingham Bay is 5.2 ft with a typical diurnal range of about 8.6 ft; however, tidal elevations can be increased by seasonal changes, storm surges and tsunamis (RETEC 2006). The entire lower area of Boulevard Park is considered to be within the tsunami evacuation area (WDNR 2007). The salinity of the surface water in the vicinity of the Site can range from 10 to 25 parts per thousand (ppt) with salinity of the deeper waters ranging from 26 to 30 ppt. Salinity can be lowered by large flooding events in the Nooksack River and Whatcom Creek, as well as higher salinities during the incoming tides (Colyer 1998). The water temperatures of the bay vary with depth and seasonal air temperature, but can range from 8 to 13 degrees Celsius (Colyer 1998). The total suspended solids (TSS) near the Site was measured by Colyer (1998) and reported to have concentrations of 3 to 25 milligrams per liter (mg/L) in the surface water and a concentration of 1 to 32 mg/L in deep water, with an average of 10 mg/L across the water column.

Future Sea Level Rise

Sea levels are rising and developing science indicates that this trend will continue due to long-term climate change. Design of a cleanup action for this Site will take into consideration the latest scientifically developed predictions at the time of design, which may differ from current sea level rise projections. A sea level rise of 2.4 ft over the next 100 years has been assumed for other cleanup sites in Bellingham Bay, including the Waterfront District Environmental Impact Statement (EIS; Blumen Consulting Group, Inc. 2010) and the Engineering Design Report (EDR) for the nearby Cornwall Avenue Landfill cleanup site (LAI 2018). For the purposes of this RI, we assume a sea level rise of 2.4 ft is likely to occur within the next 100 years, and represents an acceptable benchmark for consideration at this time.

3.2 Geology

The Site geology consists of bedrock overlaid by varying thicknesses of glacial marine drift, wood debris, and fill material consisting of granular fill, demolition debris, and other debris. Figure 4 presents in plan-view the alignments for four geological cross sections. Figures 5 and 6 present southeast-northwest trending cross sections (A-A' and B-B') and Figures 7 and 8 present southwest-northeast trending cross sections in the upper portion of the Site (C-C') and the lower portion of the Site (D-D'), respectively. The Site geology is discussed in the following paragraphs from the deepest (oldest) unit to the shallowest unit, and is also shown in cross section on the figures referenced above.

3.2.1 Chuckanut Formation

The deepest geologic unit observed on Site was bedrock that consists of sandstone and carbonaceous shale, regionally known as the Chuckanut Formation. Borings completed during RI field activities extended to the surface of the Chuckanut Formation, except in several specific locations, as discussed in the following sections. Chuckanut Formation samples observed during field sampling activities were red to gray, fine to medium grained sandstone with hardness ranging from very soft to hard, depending on the degree of weathering. Moderate weathering was observed in samples at the soil/rock interface; unweathered rock was observed in samples collected from below this interface.

As shown on the cross-sections and on the bedrock surface contour map provided in Figure 9, the Chuckanut Formation underlies the entire Site at varying depths. The top surface of the bedrock generally slopes toward the north and northwest. Bedrock outcrops are visible along the uplands slope area, especially in the eastern side of the Site. The following paragraphs summarize explorations used to identify the bedrock surface.

Upper Park Area

In the Upper Park Area, the depth to bedrock ranges from the ground surface (along the slope edge) to 26 ft below ground surface (bgs) (GP-16).On average, the surface of the bedrock slopes downward to the northwest with a gradient of approximately 0.29 ft/ft. A depression of in the bedrock is present in the vicinity of GP-16, GP-19, and GP-23, where the bedrock surface is as much as 10 ft below surrounding bedrock surface elevations.

Two borings (HP-26 and HS-43) extended below the surface of the bedrock in the upper portion of the site; soil samples indicated unweathered, gray rock at HS-26 and moderately weathered to unweathered, red/orange rock at HS-43.

Slope Area

In the Slope Area, the Chuckanut Formation is exposed in some areas visible along the walking path. The gradient of the bedrock is approximately 0.50 ft/ft, but is as steep as approximately 1.11 ft/ft in some locations. A thin veneer of soil and debris is deposited on top of the bedrock, which has become overgrown with blackberries and other invasive species.

Lower Park Area

In the upland lower portion of the Site, the depth to bedrock ranges from 4.5 ft bgs (GP-26) to 37 ft bgs (MW-55) and the surface of the bedrock slopes downward to the north with a gradient of approximately 0.15 ft/ft.

One boring (MW-58) extended below the surface of the bedrock in the lower portion of the Site; soil samples indicated unweathered, gray rock.

Marine Portion of the Site

In the intertidal and subtidal zones of the Site, sediment borings (SB-01 through SB-12) were extended to the bedrock surface. As in the lower portion of the Site, the surface of the bedrock slopes to the north at approximately 0.22 ft/ft.

Seismic Activity

Design of a cleanup action for the Site should consider slope stability analyses related to seismic activity to ensure long-term protectiveness of the cleanup action. We anticipate seismic design considerations will include evaluating the probability of an earthquake event and the anticipated peak ground acceleration. Potential seismic events will be considered during engineering design to provide for long-term stability of the completed remedy.

Based on the geologic map “Faults and Earthquakes in Washington State” (WDNR 2014) and the USGS Seismic Hazard Mapping Tool (USGS website 2018), we estimate the Sandy Point fault is the closest located to the site, approximately 12 kilometers north northwest of the Site. Further design

considerations are outside the scope of a remedial investigation report but will be included in the remedial design process. It is not anticipated that seismic hazards would affect selection of cleanup options, as any option should be readily capable of including design considerations to preserve long-term effectiveness.

3.2.2 Bellingham Drift

Overlying the Chuckanut Formation beneath most of the lower portion of the Site uplands and Bellingham Bay is glacial marine drift, referred to as the Bellingham Drift and/or Glaciomarine Drift (GMD). The GMD is typically a soft to stiff, unsorted and unstratified, pebbly, sandy silt and clay material with occasional marine shells that were derived from rock debris that emerged out of glacial ice as rising sea levels floated and melted glacial ice and deposited the material on the sea floor. In the lower portion of the Site, the GMD is generally between 1 and 2 ft thick, except at soil borings GP-38 and MW-55 where the GMD is 8 ft and 9 ft thick, respectively. Also, except in the western portion of the Site, the GMD tends to thicken toward the shoreline and beneath Bellingham Bay. In the upper and western portions of the Site, no GMD was encountered.

3.2.3 Wood Debris and Fill Material

Above the GMD, or above the Chuckanut Formation where no GMD exists, wood debris and fill material are present. In the upper portion of the Site, fill material consists primarily of silts, sands, gravels, and debris or sandy silt and silty clay. In some areas, wood and other debris (brick fragments, coal fragments, and clinker) were encountered. Throughout most of the lower portion of the Site, a layer of wood debris up to 29 ft thick (GP-42) is present immediately above the GMD or the Chuckanut Formation. In general, the wood debris layer thickens to the north and northwest. The wood debris consists of fresh to moderately decomposed wood chips and bark. Above the wood debris is a 2- to 7-ft thick layer of fill material consisting of silts, sands, and gravels with some debris (e.g., brick and wood fragments).

The wood debris extends into Bellingham Bay to the northwest of the Site and tapers out toward the northeastern shoreline. Wood debris has been encountered at thicknesses up to 20 ft in nearshore sediment borings (SB-12). Sediments from the Nooksack River are deposited on top of the wood debris in Bellingham Bay or the GMD where wood is not present. These sediments are referred to as the Nooksack Deposits and typically consist of soft silt, sandy silt, and silty clay.

3.3 Hydrogeology

Hydrogeologic conditions at the Site were evaluated during the RI, in order to understand groundwater flow conditions which may affect the transport of contaminants. Geologic and groundwater elevation data was collected during the soil investigations and monitoring well installations. Additionally, groundwater elevations were measured across the Site during the September 2010, March 2011, and February 2012 groundwater monitoring events. The effects of tidal

fluctuations were studied in 2010 and 2015 to evaluate the influence of marine waters on groundwater conditions and to determine the optimal time during a tidal cycle to collect upland groundwater samples to maximize the proportion of groundwater (instead of surface water) in the sample. Groundwater samples collected adjacent to tidally-influenced shorelines can be primarily composed of marine water when surface water is moving inland during high tides. During low tides as the marine water retreats from the shoreline, samples collected can be primarily composed of groundwater. Because these interactions vary in timing based on the tide cycle and hydrogeology, sample collection timing was selected to maximize groundwater representativeness and sample during the worst-case (highest potential contaminant concentration) conditions. The selection of the timing is discussed further below.

3.3.1 Hydrogeologic Units

Shallow groundwater is present beneath most of the upland portion of the Site within fill or native topsoil above bedrock and possibly within Bellingham Drift or weathered bedrock. Regionally, deeper hydrogeologic units may be present in and below the Bellingham Drift/Chuckanut Formation. For the purposes of understanding the fate and transport mechanisms at the Site, only the shallow hydrogeologic unit is significant, as evidenced by a lack of groundwater encountered in soil borings that extended below the top of the bedrock (HS-26, HS-43, and MW-58) and the relative impermeability of the Bellingham Drift/Chuckanut Formation, which function as an aquitard isolating the shallow groundwater observed at the Site from any deeper aquifers.

Shallow groundwater in the upland portion the Site can be separated into three zones, consistent with the divisions in the upland portion of the Site previously discussed: Upper Park Area, Slope Area, and Lower Park Area.

- Shallow groundwater in the Upper Park Area is present as a thin discontinuous water-bearing zone perched on bedrock. This zone is recharged primarily through direct rainfall infiltration and is seasonally dry in some areas. Groundwater occurrence and flow through this area is controlled by the slope and shape of the underlying bedrock surface.
- Shallow groundwater in the Slope Area appears to be largely absent, although a thin film of water is likely present seasonally moving down the steep slope within the shallow soil on top of bedrock or in weathered bedrock.
- Shallow groundwater in the Lower Park Area is generally present as a shallow unconfined (water table) water-bearing zone within the man-made fill underlying this area. It too is recharged by direct rainfall infiltration, but must also be recharged by groundwater inflow from the Slope/Upper Park Areas.

During three groundwater monitoring events, the depth to groundwater was measured at each well in the Upper and Lower Park Areas using a hand-held water level indicator. The depths to groundwater below ground surface and the groundwater elevations are summarized in Table 1. Groundwater level measurements were collected from wells in the lower portion of the Site during a falling tide prior to groundwater sampling; the approximate tide at the time of groundwater elevation measurement is

also shown on Table 1. Groundwater elevations and the associated groundwater elevation contours and flow directions for each of the three groundwater monitoring events (September 2010, March 2011, and February 2012) are illustrated in Figure 10 through Figure 12, and discussed further by area below.

Upper Park Area

Groundwater in the Upper Park Area appears to be limited within areas of significant soil thicknesses above the bedrock. Groundwater in this area is not clearly hydraulically connected to groundwater in the Lower Park Area, except that it likely passes in ephemeral instances through the Slope Area, such as during rain events. As shown in Figure 10 through Figure 12, the groundwater present in this area is at an elevation significantly higher than in the Lower Park Area, indicating that some amount of groundwater from this area migrates through the Slope Area or Lower Park Area. The most likely migration path is downward through the shallow soils covering the bedrock in the steep Slope Area, or through a weathered horizon at the top of the bedrock.

In the Upper Park Area, shallow groundwater is present along the boundary with the Slope Area, in the fill overlying the Chuckanut Formation. This groundwater zone appears to be present only in the western portion of this area, where the depth of the underlying bedrock surface is greater than in the eastern or southern portions. Groundwater monitoring wells were planned for installation in the Upper Park Area adjacent to South State Street, but were not installed due to lack of groundwater presence. Four monitoring wells were installed near the boundary between the Upper Park Area and the Slope Area. Groundwater is consistently present at two of these monitoring wells (MW-19 and MW-24) where a saturated aquifer thicknesses of up to 13 ft has been observed. These wells are located within a depression in the bedrock surface (see Figure 9). At the two wells in the eastern side of upper portion of the Site (MW-07 and MW-44), saturated thicknesses of up to 3 ft have been observed, but these two wells have each been dry during monitoring events. The observed aquifer thickness in this area corresponds logically with the higher elevation of the bedrock surface.

Due to the lack of significant groundwater in soil borings advanced along the southeast margin of the Site along South State Street noted above, no monitoring wells were installed hydraulically upgradient of the four upper monitoring wells. Also, the lack of significant groundwater in these borings and the high percentage of impermeable surfaces southeast of the Site suggest that a consistent groundwater thickness is not necessarily present and groundwater flow through the upper portion of the Site functions more as isolated perched groundwater zones subject to bedrock contours rather than as a contiguous aquifer. Groundwater in this area is assumed to flow perpendicular to the bedrock surface contours, as shown on Figure 9. During wet periods, the elevation of groundwater in the Upper Park Area may rise sufficiently high enough to flow over the bedrock into the Slope Area, as is discussed in the following section.

Despite the likely discontinuous nature of groundwater discharge from the Upper Slope Area, Figures 10 through 12 do show a slight divergence of flow to the north and southwest away from an

apparent bedrock high point at HA-12, about 60 ft northeast of MW-19. This divergence suggests that groundwater discharging into the Slope Area may be concentrated in two areas, rather than across the entire length of the Slope Area.

Slope Area

Groundwater has not been observed in the Slope Area of the Site. Twelve hand-auger borings (HA-01 through HA-12) were advanced in the Slope Area through the thin veneer of soil to the bedrock surface and did not encounter saturated soil. Based on the presence of groundwater in the Upper Park Area, it is assumed that infiltrating stormwater and temporal flow from the perched groundwater in the Upper Park Area may ephemerally migrate through this area. The only indication of water in this area is a wet condition on the surface of the bedrock observed during rain events. No groundwater contours are shown in the Slope Area on Figure 10 through Figure 12 based on these findings.

Lower Park Area

Groundwater in the Lower Park Area is primarily recharged by direct precipitation and infiltration in the grass lawn, and also from stormwater infiltration and discharge from higher elevation areas both on and offsite. Groundwater presence and flow characteristics in this area are as expected; shallow, flowing toward the Bay, and having varying degrees of influence by the changing tides of the adjacent Bellingham Bay.

North of the pocket beach, it is not clear whether any significant groundwater is actually present, or if water observed in this area is seawater intrusion into the fill material at the shoreline. Groundwater was not observed in soil borings SB-26 and HS-26 in this area where depth to bedrock is shallow. Groundwater also has not been observed at monitoring well MW-58 in this area. Limited water was present in MW-58 during groundwater sampling events, but not at sufficient quantity to allow for recharge after minimal purging efforts. This water observed in the casing was likely trapped in the well (drilled into the bedrock) sourced from condensation within the well casing or temporal flow across the top of the bedrock surface during precipitation events.

Based on the fluctuation in groundwater table elevation observed in the Lower Park Area, the tidal influence was evaluated to determine the best time for collecting groundwater samples for chemical analysis while minimizing dilution effects of seawater. The tidal influence on groundwater levels at the Site was first evaluated by using data collected from three monitoring wells during a 5-day period in 2010 (Landau Associates 2010). The results were used to estimate where tidal influence was heavy, moderate, or not observed in the Lower Park Area. The hydrographs provided on Figure 13 through Figure 15 show the tidal influence is heavy in the area of MW-36, moderate in the area of MW-38, and not observed at MW-28. The lag between fluctuations was compared with the tide to select sample collection timing.

In 2015, additional efforts were taken to improve and refine sample collection timing by monitoring the conductivity and groundwater level within MW-46 over a 7-day period (Landau Associates 2016). The evaluation concluded the optimal timing for sample collection for nearby groundwater monitoring wells was just over 3 hours following low tide in Bellingham Bay. And, the findings suggested the groundwater in the deeper portions of the well were significantly less affected by seawater than shallower water which exhibited much higher conductivity values, which indicated the presence of saline seawater.

3.4 Natural Resources

The natural resources of the SSSMGP Site and surrounding area are summarized in the following sections, with some additional detail provided in Appendix C: Terrestrial Ecological Evaluation Report. The types and functions of marine and nearshore habitats are presented first followed by the types of plants and animal species that are utilizing the Site.

3.4.1 Types and Functions of Habitats

The Site area consists of four distinct habitats and associated communities including the marine riparian, intertidal, shallow subtidal, and deep subtidal zones; each with a unique set of characteristics that support varied plant and animal species as described below.

3.4.1.1 Marine Riparian Habitat

Riparian corridors generally transport water, plant seeds, and nutrients to water resource areas and thereby serve as important migration routes for many wildlife species. Riparian areas, though small in overall size, are one of the most important sources of wildlife biodiversity in the landscape. The marine riparian zone extends inland from the ordinary high water mark (OHWM) *"to that portion of the terrestrial landscape that is influenced by, or that directly influences, the aquatic ecosystem"* (WDFW 2011). The riparian zone encompasses all of the uplands on the SSSMGP Site.

The marine riparian zone consists of the developed landscape of Boulevard Park (lawns, buildings, trails, and parking lots), the railroad right-of-way, armored shorelines, residential buildings and apartments, and a small forested sloped area. The forested slope consists of a mixed deciduous and conifer forest with an understory of shrubs and herbaceous plant species. The plant species include, but are not limited to, red alder, western hemlock, big leaf maple, Douglas fir, Sitka spruce, shore pine, American elm, salmonberry, oceanspray, snowberry, Indian plum, Scotch broom, thimbleberry, elderberry, Himalayan blackberry, English ivy, nightshade, old man's beard, and various other herbaceous plants (Herrenkohl Consulting 2011a). A number of state priority habitat species may utilize the Site marine riparian zone and include a variety of birds and waterfowl, similar to those found in the intertidal zone (refer to Section 3.4.1.2).

The Site is mostly developed as a park and is utilized by large numbers of people. The intensity of land use generally limits the types of animal species that can inhabit the area to urbanized species that can

tolerate small isolated patches of forest (refer to Section 3.4.2). However, the trees on the site do provide potential perching and nesting areas for a wide range of birds.

3.4.1.2 Intertidal Habitat

The intertidal zone extends from the OHWM to the extreme lower low water (ELLW) (WDFW 2011). In elevation, the intertidal zone on the Site encompasses land from +10 ft MLLW to about -4 ft MLLW. These intertidal areas Site consist of rocky substrate, sand and gravel beaches, armored shoreline, and historical piers and pilings. The upper portion (+10 ft to 0 ft MLLW) of the intertidal zone on the Site is dominated by rocky substrate, armored shoreline and beaches. Very few vascular plants are currently growing in this area, but a wide variety of clams, mussels, crabs, fish, barnacles, invertebrates, and some macroalgae occur here (WDFW 2011; RETEC 2006; Herrenkohl Consulting 2011b). The lower intertidal (0 ft to -4 ft) substrate consists of mud, sand, gravel, and cobbles with fine wood debris. Native eelgrass and some macroalgae occupy a large portion of this area and provide high quality habitat, food, and refuge to various organisms, including juvenile salmon, shrimp, crab, and flat fish. The sand and mud substrate offers habitat for epibenthic prey that in turn feed juvenile salmon (WDFW 2011, RETEC 2006, Grette & Associates 2009). Additionally, eelgrass and macroalgae are both used by forage fish, such as Pacific herring, as spawning habitat. Native eelgrass is listed as a priority habitat by WDFW and is protected under state law (WDFW 2011).

3.4.1.3 Shallow Subtidal Habitat

The shallow subtidal zone extends from about -4 ft MLLW to about -10 ft MLLW. Subtidal areas within the Site consist of rocky substrate, fine sands and silts, wood waste, fill material, and native vegetation such as eelgrass and macroalgae. The native eelgrass and macroalgae occupy the entire vertical extent of this zone, but eelgrass does not extend below -10 ft MLLW (Grette & Associates 2009). This habitat can be used for food, refuge, and reproduction by a variety of organisms including crab, shrimp, sponges, sea anemones, worms, sea stars, clams, oysters, and a variety of fish such as perch, prickleback, flat fish, and some juvenile salmon. Additionally, Dungeness crab mating and egg brooding can occur in this zone (RETEC 2006).

3.4.1.4 Deep Subtidal Habitat

The deep subtidal zone on this Site extends from -10 ft MLLW to approximately -20 ft MLLW (WDFW 2011, Herrenkohl Consulting 2010). The deep subtidal zone within the Site boundary consists of mostly fine silts and sands with some cobbles and gravels. Eelgrass is lacking in this zone, but some red, brown and green algae can grow in this range. Similar species of animals can occupy this zone as live in the shallow subtidal zone. However, some clams drop in abundance with increasing water depth; however, others (e.g., geoducks) prefer deeper water compared to the shallow zone (RETEC 2006).

3.4.2 Utilization by Animal Species

Due to the property usage as a park with a large number of visitors, and the existing railroad track crossing through the middle of the Site, only a relatively small portion of the Site can be utilized for wild species. Documented uses for significant animal species in the area are summarized below. The animals that are protected by the Federal Endangered Species Act (ESA) and Washington State Priority Species laws (RCW Title 77) are discussed in Section 3.4.2.5.

3.4.2.1 Birds

The open waters, shoreline habitat, shallow estuarine habitats, and man-made habitats of Bellingham Bay provide foraging, nesting, resting, and homes to a wide variety of birds throughout the year. The location of Bellingham Bay between the Fraser River estuary and the Skagit Bay allows migrating seabirds and waterfowl to utilize the bay as a stopover point as they complete their migrations (RETEC 2006). Large populations of waterfowl are uncommon on the bay, but the winter populations of migratory species are generally 10 to 15 times larger than the summer populations (Manual, et al. 1979).

There are hundreds of types of birds that could possibly use the marine waters off the shores or the riparian area on the Site, some of which are listed as a protected priority species. Some of the species that were observed or may be found on the Site include but are not limited to loons; grebes; cormorants; herons; scoters; western Grebe; Canadian geese; cormorants; a variety of ducks; sandpipers; gulls; crows; jays; nuthatches and chickadees; woodpeckers; sparrows; winter wrens; band-tailed pigeons; owls; hawks; bald eagles; blue herons; murrelets; and osprey (Herrenkohl Consulting 2011; Audubon Society 2012). The marbled murrelet is listed federally under the ESA and a large number of species utilizing the Site are also listed as state priority species (refer to Section 3.4.2.5).

3.4.2.2 Fisheries and Invertebrate Resources

The shoreline, shallow waters and deep waters off the SSSMGP Site provide a foraging, migration, and breeding habitat for a wide range of fisheries and invertebrate resources including surf smelt, Pacific sand lance, Pacific herring, salmonids, ground fish, clams, geoducks, oysters, shrimp, and crabs (RETEC 2006, Grette & Associates 2009).

Surf smelt and Pacific sand lance utilize the shallow waters of Bellingham Bay year round for foraging and migration. The habits of surf smelt and Pacific sand lance indicate that they spawn in the high intertidal portions of coarse sand and gravel beaches (WDFW 1998a); however, no surf smelt or sand lance spawning has been documented within the Site. The lack of spawning documentation is likely due to a lack of suitable spawning substrates.

Pacific herring are more widely known and are better studied compared to surf smelt and Pacific sand lance. The interest in Pacific herring is the result of the existence of commercial fisheries for herring,

the importance of herring as food for salmonids, use as bait for salmon fishing, and the presence of herring through the marine waters of Washington (WDFW 1998a). Pacific herring spawn between January and June on marine vegetation such as eelgrass and algae in the shallow subtidal and intertidal zones between +1 ft and -5 ft MLLW (WDFW 1998a, RETEC 2006, Grette & Associates 2009). Although they utilize the subtidal and intertidal zones, they have also been found in the deeper water of Bellingham Bay. The eelgrass located on the Site is a potential suitable spawning habitat for the Pacific herring (RETEC 2006, Grette & Associates 2009).

Bellingham Bay is used by six different species of anadromous salmon species including Chinook, chum, Coho, pink, sockeye, and steelhead. Several species of closely related fish including bull trout, Dolly Varden, and sea-run cutthroat also utilize Bellingham Bay (Shea et al. 1981, WDFW 2011). A number of these fish species are listed as endangered or priority species (see sections below) under both federal and state regulations. The rivers draining into Bellingham Bay all have at least one species of salmon or salmonid use in their waters. Additionally, salmon and salmonids utilize the shoreline and offshore waters as migration routes, foraging habitat, and rearing areas (Salo 1991). The numbers of chum, Coho, and Chinook in the bay peak in mid-May and likely use the shoreline for foraging and as a migration route toward Whatcom Creek, the Nooksack River, and Squalicum Creek (RETEC 2006, Salo 1991).

There are several species of groundfish that are known to utilize the shallow and deep water habitat nearby. Groundfish are defined by WAC 220-16-340 and include a wide variety of species of bottomfish such as Pacific cod, Pacific whiting (hake), all species of dabs, sole, flounder, greenling, ratfish, cabezon, sculpins, wolf-eel, spiny dogfish, rockfishes, and surf perches except shiner perch (WDFW 1998b, 2011). Of these, rockfish are considered a priority species under state regulations. Little information is available on which of these species utilize Bellingham Bay and the shallow and deep subtidal at the Site. Likely some of these species utilize the deeper portions of the Site for at least a portion of their life cycle.

There are many different marine invertebrates that dwell off the Site and in Bellingham Bay including worms, clams, geoducks, oysters, small ghost shrimp that penetrate benthic sediments, very small crustaceans or epibenthic plankters, crabs, and shrimp (RETEC 2006). The clams in the bay occupy the intertidal and subtidal zones, and can include butter clam, littleneck clam, Manila clam, purple varnish clam, horse clam, soft-shell clams, and cockles. Studies on the SSSMGP Site have found populations of Manila clam, purple varnish clam, littleneck clam, horse clam, and mud clam but no oysters or geoducks (RETEC 2006; Herrenkohl Consulting 2011). The types of shrimp species that occupy the nearshore and deep waters off of the Site include pink shrimp, coonstripe shrimp, dock shrimp, and spot shrimp (RETEC 2006). Several types of species of crab are also common in the nearshore next to the SSSMGP Site and include purple/graceful crab, red rock crab, and Dungeness crab (RETEC 2006). The majority of rock crab tends to be located below the -20 ft MLLW deep subtidal zone of the Site; however, both rock and Dungeness crab utilize the shallower waters of the intertidal and subtidal zones for portions of their life cycle particularly during the nursery/rearing stages for juvenile

Dungeness crab (RETEC 2006, Ecology 1996). The beach habitat located at the Site is made up of gravel, sand, and shell substrate which is the preferred habitat for the first 8 to 10 weeks after larvae settle for Dungeness crab (RETEC 2006). Additional substrates and habitats that are important to young crabs include small cobbles, gravel, algae, and eelgrass (RETEC 2006).

3.4.2.3 Marine Mammals

Several species of marine mammal have been observed in Bellingham Bay and by proximity have the potential to be offshore of the SSSMGP Site. These marine mammals include harbor seals, Steller sea lions, Orca whales, gray whales, and harbor porpoises. The presence and residence time of most of the marine mammals in Bellingham Bay is not widely understood (PTI 1989). Several of these species are listed as endangered species or state priority species (see section below). Only a few marine mammal species have been observed to use the nearshore habitat next to the Site. Harbor seals utilize this nearshore habitat most frequently and gray whales have also been known, on rare occasions, to utilize the subtidal portions around the bay for feeding (RETEC 2006, WDFW 2011). No documentation was found to indicate that gray whales have ever used the nearshore area adjacent to the Site. Orca whales and the rest of the species are rarely seen in Bellingham Bay and generally do not utilize the shallow waters of the intertidal and shallow subtidal located at the Site (RETEC 2006, WDFW 2011).

3.4.2.4 Upland Mammals and Other Species

The riparian headlands of this Site provide potential habitat for a wide variety of large and small mammals and reptiles that have adapted or can tolerate a semi-urban environment. The most common mammals and other species on the Site include Douglas squirrels, introduced eastern gray squirrels, introduced cottontail rabbits, raccoons, Garter snakes, and a wide variety of insects (Herrenkohl Consulting 2011). A soil biota survey revealed that several types of worms and arthropods use the Site's landscaped areas including earthworms, arthropods and other unidentified worm species (Herrenkohl Consulting 2011).

3.4.2.5 Threatened, Endangered, Sensitive, and Candidate Species

This section provides information on the occurrence of state and federally listed, threatened, endangered, sensitive, or candidate species for bird, fish and marine mammal species in Bellingham Bay. The federal ESA categorizes a species as "endangered" if that species is likely to become extinct. Additionally a "threatened" species is one that is likely to become endangered within the foreseeable future. Washington State also has a priority species list that requires similar protective measures but for a larger list of animals (WDFW 2011).

A number of federally listed threatened and endangered species may potentially utilize the Site and vicinity. The threatened species include Puget Sound Chinook salmon, coastal-Puget Sound bull trout, Puget Sound steelhead trout, Steller sea lion, and marbled murrelet. The listed endangered species

include southern resident Orca whale, humpback whale, and leatherback sea turtle (Grette & Associates 2009).

In addition, a number of state priority species have been identified as potentially utilizing Bellingham Bay including but not limited to surf smelt, Pacific sand lance, Pacific herring, Pacific salmonids and trout (Coho, chum, Chinook, pink, sockeye, and cutthroat), a number of groundfish (e.g., rock sole, English sole, lingcod, Pacific cod, Pacific hake, walleye Pollock, starry flounder), several types of rockfish (e.g., black, brown, canary, copper, greenstriped, quillback, redstripe, yelloweye, and yellowtail), a variety of bivalves (butter clam, native littleneck clam, geoduck, Olympia oysters), pandalid shrimp, Dungeness crab, a variety of small and large marine invertebrates, and a variety of marine mammals (harbor seal, sea lions, Orca whale, gray whale, Dall's porpoise, and Pacific harbor porpoise), leatherback sea turtles, seabirds and waterfowl (e.g., widgeon, scoter, golden eye glaucous-winged gulls and pigeon guillemots), bald eagles, and peregrine falcon (WDFW 2011, RETEC 2006).

Although a large number of species have the potential to be utilizing the habitat in or adjacent to the Site, the frequency and density of usage varies drastically between species and time of the year. Some of the listed species have not been seen or expected on the Site (e.g., Steller sea lion, humpback whale, and leatherback sea turtle); however, some are common occurrences everyday year round (e.g., harbor seal, butter clam, native littleneck clam, gulls, cormorants, and some waterfowl).

3.5 Historical and Cultural Resources

No cultural artifacts were encountered during the field investigation for the RI.

Archaeological surveys were conducted for portions of Boulevard Park by Wessen & Wahl (2009) and Wessen & Associates (2010). The 2009 assessment of archaeological potential focused on the southern end of the park where improvements to the existing Pattle Point Trestle walkway are proposed by the City. The 2010 cultural resources evaluation was completed for the lower southern portion of the park and surrounding areas in support of the engineering design for shoreline improvements and construction of an over-water walkway between Boulevard Park and the former Cornwall Avenue landfill. Both studies consisted primarily of a literature review, but neither included the upper portion of the Site. The 2010 study by Wessen & Associates also included a pedestrian reconnaissance of the lower portion of the park, noting areas where prehistoric or historic cultural resources could be present.

Both studies included examining relevant archaeological, ethnohistorical, and historical reports to understand the cultural history of the project areas and facilitate identification of potential culturally sensitive areas.

According to both reports, there were no indications of the presence of prehistoric or early historic archaeological deposits or features within the project area, including the lower portion of the SSSMGP

Site. It was reported that these areas have been disturbed by a variety of both natural and historic cultural affects (e.g., railroad activities) and the latter may have impacted any archaeological resources.

3.6 Land and Navigation Uses

The entire upland portion of the Site is zoned for public land use—Boulevard Park. The three property owners are the City, BNSF, and the State. The Upper Park Area and the Slope Area are owned solely by the City. The inner harbor line delineates the property boundary between BNSF and State lands, managed by WDNR. The City leases the Lower Park Area and aquatic lands from WDNR.

Potential future development within the Site boundary includes shoreline restoration, maintenance and replacement of underground utilities, safety improvements at the railroad crossing, and the repair for the pedestrian bridge between the Upper and Lower Park Areas.

Current uses for the aquatic land within the Site include transit and transient moorage use by recreational vessels (e.g., kayak use of the pocket beach). Some tribal, recreational, and commercial fishing and shellfish harvesting activities may also occur seasonally. Deep-water navigation is restricted in this area due to the proximity of natural shallow-water obstructions (e.g., Starr Rock), and by the lack of adjacent upland navigation support facilities (RETEC 2006). No changes to these existing uses are anticipated.

Shallow groundwater at the Site is classified as non-potable based on the criteria under WAC 173-340-720(2):

- "*The ground water does not serve as a current source of drinking water*" [WAC 173-340-720(2)(a)].
  - Drinking water is currently supplied by the City of Bellingham. Water supply wells are not known to exist at or near the Site.
- *"The department determines it is unlikely that hazardous substances will be transported from the contaminated ground water to ground water that is a current or potential future source of drinking water, as defined in (a) and (b) of this subsection [i.e., -720(2)], at concentrations which exceed ground water quality criteria published in chapter 173-200 WAC"* [WAC 173-340-720(2)(c)].
  - RI data indicate that contaminated groundwater occurs in the uppermost water-bearing zone at the Site. This water-bearing zone occurs in manmade fill placed into Bellingham Bay and above the Chuckanut Formation. The shallow aquifer discharges directly into Bellingham Bay. Contaminated groundwater in the shallow aquifer will not flow laterally inland toward other aquifers that may be a current or potential future source of drinking water, because inland aquifers are hydraulically upgradient of the shallow aquifer. Similarly, contaminated water in the shallow aquifer will not flow vertically downward into deeper aquifers that may be a current or potential future source of drinking water, because groundwater flow between aquifers at the shoreline is upward, reflecting increasing hydraulic heads with depth.

- *"Even if ground water is classified as a potential future source of drinking water… the department recognizes that there may be sites where there is an extremely low probability that the ground water will be used for that purpose because of the site's proximity to surface water that is not suitable as a domestic water supply. An example of this situation would be shallow ground waters in close proximity to marine waters such as on Harbor Island in Seattle. At such sites, the department may allow ground water to be classified as nonpotable if each of the following conditions can be demonstrated. These determinations must be for reasons other than that the ground water or surface water has been contaminated by a release of a hazardous substance at the site" [WAC 173-340-720(2)(d)].*
  - *"There are known or projected points of entry of the ground water into the surface water" [WAC 173-340-720(2)(d)(i)].*
    - RI data indicate that groundwater in the shallow aquifer discharges directly into Bellingham Bay.
  - *"The surface water is not classified as a suitable domestic water supply source under chapter 173-201A WAC" [WAC 173-340-720(2)(d)(ii)].*
    - Bellingham Bay is a marine surface water body, and is not suitable as a domestic water supply under chapter 173-201A WAC.
  - *"The ground water is sufficiently hydraulically connected to the surface water that the ground water is not practicable to use as a drinking water source [WAC 173-340-720(2)(d)(iii)].*
    - RI data indicate that the shallow aquifer is directly connected with and discharges into Bellingham Bay. It is not practicable to utilize the shallow aquifer for water supply due to the potential for drawing saline water into the aquifer (salt water intrusion).

4.0 SITE SCREENING LEVELS

To allow for evaluation of the RI analytical results, preliminary Site screening levels that are protective of both human health and the environment were developed for each medium sampled during the RI and for each constituent detected in these media. The soil, groundwater, stormwater, and soil vapor screening levels were developed in accordance with MTCA requirements for development of cleanup based on the highest beneficial current and future land and water uses at the Site, potential exposure pathways for Site contaminants, and the potential receptors of these contaminants. Sediment cleanup levels were developed in accordance with Ecology's SMS and SCUM II (Ecology 2017). The screening levels for use at this Site are presented in Tables 2 through 6.

4.1 Soil

Screening levels for soil were developed using the standard MTCA Method B approach and are based on protection of human health for direct contact with soil and also for the protection of groundwater (Table 2). MTCA Method B soil screening levels were developed in accordance with WAC 173-340-740 using Ecology's Cleanup Levels and Risk Calculations (CLARC) database, except for total petroleum hydrocarbons (TPH). No MTCA Method B cleanup levels are available for TPH; therefore, MTCA Method A cleanup levels were used for TPH screening levels.

Soil screening levels protective of groundwater were determined using the fixed parameter three-phase partitioning model in accordance with WAC 173-340-747(4). The three-phase model provides a conservative estimate of the concentration of a contaminant in soil that is protective of groundwater in consideration of both soil in the vadose zone, and soil in the saturated aquifer.

Soil screening levels protective of terrestrial ecological receptors (plants, soil biota, and terrestrial wildlife) were considered in accordance with MTCA regulations. A site-specific terrestrial ecological evaluation (TEE) was conducted for the site uplands and is presented in Appendix C. Based on the findings of the TEE, the screening levels for this Site will be based on protection of human health and the adjacent marine environment, rather than the plants or wildlife in the uplands.

Soil screening levels are presented in Table 2.

4.2 Groundwater

Standard MTCA Method B screening levels were developed for groundwater based on protection of marine surface water because Site groundwater discharges directly to Bellingham Bay. Because human ingestion of hazardous substances in groundwater is not a potential exposure pathway, as described in Section 3.1, potable groundwater screening levels were not developed for Site groundwater.

MTCA Method B marine surface water screening levels were selected in accordance with WAC 173-340-730(3) for each detected constituent in groundwater, except for TPH. Under WAC 173-340-

730(3), Method B cleanup levels must be as stringent as criteria established under applicable state and federal laws. Applicable federal and state criteria include the National Toxics Rule (40 CFR 131.36) and National Recommended Water Quality Criteria (EPA 2009) and Chapter 173-201A WAC surface water criteria based both on human consumption of fish and protection of aquatic life.

Because surface water quality criteria for TPH have not been developed, MTCA Method A cleanup levels for groundwater were used as screening levels for these constituents, as provided for in WAC 173-340-730(3)(b)(iii)(c). Also, in accordance with WAC 173-340 730(5)(c), screening levels for some metals (arsenic, lead, mercury, and silver), some PAHs (benzo(a)anthracene, benzo(b,k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene), total carcinogenic PAHs (cPAHs), total cyanide, and weak acid dissociable (WAD) cyanide were adjusted to be no less than the practical quantitation limit.

Groundwater screening levels are presented in Table 3.

4.3 Stormwater

No screening levels were developed specifically for stormwater. Because the groundwater screening levels were developed to be protective of marine surface water and the stormwater discharges directly to Bellingham Bay, the groundwater screening levels (Table 3) are used to evaluate the stormwater results for consideration as a possible source for contaminant migration to the marine environment (surface water or sediments).

4.4 Soil Vapor and Crawl Space Air

Screening levels were developed to evaluate data collected in soil vapor or crawl space air beneath buildings adjacent to the Site. The screening levels presented in Table 4 were developed to be protective of indoor air quality, defined for this Site by the MTCA Method B air cleanup levels for indoor air. These screening concentrations are applicable if it is established that a significant amount of chemicals in soil vapor may be migrating off-site.

As recommended by Ecology in its Draft Vapor Intrusion Guidance: Changes to the 2009 Toxicity Values and Screening Levels (Ecology 2015a), screening level development requires the use of a vapor attenuation factor (VAF) to determine what an acceptable concentration in soil (or crawl space) air would be to protect indoor air. As indicated on Table 4 and in accordance with Ecology's guidance, a VAF value of 0.03 was used for this Site, allowing the development of MTCA Method B air screening levels to assess soil vapors, or samples collected from building crawl spaces.

4.5 Marine Sediment

Screening levels were developed to evaluate the marine sediment quality data. The screening levels were developed for the protection of both benthic organisms and human health through consumption of potentially-impacted seafood. Screening levels are used herein to evaluate the RI data. The actual

cleanup levels that will be used when implementing site cleanup will be established by Ecology in the Cleanup Action Plan.

Benthic screening levels for Site surface sediment (0-12 centimeters beneath the mudline) were obtained from the Marine SMS, WAC 173-204 (Ecology 2013a,b) and the AET values (PSEP 1988) (Table 5). Benthic screening levels are provided in Table 5. The screening levels are provided for both carbon-normalized data, and dry-weight equivalents. The organic carbon-normalized RI data will be compared to SMS marine criteria, including sediment cleanup objectives (SCOs) and cleanup screening levels (CSLs) as described in WAC 173-204-320. Non-ionizable chemical (e.g., PAHs) concentrations were compared to organic carbon-normalized screening levels when total organic compound (TOC) concentrations were from 0.5 percent to 3.5 percent per current Ecology guidance. If TOC concentrations are outside the 0.5 percent to 3.5 percent range, then chemical concentrations will be compared to 1988 AET SCOs and CSLs in accordance with SMS (2013) and SCUM II (2017) protocols.

The marine sediment SCOs define the lower end of the range of chemical concentrations or biological effects based on protecting the benthic community or bioaccumulation risk to humans or higher trophic level species. The CSL is developed to establish the maximum chemical concentration or biological effects level allowable as a sediment cleanup level (WAC 173-204-560 through 564).

Sediment data will be assessed for potential hazards to human health from the bioaccumulative constituents presented in Table 5. The following constituents of potential concern for this Site are considered bioaccumulative toxins: cPAHs, pentachlorophenol, arsenic, lead, mercury, and cadmium.

The screening levels protective of bioaccumulative risk were developed in accordance with the procedures in SCUM II described as Option 1, Parts 1 and 2. This option uses background concentrations (natural or regional) and calculated risk-based concentrations developed to protect humans from incidental ingestion of sediment. In accordance with SCUM II, the resulting screening levels appropriately address impacts to human health through direct contact, incidental consumption, seafood consumption; and protect higher trophic level species.

Ecology encourages the use of background (natural or regional) concentrations for sediment cleanup levels (and screening levels) for bioaccumulatives. Development of site-specific, risk-based concentrations based on the consumption of fish/shellfish are often below background concentrations. As a result, those risk-based concentrations are increased to the background levels, since achieving and maintaining cleanup levels below the background is not feasible. Background levels used in this RI were based on the Puget Sound Bold Plus (DMMP 2009) data set and regional Bellingham Bay sediment data (Ecology 2015b). Per Ecology guidance, the 90/90 Upper Tolerance Limit (90/90 UTL) calculated from each COC available in either data set were used to estimate the background levels.

In 2015, Ecology finalized the results of a study that determined the regional background concentrations of contaminants in Bellingham Bay (Ecology 2015b). The study characterized the concentrations of contaminants in sediments in locations not influenced by specific contaminant sources or cleanup sites. The values are useful in determining cleanup levels for a site because the regional background concentrations represent the levels to which surface sediment will equilibrate to over time, even if a cleanup action temporarily attains lower sediment concentrations through remediation. These values are different from natural background concentrations, which were determined during the Bold Plus study (DMMP 2009) and represent the natural background throughout the Puget Sound.

For cPAHs, which are of primary relevance to sediment quality at this Site, Ecology's Bellingham Bay study (Ecology 2015b) identified a regional background concentration of 86 micrograms per kilogram (µg/kg).

As discussed in SCUM II for Option 1, the SCO and CSL values for bioaccumulative toxins are established at background (natural or regional, respectively) or the practical quantitation limit, whichever is higher. Using Option 1 also requires developing risk-based screening levels for protection of human health through direct contact (including incidental ingestions) as this is the only human exposure pathway for intertidal sediments.

Secondary exposure pathways considered consist of the following scenarios:

- beach play (calculated exposure to children),
- subsistence clam digging (calculated exposure to adults), and
- subsistence net fishing (calculated exposure to adults).

Bioaccumulative and secondary exposure pathways for each bioaccumulative constituent at the site are presented in Table 6. As shown in the table, the consumption of fish/shellfish represents the highest risk and therefore the lowest screening levels. As a result, the background concentrations are the most conservative screening levels and will be used to assess sediment quality at this Site. More specifically, the regional background values determined by Ecology for Bellingham Bay will be used as the CSL, and used for delineating the Site boundary in the marine portion of the Site per SCUM II guidance.

5.0 NATURE AND EXTENT OF CONTAMINATION

This section describes the nature and extent of contamination characterized at the Site based on the most protective screening levels developed for the Site with Ecology. Sampling results were reviewed and the sampling process was reiterated in areas where the limit of Site-related contamination was not adequately defined. This process was repeated until the data set was considered adequate to characterize the extent to which Site-related contaminants had migrated.

Samples were collected from the following media in the locations shown on Figures 16 and 17: soil, groundwater, stormwater, soil vapor (including crawl space air samples), and marine sediment using field and laboratory methodology described in the RI Work Plan and its addendums (Herrenkohl Consulting and Landau Associates 2010, 2011b, 2011c, 2012, 2013, and Landau Associates 2016). Laboratory data validation reports are provided in Appendix D.

The samples were analyzed for a list of constituents developed to assess for potential impacts from the historical operations and potential byproducts discussed in Section 2.1.3 related to manufactured gas plants. As noted in Section 2.1.3, the Gas Research Institute developed a list of 25 organic and 22 inorganic chemicals potentially associated with manufactured gas plant cleanup sites. The RI for this Site evaluated each of the 25 organic chemicals and 15 of the 22 inorganic chemicals of interest. Some inorganic compounds from the Gas Research Institute list, such as aluminum, iron, and manganese were not investigated based on their high prevalence in natural background soil and low risk of toxicity. As part of this RI, 70 individual chemicals were analyzed for in Site soil and groundwater samples, 185 individual chemicals in marine sediment, and 13 volatile chemicals in soil vapor to investigate the wide array of COPCs. These chemicals are discussed generally in the following categories:

- Total petroleum hydrocarbons - gasoline, diesel, and oil range (TPH-G, TPH-D, and TPH-O)
- Metals (antimony, arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc)
- Volatile organic compounds (VOCs)
- PAHs (including cPAHs[11])
- Cyanide.

Both total and weak acid dissociable (WAD) cyanide were evaluated in this RI. WAD cyanide refers to cyanide species that can dissociate and release hydrogen cyanide at mildly acidic conditions (pH 3 to 6). The total cyanide analysis used a strong acid and high heat extraction process that measures free cyanide, simple cyanides, and complex metal cyanides. The WAD analysis uses a weak acid

[11] For the purposes of this report, cPAHs refers to the group of PAHs that are known or probable carcinogens (benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene), normalized to the toxic equivalent of benzo(a)pyrene using the procedures in WAC 173-340-708(8).

extraction process that measures free cyanide, simple cyanides, and metallocyanides. Results of WAD cyanide analysis provide an estimate of the bioavailable fraction of cyanide.

The field investigation effort for the RI was initiated in the fall of 2010, beginning with sampling and analysis of soil, groundwater, soil vapor, stormwater, and sediment. The initial investigation extended through spring of 2011. Based on the RI findings, additional follow-up investigations were designed and implemented through fall of 2016 in coordination with Ecology to fill data gaps and develop a sufficiently thorough understanding of the nature and extent of contamination to enable selection of a cleanup action in accordance with WAC 173-340-350. After the initial investigation work in 2010 and 2011, additional field investigations were conducted through fall of 2016 to develop the RI data set.

Sections 5.1 through 5.5 evaluate the nature and extent of contamination through an evaluation of concentrations of COPCs in soil, groundwater, stormwater, soil vapor, and marine sediment in relation to the most protective screening levels developed in Section 4. Per Ecology's request, the initial data screening to evaluate the nature and extent of contamination is conducted prior to screening level adjustments or selection of indicator hazardous substances (IHS). Based on this approach, some detections discussed as exceedances of screening levels below and on the synoptic summary figures are later shown to be adequately protective of human health and the environment.

Section 5.6 presents a discussion of media of concern and IHS for the Site based on further evaluation of the data. Some screening levels used in Sections 5.1 through 5.5 warrant adjustment when RI data show existing conditions are already protective of exposure pathways. For instance if a screening level for soil was developed to be protective of groundwater, but the groundwater data demonstrate that existing concentrations are adequately protective of the groundwater exposure pathway, the soil data will be evaluated based on protection of the remaining applicable exposure pathways.

Section 5.7 presents a discussion of the Site Boundary development relative to each environmental medium with consideration of the adjustments to screening levels and the IHS evaluation.

5.1 Soil

The nature and extent of contamination in soil described below is based on analytical data for over 200 individual soil samples collected from the Site and surrounding area. Samples were typically collected from borings so samples from multiple depths could be analyzed to assess a vertical profile of soil quality from the surface down to the bedrock interface. Samples were analyzed for the following COPCs using Washington State and US EPA analytical methods as shown in Table 7:

- Petroleum hydrocarbons (gasoline, diesel, and oil-range)
- Metals (antimony, arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc)
- PAHs , including cPAHs
- VOCs (benzene, toluene, ethylbenzene, and xylenes [BTEX] and others)

- Cyanide.

Soil analytical results were compared to the screening levels developed in Section 4.1. The screening levels are concentrations considered protective of the appropriate receptors and exposure scenarios. For soil, the screening levels must be protective of humans potentially in direct contact with the soil, and must also be protective of groundwater quality, so the soil does not cause contamination of the adjacent groundwater at concentrations exceeding groundwater screening levels. The soil analytical results are presented Table 7 with comparisons to the screening levels.

As discussed in Section 4.1, there are separate soil screening levels for protection of groundwater depending upon whether the soil is above or below the groundwater table. Table 8 provides a statistical summary of the data, indicating the total number of tests for each parameter, the number of screening level exceedances (if any), and an estimate of the mean concentration at the Site with a confidence of 95 percent (95% UCL). The 95% UCL is calculated in accordance with Ecology's rules and guidance if the resulting value will be used to assess compliance. These instances are discussed later in this report, and include an evaluation of data distribution to select the proper method of calculating the 95% UCL. Other 95% UCL data are for summary purposes and do not include the same level of rigor in calculation. In these latter instances, these data are assumed to have a normal distribution, and no accounting is made of impacts from censored data. Figures 18 through 23 present synoptic summaries of the screening results, indicating whether COPC concentrations are greater than or less than screening levels, organized by analytical group. The following sections provide a summary of the relevant results by area, separated into contaminant groups.

5.1.1 Shallow Soil

This section presents a summary of the soil quality in the upper 2 ft of soil across the Site. Although the point of compliance for soil is from the surface down to 15 ft bgs for direct contact, this upper interval represents soil that typical park visitors could come into contact with; however, MTCA provides a 15-ft bgs point of compliance in recognition of the possibility that soils may be brought to the surface via excavations to this depth.

As indicated in Figures 18 and 19, sample collection focused primarily on the Upper Park Area where the manufactured gas plant was located, and the Slope Area directly downhill. Because the bedrock is present in the Slope Area at depths ranging from 0.5 to 1.0 ft bgs, the only soil available for collection and analysis is shallow, though not actually as deep as 2 ft bgs in this area. Samples were collected with a slightly wider spacing between samples in the Lower Park Area.

In general, there were detections of PAHs (including cPAHs) across much of the Site in the shallow interval. There were no exceedances of screening levels for VOCs, TPH, or cyanide, and there were a moderate number of metals detected at concentrations exceeding the screening levels. The screening level exceedances in this interval are concentrated mostly in the Slope Area, which has little to no foot-traffic due to the steepness of the slope, and since it is overgrown with vegetation.

The following sections summarize the shallow soil quality by COPC and area.

Petroleum Hydrocarbons

Only one sample in this interval (BLVD-01) was analyzed for petroleum hydrocarbons, and it was less than the screening level.

Metals

In the Upper Park Area, metals exceeding the screening levels include copper, mercury, and zinc in the vicinity of the former manufacturing buildings (GP-20 and GP-22), within the existing gas holder Tank #2 (GP-08), around and below the former gas holder tanks (GP-01, GP-06, GP-14, GP-15, and GP-16), and next to the existing electric/generator building (HA-14). Metals concentrations only slightly exceeded the screening levels, except at GP-06 (Figure 18), which is between Gas Holder Tanks #2 and #3, where the former "Valve House" was located (Figure 2). Mercury at this location was detected at a concentration of 1.37 milligrams per kilogram (mg/kg). This concentration is greater than the SL developed for groundwater protection. However, mercury was not detected in groundwater, and the detection of 1.37 mg/kg is less than the MTCA Method B SL for protection direct contact (24 mg/kg).

In the Slope Area, arsenic, copper, lead, mercury, and zinc were each detected at concentrations greater than the screening levels. Mercury exceeded the screening level at all 12 sample locations; copper at 6, zinc at 4, and arsenic exceeded at 1. Exceedances were typically less than twice the screening levels of 20 mg/kg, 36 mg/kg, 250 mg/kg, 0.07 mg/kg, and 85 mg/kg, respectively; except for copper, which was present at up to 116 mg/kg, and mercury, which was present at up to 0.84 mg/kg.

In the Lower Park Area, copper, mercury, and zinc were detected at concentrations exceeding the screening levels near the toe of the Slope Area (GP-26, GP-28, GP-30, GP-33, and GP-45) and at one location along the shoreline (GP-40). Metals concentrations were elevated only slightly above the screening levels of 36 mg/kg, 0.07 mg/kg, and 85 mg/kg, respectively.

PAHs

In the Upper Park Area, PAHs exceeded the screening levels at six separate soil boring locations, with five locations along the border between the upper park and slope areas of the Site, and one location from within gas holder tank #2. The exceedances are co-located with cPAH exceedances, except at GP-18 and GP-19, where PAH exceedances are limited to naphthalene concentrations that are just above the screening level.

In the Slope Area, PAHs were detected at concentrations greater than screening levels in all samples, though significantly lower in concentration than detections in the Upper Park Area.

In the Lower Park Area, PAHs are present at concentrations exceeding screening levels along the toe of the Slope Area (GP-26, GP-27, GP-28, GP-29, GP-30, GP-31, and GP-33) and along the shoreline (GP-34, GP-40, and GP-42). Significant detections include naphthalene (14 mg/kg at GP-27 which is greater than the screening level of 0.13 mg/kg.

cPAHs

In the Upper Park Area, cPAH concentrations exceeded the screening levels in most samples, with the highest detections generally concentrated in the vicinity of the former manufacturing buildings, the existing and former gas holder tanks, and next to the existing electric/generator building. The most elevated concentrations were detected at locations near the existing and former gas holder tanks #2 and #3.

In the Slope Area, cPAH concentrations exceeded the screening level of 0.14 mg/kg in all 12 samples with the maximum concentration at HA-02 (140.11 mg/kg), located immediately downgradient of the former gas holder tanks.

In the Lower Park Area, cPAH concentrations exceed the screening level of 0.14 mg/kg at nearly all sample locations, including at the toe of the slope, the central area of the lower park, and along the shoreline. The highest concentrations are near the toe of the Slope Area, where cPAH concentrations exceeded 10 mg/kg at GP-27 (48.24 mg/kg), GP-28 (46.2 mg/kg), GP-30 (110.45 mg/kg), and GP-31 (13.99 mg/kg). cPAH concentrations in the central portion of the Lower Park Area and near the shoreline were generally lower than concentrations at the toe of the slope. The highest concentrations in this area were at locations GP-33 and GP-34.

Cyanide

In the Upper Park Area at GP-25, total cyanide was detected at a concentration of 1.46 mg/kg, which exceeds the screening level of 1.01 mg/kg.

In the Lower Park Area, seven out of the seven tested soil samples in the upper 2 ft exceed the screening level. Concentrations were below the screening level developed for protection of human health through direct-contact, but above the concentration developed to protect groundwater.

5.1.2 Soil from 2 to 15 ft Below Ground Surface

This section describes soil quality in the interval just below the shallow interval discussed above, and down to the point of compliance (for assessing impacts from direct contact). Figures 20 and 21 present the results of the screening level evaluation for this depth interval.

In general, soil quality in this interval is impacted by most Site COPCs at concentrations significantly higher than observed in the shallow soil. Although it is unlikely that park visitors could be impacted by soil at this depth, it is possible that direct contact exposure could be realized by Site workers during excavations or other intrusive activities. Soil in this interval is also in contact with groundwater, which

could mobilize contamination resulting in migration or downgradient impacts. Soil is only present in a thin layer in the Slope Area above the bedrock, so no samples could be collected for this interval.

The following sections summarize the soil quality in this depth interval by COPC and area.

Petroleum Hydrocarbons

In the Upper Park Area, petroleum hydrocarbons were detected at concentrations well above screening levels, primarily along the western portion of the Upper Park Area near the Slope Area. Exceedances were greatest in the TPH-G range, with concentrations at most locations more than 10 times the screening level of 30 mg/kg and a maximum detection of 67,000 mg/kg (GP-18). TPH-D and TPH-O were detected above the screening levels in many of the samples with TPH-G exceedances, but were not elevated as high in comparison to their respective screening levels of 2,000 mg/kg.

Field observations (Appendix B) in the Upper Park Area are consistent with the analytical results, which indicate the soil was "saturated in an unidentified black liquid" (GP-18), wood "saturated in a petroleum-like product" (GP-24), and containing a "strong petroleum-like odor," potentially indicating the presence of residual NAPL.

In the Lower Park Area, TPH is present at concentrations above the screening levels, with maximum detections of TPH-G and TPH-D of 5,200 mg/kg and 8,000 mg/kg, respectively.

Metals

In the Upper Park Area, copper, mercury, lead, zinc were above screening levels. Arsenic and cadmium concentrations were also detected at concentrations just above the screening levels in isolated locations. The concentrations of copper, mercury, lead, and zinc were above the screening levels throughout much of this area with concentrations ranging generally up to 2 to 3 times the screening levels with some exceptions being higher. The most notable metals results in this area include the maximum copper detection of 351 mg/kg (GP-07), which is about 10 times the screening level of 36 mg/kg; the zinc detection of 430 mg/kg (GP-17), which is about 5 times the screening level of 85 mg/kg; and the mercury detection of 2.52 mg/kg (GP-22), which is about 36 times the screening level of 0.07 mg/kg.

In the Lower Park Area, copper, mercury, and zinc were detected throughout the central/shoreline portions of the lower park, and at two locations along the toe of the slope. The most significant exceedances were at GP-33 and GP-35, where the mercury concentrations (0.85 mg/kg and 1.01 mg/kg) were both more than 10 times the screening level of 0.07 mg/kg.

PAHs

In the Upper Park Area, the concentration of PAHs is more than 10 times the screening levels in all but four sample locations. PAH exceedances were co-located with cPAH exceedances in each instance. One specific PAH, naphthalene, was detected at concentrations greater than 1,000 mg/kg at GP-04

(2,000 mg/kg), GP-07 (2,200 mg/kg), GP-09 (1,100 mg/kg), GP-17 (1,030 mg/kg), GP-18 (10,000 mg/kg and 15,000 mg/kg), GP-23 (2,730 mg/kg), and GP-44 (2,100 mg/kg and 2,200 mg/kg). These exceedances are up to as much as 6 orders of magnitude above the screening level for naphthalene of 0.013 mg/kg.

In the Lower Park Area, PAHs were detected at concentrations exceeding the screening levels near the Slope Area (GP-28 through GP-31, and GP-45), and throughout the grass lawn and along the shoreline. Naphthalene was detected at concentrations as high as 725 mg/kg (GP-28) near the Slope Area and as high as 4,800 mg/kg elsewhere (GP-34).

cPAHs

In the Upper Park Area, the concentration of cPAHs is more than 10 times the screening level of 0.14 mg/kg in all but four sample locations, and up to 1,000 times the screening level at GP-18 (375.9 and 238.8 mg/kg), GP-24 (532.3 mg/kg), and GP-44 (259.1 mg/kg) near the area of historical operations. During sample collection at GP-18, field personnel noted the soil was saturated by an "unidentified black liquid with a strong creosote-like odor" below 9 ft bgs.

In the Lower Park Area, cPAH concentrations were greater than the screening levels at all tested locations in this interval. Concentrations were greater than 10 times the screening level of 0.14 mg/kg in all locations except GP-26, at the eastern site boundary, and at GP-53 and GP-57, near the western Site boundary. The maximum detected cPAH concentration in soil was observed at GP-33 (1,016 mg/kg), located near the restroom approximately 50 ft north of the railroad. This location, and other locations with concentrations more than ten orders of magnitude greater than the screening level, are generally located in the central part of the lower portion of the Site, downgradient of the historical MGP operations.

VOCs

In the Upper Park Area, the concentration of VOCs near the historical manufacturing buildings and gas holder tanks are more than 10 times the screening levels at many of the sample locations. Each exceedance was co-located with an exceedance of the TPH-G screening level. Benzene has been noted as a typical manufactured gas plant contaminant, and based on its mobility in the environment and toxicity, it is an important indicator substance to evaluate the extent of impacts from Site releases. Benzene in this area was detected at concentrations up to 1,800 mg/kg (GP-18), near the historical machine shop, oil storage tank, and underground pipes. This benzene concentration was an order of magnitude greater than at other locations of the Site, and the maximum detection of 1,800 mg/kg is about 4 orders of magnitude above the screening level of 0.2 mg/kg.

In the Lower Park Area, the screening levels for VOCs were exceeded at the toe of the slope (GP-28) and at one location in the grassy lawn (GP-34). At GP-28, benzene was present at 38 mg/kg, and at GP-34, benzene, ethylbenzene, and total xylenes concentrations ranged from 10 times to more than

100 times the screening levels (3.4 mg/kg, 290 mg/kg, and 269 mg/kg, respectively). GP-28 is located downgradient of the former gas holder tanks. VOC concentrations at GP-29, GP-31, and GP-33 also exceeded screening levels, but to a lesser degree.

Field screening did not indicate the presence of VOCs in soil at the east end of the toe of the slope, near the site boundary; these samples were not analyzed for VOCs.

Cyanide

In the Upper Park Area, the concentration of cyanide in soil is greater than the screening level at sample locations GP-19, GP-22, GP-23, GP-24, and GP-25. The cyanide concentrations in this area and depth interval range from non-detectable to 141 mg/kg.

In the Lower Park Area, soil samples collected at locations at the toe of the Slope Area (GP-26 through GP-31, and GP-45) were analyzed for cyanide. Cyanide concentrations ranged from non-detectable to 38.3 mg/kg.

5.1.3 Deep Soil Interval

The following paragraphs summarize the soil screening results for samples collected at depths of 15 ft bgs or greater. Similar to the previous section describing soil results for the interval from 2 ft bgs to 15 ft bgs, the presence of shallow bedrock results in no media available for characterization for this deeper interval in the Slope Area. The analytical results discussed below are presented in Table 7 and summarized in regards to the screening evaluation in Figures 22 and 23.

Petroleum Hydrocarbons

In the Upper Park Area, TPH-G was detected at concentrations above the screening level of 30 mg/kg at GP-10 (2,800 mg/kg) and GP-23 (3,900 mg/kg).

In the Lower Park Area, TPH-G was detected at two locations at concentrations greater than the screening level of 30 mg/kg. The detected concentrations were 1,500 mg/kg at GP-35 and 720 mg/kg at GP-37.

Additional samples analyzed for TPH collected from this interval (GP-38, GP-40, GP-41, HS-54, and HS-55, did not have TPH concentrations above the screening levels, indicating that deep TPH exceedances are limited to areas closer to former MGP operations.

Metals

In the Upper Park Area, arsenic and copper were detected in this interval at concentrations above the screening levels in GP-16 and mercury was detected at concentrations above the screening level at GP-23. These concentrations are all less than two times the screening levels of 20 mg/kg, 36 mg/kg, and 0.07 mg/kg, respectively.

In the Lower Park Area, cadmium and mercury are present at concentrations at or above their respective screening levels of 0.77 and 0.07 mg/kg at GP-37 and GP-39 (mercury only), and at GP-41 (cadmium and mercury). These concentrations are within an order of magnitude of the screening levels, and at GP-37 and GP-41, are in the same intervals the elevated cPAH concentrations in this interval, discussed below.

PAHs

In the Upper Park Area, PAHs were present at concentration greater than the screening levels in GP-10 and GP-23, though in both instances, the concentrations are lower than in the overlying soil intervals.

In the Lower Park Area, PAH concentrations were detected above the screening levels at GP-35, GP-36, GP-37, GP-38, GP-41, and GP-42. Naphthalene concentrations were greater than 100 times the screening level of 0.013 at GP-35 (400 mg/kg) and GP-37 (2,600 mg/kg).

cPAHs

In the Upper Park Area, cPAHs are present in deep soil at concentrations greater than the screening levels in GP-10, GP-15, GP-16 and GP-23. As with the PAH results, concentrations were relatively high; for example, cPAH TEQ concentrations were 34.78 mg/kg at GP-10, 37.81 mg/kg at GP-16, 21.76 mg/kg and 27.77 mg/kg at GP-23. These concentrations are lower than in the overlying soil intervals. Based on these results and field observations, it does not appear that NAPL resides on the confining bedrock layer in the Upper Park Area.

In the Lower Park Area, the concentrations of cPAHs are greater than the screening level of 0.14 mg/kg at GP-35, GP-36, GP-37, GP-38, GP-41, and GP-42. The highest concentrations were detected at GP-35 (129.54 mg/kg), GP-37 (709.5 mg/kg), and GP-41 (309.1 mg/kg).

Soil samples were collected from just above the bedrock at a majority of locations in the Lower Park Area at GP-30 through GP-35, GP-37, and GP-41 where field screening indicated the presence of significant contamination (indications of NAPL, strong petroleum-like odors, or elevated PID readings; Appendix B). These locations are below the historic manufactured gas plant operations.

cPAH concentrations were as high as 309.1 mg/kg at depths of 28 ft to 29 ft bgs at GP-41. At sample locations along the western shoreline and Site boundary (HS/GP-40, HS-55 through 57), cPAH concentrations in intervals just above the bedrock were much lower—either below or only slightly above the screening level.

VOCs

In the Upper Park Area, VOCs were detected at concentrations greater than the screening levels in GP-10 and GP-23—benzene was present at 1.2 mg/kg and 0.72 mg/kg, respectively. These

concentrations are relatively low as compared to other VOC concentrations in the overlying soil intervals.

In the Lower Park Area, several VOCs were detected at concentrations just above the screening levels in this interval, including benzene, toluene, and xylenes. VOCs were not detected at concentrations above the screening levels at the locations closer to the shoreline (GP-38, GP-40, GP-41, and HS-55).

Cyanide

Cyanide was detected at a concentration of 4.66 mg/kg at GP-23, exceeding the screening level of 0.05 mg/kg for soil in the saturated zone.

5.2 Groundwater

The nature and extent of contamination in groundwater was evaluated by comparing groundwater analytical results to the screening levels developed in Section 4.2. This evaluation is separated into a discussion of results in the Upper Park Area and Lower Park Area. In the Slope Area of the Site, there is only a thin layer of soil over bedrock. As discussed in Section 3, explorations confirmed that no groundwater accumulates to a measurable thickness in this area.

Overall, more than 50 groundwater samples were collected from 21 sample locations and analyzed for the following COPCs:

- Petroleum hydrocarbons (TPH-G, THP-D, and TPH-O)
- Total and Dissolved Metals, consisting of antimony, arsenic, barium, cadmium, calcium, chromium, copper, lead, magnesium, mercury, selenium, silver, and zinc
- VOCs
- PAHs (including cPAHs)
- Cyanide (Total and WAD).

In addition to the analyses listed above, some groundwater samples were analyzed for general chemistry parameters including conductivity, total organic carbon (TOC), dissolved organic carbon, total and dissolved hardness, salinity, total dissolved solids (TDS).

Groundwater analytical results are presented in Table 9 with a comparison to the screening levels. Table 10 presents a statistical summary of the data. Figure 24 and Figure 25 present a qualitative summary of the screening level evaluation, indicating which sample locations exceed the screening levels. The exceedances noted in those figures and discussed below are based on the maximum detections at each sample location. Because not all wells were monitored during each sampling event, a temporal comparison has not been conducted to observe for increasing or decreasing trends over time. Anecdotally, concentrations of COPCs appear somewhat lower in the more recent monitoring events.

5.2.1 Upper Park Area

Analytical results for groundwater samples collected from monitoring wells (MW-07, MW-19, MW-24, and MW-44) are discussed in this section. These wells were sampled during three groundwater monitoring events (September 2010, March 2011, and February 2012). MW-7 and MW-44 were dry during two of the three monitoring events, and MW-24 was dry during one of the three monitoring events. Groundwater samples in this area of the Site were analyzed for all of the COPCs: TPH, dissolved metals, VOCs, PAHs, cPAHs, and total and WAD cyanide. Based on the very limited volume of groundwater available at MW-07 and MW-44, it was not possible to collect enough water from these locations to analyze for all of the COPCs. As a result, groundwater from MW-07 and MW-44 was analyzed only for gasoline-range TPH, and VOCs—each of which require only a small volume of water to complete the analytical methods.

In general, groundwater in the Upper Park Area is heavily impacted by TPH, PAHs, cPAHs, and VOCs. Groundwater is also impacted by cyanide at the locations of the former MGP operations buildings.

Dissolved Metals

Concentrations of dissolved metals in the Upper Park monitoring wells do not exceed the screening levels.

VOCs

Groundwater samples from all four monitoring wells in the Upper Park Area were analyzed for VOCs. Benzene concentrations exceeded the screening level in all four monitoring wells, with the highest detections in samples collected from MW-19 (6,000 micrograms per liter [µg/L] in September 2010), and MW-24 (1,400 µg/L in September 2010), exceeding the screening level of 2.4 µg/L. The maximum detected benzene concentration in groundwater at MW-19 is located in the vicinity of the former machine shop and oil storage tank, and the location of underground pipes that historically transported gas and waste materials to and from the former gas holder tanks (Figure 2). Other groundwater concentrations exceeding the benzene screening level were detected in the area of historical MGP operations (MW-24) and immediately downgradient of the former gas holder tanks (MW-07 and MW-44).

PAHs

Groundwater samples from all four monitoring wells in the upper portion of the Site were analyzed for PAHs. Naphthalene concentrations greater than 1,000 µg/L (and greater than 100 times the screening level of 8.9 µg/L) were detected in all four monitoring wells, with a maximum concentration of 9,400 µg/L at MW-24 detected during the September 2010 monitoring event. PAH exceedances are present in monitoring wells in the vicinity of the former machine shop and oil storage tank, the location of underground pipes that historically transported gas and waste materials to and from the former gas holder tanks, and the former and current gas holder tanks.

cPAHs

Groundwater samples from three monitoring wells in the upper portion of the Site were analyzed for cPAHs; MW-44 did not produce a volume of water sufficient to analyze for cPAHs. Carcinogenic PAH concentrations exceeded the screening level of 0.015 µg/L in the other three monitoring wells: MW-07, MW-24, and MW-19. The maximum detected cPAH concentration in groundwater (5.242 µg/L) was observed in MW-19, which is located in the vicinity of the former machine shop, oil storage tank, and underground pipes.

Total and WAD Cyanide

Groundwater samples collected from MW-19 and MW-24 were analyzed for both total and WAD cyanide. The greatest concentrations were at MW-24, in the vicinity of the historical MGP operations. Total cyanide concentrations exceed the screening level of 0.005 mg/L by greater than an order of magnitude, with a maximum concentration at MW-24 of 0.272 mg/L. WAD cyanide concentrations exceed the screening level by less than an order of magnitude, with a maximum concentration at MW-24 of 0.046 mg/L.

5.2.2 Lower Park Area

Groundwater samples in the Lower Park Area were analyzed for TPH, total and dissolved metals, VOCs, SVOCs (PAHs and cPAHs), and total and WAD cyanide. In general, groundwater is heavily impacted near the Slope Area, directly below the former MGP operations and gas holder tanks, and only moderately to slightly impacted nearer the shoreline.

Groundwater monitoring at the shoreline is likely to greatly overestimate the actual contaminant concentrations reaching surface water at the point of discharge, due to hydrodynamic dispersion. Groundwater flow through a porous media (soil) is diluted considerably when entering a still body of surface water within the aquifer mixing zone. The mechanical mixing of water in the pore spaces is increased even further by pumping action caused by tidal fluctuations. These effects are discussed further in Section 6.

Petroleum Hydrocarbons

Groundwater screening levels were exceeded for TPH-G at MW-28 and MW-31, and also for TPH-D MW-31. Two of the detected TPH-G concentrations are an order of magnitude greater than the screening level of 0.8 mg/L. The TPH-D exceedance at MW-31 is just above the screening level of 0.5 mg/L. These two monitoring well locations are near the Slope Area, just below the historic MGP operations and the former and existing gas holder tanks.

Additional groundwater samples analyzed for TPH in the lower park indicate the TPH does not to the shoreline.

Total and Dissolved Metals

Total lead, and dissolved copper and selenium were detected at concentrations above the screening levels of 20 mg/L, 2.4 mg/L, and 71 mg/L, respectively, at MW-29, MW-34, MW-36, MW-38, MW-40, and MW-42. The maximum concentrations of dissolved copper and dissolved selenium were not significantly greater than the screening levels, with a maximum dissolved copper concentrations of 7 µg/L (MW-34) and a maximum dissolved selenium concentration of 200 µg/L (MW-38). Total lead was detected at MW-34 at concentrations of 34 µg/L (June 2016) and 4,710 µg/L (September 2016).

The elevated dissolved lead concentration in the groundwater sample collected in September 2016 is likely the result of particles entrained in the sample, as the turbidity measured in the groundwater sample during collection was greater than 100 nephelometric turbidity units (NTU), which is much greater than the maximum turbidity (12.18 NTU) collected from the remainder of the monitoring wells during that sampling event. Also, soil data collected at MW-34 do not indicate elevated lead (soil concentrations ranged from 6 mg/kg to 14 mg/kg) that could potentially leach into groundwater.

VOCs

Groundwater samples from all thirteen monitoring wells (not including GP-56 and GP-57) in the lower portion of the Site were analyzed for VOCs and/or BTEX. Benzene concentrations exceeded the screening level of 2.4 mg/L in two monitoring wells: MW-28 and MW-31. The maximum detected benzene concentration in groundwater (4,400 µg/L) was observed in MW-28, which is located at the toe of the Slope Area, downgradient of the former gas holder tanks.

Results downgradient of MW-28 (MW-46, WP-01, and WP-02) and MW-31 (MW-38 and MW-40) demonstrate that benzene in groundwater decreases to concentrations less than screening levels prior to the point of discharge to Bellingham Bay.

PAHs

PAH concentrations in groundwater collected from monitoring wells in the Lower Park Area were above the screening levels at monitoring wells MW-28, MW-29, MW-45, MW-31, and MW-36. Exceedances in wells near the toe of the slope were greater than 100 times the screening levels (naphthalene concentrations as high as 2,350 µg/L at MW-28 and 3,200 µg/L at MW-31), while one PAH exceedance at downgradient/shoreline monitoring well MW-36 (naphthalene concentration of 12 µg/L) was just above the screening level of 8.9 µg/L.

PAH concentrations at shoreline wells, excluding the minor exceedance at MW-36, did not exceed the screening levels during any of the groundwater monitoring events, and indicate that PAHs are not discharging to the surface water in Bellingham Bay.

cPAHs

cPAH concentrations in groundwater exceeded the screening level of 0.015 mg/L at monitoring wells at the toe of the slope (MW-28, MW-29, and MW-45), and along the north/northeast shoreline areas of the lower park (MW-34, MW-36, MW-42, MW-46, WP-01, and WP-02).

cPAH concentrations were greater than ten times the screening level at locations at and just downgradient of the toe of the Sloe Area, with a maximum concentration of 0.333 µg/L at MW-46. Except for this anomalously high result at MW-46, the remaining exceedances in wells at the toe of the slope were lower than 0.04948 µg/L at MW-29.

Elevated concentrations of cPAHs at WP-01 and WP-02 are consistent with estimated porewater concentrations that would be anticipated based on the elevated concentrations of cPAHs in nearby sediment.[12] Additionally, based on transport properties (cPAHs have very limited mobility in groundwater as described in Section 6.4.1), the cPAHs in groundwater at WP-01 and WP-02 are likely derived from nearby contaminated sediment rather than upland sources (upland groundwater).

Cyanide

Total and WAD cyanide are present in groundwater at concentrations above the screening level of 0.005 mg/L at all monitoring wells except for MW-54 and GP-57, which are both located along the southwest site boundary.

At the southwest Site boundary, the one exceedance of the screening level (GP-56; 0.006 µg/L) is only slightly above the screening level, and other nearby samples at MW-54 and GP-57 indicate cyanide concentrations are below the screening levels. These results indicate the concentrations are decreasing and below the screening levels at the southwest Site boundary.

5.3 Stormwater

Samples were collected from the two stormwater outfalls at the Site to assess for potential impacts to the marine sediment. Two samples were collected from each sample location (SW-01 and SW-02; Figure 2), and analyzed for metals, petroleum hydrocarbons, VOCs, PAHs, and cyanide.

The analytical results are presented in Table 11 with a comparison to screening levels developed for the protection of surface water.

As summarized in Table 11, copper and cPAHs are the only constituents which exceed the screening levels. The reporting limit for cPAHs during the first sampling event was elevated and precluded a determination of whether cPAHs were present at concentrations exceeding screening levels.

[12] Detected cPAH concentrations in surface sediment samples MGP-SS-02 and BBP-SS-03 yield equilibrium groundwater concentrations ranging between 0.017 and 0.494 µg/L, which are similar to the detected cPAH concentrations in WP-01 and WP-02 (ranging between 0.035 and 0.164 µg/L).

However, during the second event, cPAHs were detected at 0.15 µg/L in SW-01 and 0.629 µg/L in SW-02, indicating that stormwater discharge from both of the outfalls may contribute to copper and cPAH-loading in Site sediments.

5.4 Soil Vapor and Crawl Space Air

Soil vapor samples, ambient air samples, and crawl space air samples were collected in the locations shown on Figure 26 to evaluate soil vapor quality. Analytical results are presented in Tables 12A and 12B with a comparison to the screening levels developed in Section 4.4.

Sixteen soil vapor samples from 10 locations were analyzed for VOCs. All but one of the samples were collected from the upper portion of the Site. The sole sample collected from the lower portion of the Site (SV-32), located adjacent to the restroom facility, did not contain detectable concentrations of VOCs except for a minor detection of toluene of 16 micrograms per cubic meter (µg/m^3), which is below the screening level of 76,000 µg/m^3.

VOCs were detected in excess of the soil vapor screening levels at most of the tested locations. At the time of testing, the results were actually acceptably below the screening levels. However, lower and more conservative screening levels were established. Although the results compared to the older screening levels were acceptable, the project team chose to investigate further, by collecting additional samples from crawl spaces in the nearby Spinnaker Reach Condominiums to evaluate for potential vapor intrusion risks.

Those samples were analyzed for benzene, as indicated on Table 12B, which was the indicator parameter used for testing during this follow-up study based on its low screening level, since it posed the greatest risk to health based on carcinogenic toxicity, and based on it being the highest-concentration VOC detected in the soil vapor samples.

Crawl space air samples (CA-01 and CA-02) were collected (in conjunction with an ambient air sample, AA-01, to establish background air quality conditions not related to vapor intrusion) on two different occasions (February and May 2013) to determine whether vapor intrusion could contribute indoor air quality. Benzene concentrations in crawl space air were less than background ambient air concentrations during the first crawl space sampling event, indicating no measurable impact associated with vapor intrusion. Benzene concentrations in crawl space air during the second sampling event were slightly greater than ambient background concentrations, with a concentration differential up to 0.11 µg/m^3, which is less than the indoor air screening level of 0.32 µg/m^3. Both crawl space sampling events yielded consistent results, which are presented in Table 12B and on Figure 26, indicating that vapor intrusion does not contribute to VOC concern in crawl space air (Landau Associates 2013a,b).

The Site is developed as a recreational park maintained by the City. The only building in which recreational receptors may be exposed to indoor air is a restroom facility in the lower portion of the

Site where benzene and other VOCs did not exceed soil vapor screening levels. The City has no plans to construct any additional enclosed buildings at the park; therefore, the vapor intrusion pathway for onsite buildings is not considered a pathway of concern for current or anticipated future Site receptors. However, it is a pathway of concern for unanticipated future property development unless it is addressed as part of the MTCA cleanup. The feasibility study will therefore need to evaluate appropriate means of cleaning up the Site to include reducing or eliminating exposure to VOCs in soil vapor via the vapor intrusion pathway.

5.5 Marine Sediment

As part of the RI, marine sediment quality was evaluated by analyzing 24 surface sediment samples and 103 subsurface samples, collected between 2010 and 2016. Samples were analyzed by an Ecology-accredited laboratory for COPCs to evaluate for potential impacts from Site releases. This section presents the results of the investigation with a comparison of the sediment quality data to the SLs developed in Section 4.5. Sediment samples were analyzed for conventional parameters (e.g., TOC, grain size), and COPCs for sediment including metals, petroleum hydrocarbons, SVOCs (including PAHs), PCBs, and dioxins/furans.

Surface samples were collected in order to evaluate sediment quality horizontally in the biologically active zone (surface sediments from 0 to 12 centimeters below the mudline), and subsurface samples were collected to characterize sediment quality vertically beneath the biologically active zone. In addition to the samples collected for this RI, additional sediment quality data from other nearby projects (Whatcom Waterway Cleanup site, and the Boulevard Park Over-Water Walkway) were used to supplement the dataset for this evaluation. Figure 17 presents the sediment sample locations for the RI data, and also the nearby project data used in this evaluation. Sediment core logs for the subsurface sediment samples are included in Appendix B. Samples were typically collected from a sampling barge in Bellingham Bay as described in the Work Plan. Some surface sample locations near the shoreline were collected by walking out into the sediment during low tide.

The analytical results for surface sediment samples are presented in Table 13, and for subsurface sediment samples in Table 14. Sediment screening levels are applicable in the biologically active zone, since sediment below this level is unlikely to affect the benthic organisms or human health (through food-chain exposures) that the screening levels were developed to protect. However, because future Site activities could include shoreline maintenance, shoreline protection improvements, or cleanup activities involving removal of affected surface sediment, the RI also evaluated subsurface sediment conditions and quality.

Tables 13 and 14 present the analytical results with a comparison to the screening levels developed for the protection of benthic organisms living in the surface sediment. Table 15 presents the surface sediment results for constituents that are considered bioaccumulative compounds, with screening levels developed to protect human health. Statistical summaries of the surface and subsurface results

are presented in Table 16 and Table 17, respectively. Laboratory analytical reports are maintained on file by Landau Associates, Inc. and are available upon request.

Figures 27, 28, 29, and 30 show the sample locations and present the qualitative results of the screening level evaluation—indicating whether the resulting concentrations exceed the SCO or CSL screening levels for both surface and subsurface sediment samples. These synoptic figures provide an assessment of where contaminants are located in the marine environment at concentrations exceeding the screening levels. The figures supplement the data tables and sediment core logs which provide additional detail relating to the materials encountered and laboratory results.

In addition to these summary figures, Figure 31 presents the detected cPAH concentrations for surface sediment. As discussed further in the following subsections, cPAHs are the COPCs that was most often detected above screening levels, and the COPCs detected the furthest distance from the historical manufactured gas plant operations. As a result, the concentrations of cPAHs in surface sediment are utilized for establishing the marine Site boundary, based on the CSL. The northeast boundary of the marine portion of the Site is delineated further offshore, but not near the shoreline. Additional data in this area may be needed during the remedial design phase to better approximate the boundary.

5.5.1 Surface Sediment Quality

This section summarizes the analytical results for surface sediment samples relative to the screening levels developed for the protection of benthic organisms and human health. Much of the benthic criteria are based on OC-normalized data. If sediment TOC is less than 0.5 percent or greater than 3.5 percent, the analytical results were compared to dry-weight equivalents of the SMS benthic criteria rather than the OC-normalized criteria. Analytical results in Table 13 are presented with comparisons to SCO and CSL values for OC-normalized and dry-weight equivalent criteria, as applicable. Results in the table are shaded to indicate exceedances of SCO or CSL criteria, including instances where laboratory reporting limits are above the screening levels. Ultimately, Ecology will select a cleanup level to be a value between the SCO and CSL screening levels. In addition to the sediment surface sample data presented in Table 13, some sediment core data presented in Table 14 represents surface sediment because the uppermost samples in the core include sediment from 0 ft to 2 ft below the mudline. To allow for a comprehensive evaluation of data, results from Table 14 representing the upper 2 ft of sediment are included in the discussion of results below and shown on Figure 27 and Figure 28 as representing surface sediment.

Comparison of RI Data to Benthic Criteria

As shown in Table 13, there are very few instances of COPCs exceeding the screening levels developed for the protection of benthic organisms. Exceedances of the benthic screening levels include mercury, benzyl alcohol, and several PAHs.

The only concentration of mercury exceeding the screening level was at BLVD-SS-07. Mercury is in surface sediment in this vicinity due to releases associated with the Whatcom Waterway cleanup site. Mercury concentrations exhibit a clearly decreasing trend toward the Site and this detection is not considered associated with the SSSMGP Site.

Benzyl alcohol was found present at concentrations greater than the screening level at 4 of 21 tested locations (MGP-SS-17, MGP-SS-21, MGP-SS-23, and MGP-SS-31). Benzyl alcohol is associated with the decay of organic matter, so is often found at concentrations in Puget Sound above cleanup screening levels, potentially unrelated to site releases (USACE 2016).

For PAHs, SMS provides screening levels protective of benthic organisms for both low- and high-molecular weight PAHs (LPAHs and HPAHs, respectively). The LPAH screening levels were exceeded at 2 locations (MGP-SS-15 and MGP-SS-16), and HPAH screening levels were exceeded at 4 locations (MGP-SS-16, MGP-SB-03, MGP-SB-08, and MGP-SB-09).

The screening level evaluation summarized on Figures 27, 28, 29, and 30 shows the results for both the benthic criteria discussed above, and the human health criteria discussed in the following section. A "B" indicates exceedances of benthic criteria.

Comparison of RI Data to Human Health Criteria

The analytical results for surface sediment samples are also compared to screening levels protective of bioaccumulative risk.[13] The screening levels protective of bioaccumulative risk were developed in accordance with the procedures in SCUM II (Ecology 2017), described as Option 1, Parts 1 and 2 as summarized in Section 4.5. In accordance with SCUM II, the resulting screening levels appropriately address impacts to human health through direct contact, incidental consumption, seafood consumption; and protect higher trophic level species. The SCO and CSL for bioaccumulative toxins were established at background (natural or regional, respectively) or the practical quantitation limit, whichever is higher. This approach also requires developing risk-based screening levels for protection of human health through direct contact and incidental ingestions, as shown in Table 6. Table 15 presents the results for bioaccumulative toxins with comparison to SCO and CSL values.

The subset of PAHs with carcinogenic risk are used to calculate a toxicity equivalent quotient for cPAHs as described in WAC 173-304-108(8), normalizing the cumulative cancer risk from this group of compounds to the toxicity of benzo(a)pyrene. The cPAH results are then compared to bioaccumulative screening levels developed for the protection of human health, and adjusted based on regional and natural background cPAH concentrations in surface sediment.

[13] Consistent with guidance in the Sediment Cleanup User's Manual II (SCUM II), the screening levels used for this evaluation conservatively default to natural or regional background levels based on the assumption that screening levels calculated to be protective of human fish/shellfish consumption or non-human higher trophic levels could be lower than background levels.

Exceedances of the screening levels for bioaccumulative compounds developed for the protection of human health include metals (arsenic, cadmium, mercury, lead) and cPAHs.

The metals in sediment detected above the screening levels have only minor detections in the uplands. Each metal detected above the screening levels exhibits a concentration trend indicating they come from a source not related to the SSSMGP Site; concentrations are more elevated at greater distance from the pocket-beach area.

The cPAH concentrations in surface sediment are elevated and exceed the screening levels throughout an area reaching about 1,000 ft into Bellingham bay from the pocket beach area. Concentrations in the pocket beach area are elevated to greater than 10x the screening level and decrease with distance away from this location. Based on the distribution in surface sediment and historical activities at the Site, the cPAHs in surface sediment appear to be related to Site releases. There are other likely sources which contribute to the concentrations of cPAHs observed in the sediment, including activities associated with the historical lumber mill, non-point source contributions from the urban environment, historical industrial activity around Bellingham Bay, stormwater outfalls that discharge surface water impacted by vehicular traffic, creosote treated timbers in the sediment, and possibly burned materials from the fire that burned down the historical lumber mill.

Summary of Surface Sediment Quality

Figure 27 and Figure 28 present the results of the screening level assessment for both benthic and human health considerations, showing where exceedances of screening levels were observed for cPAHs, LPAHs, HPAHs, and metals. Figure 27 presents the evaluation results for the SCO, and Figure 28 presents the results using the CSL.

As illustrated in the figures, cPAHs are the primary COPC that exceeds screening levels in surface sediment, and most other exceedances are either co-located with cPAH exceedances, or exhibit a distribution suggesting they are not related to Site releases. The marine Site boundary shown on the figures is based primarily on the footprint of screening level exceedances for cPAHs, generally showing where cPAHs are estimated to be at the regional background concentration of 86 µg/kg.

Figure 31 presents the cPAH concentrations in surface sediment. As shown in the figure, cPAH concentrations are generally highest in the pocket beach area, though the maximum detection is just outside of this area, at MGP-SS-16. Concentrations of cPAHs in surface sediment near the upland portion of the Site and extending out to the shallow subtidal zone range from as low as 10 µg/kg (MGP-SS-13) to as high as 2,405 µg/kg (MGP-SS-16). Surface cPAH concentrations observed near the shoreline at UW122010-60 and BBP-SS-01 indicate concentrations are above regional background.

5.5.2 Subsurface Sediment Quality

The subsurface sediment quality was evaluated as part of this RI to evaluate the vertical extent of contamination, and to support potential future Site cleanup and other activities including, dredging, capping, maintenance, shoreline stabilization, or evaluation of cleanup alternatives that could include the removal or capping of subsurface sediment. Table 14 presents the analytical results for subsurface sediment samples, and a comparison to screening levels protective of benthic organisms. Figure 29 and Figure 30 present the results of the screening level evaluation. It should be noted that cleanup and screening criteria for sediment are applicable to sediment in the biologically active zone at the surface and may not be directly applicable to subsurface results under current Site conditions. The figures summarize where screening level exceedances were observed at any vertical location in the subsurface core sample. A number beside the sample location indicates the deepest observation of screening level exceedance.

Subsurface sediment quality is impacted by similar COPCs as the surface, with concentrations of metals and PAHs (including cPAHs) above the screening levels. The concentrations of PAHs detected in the subsurface are significantly higher than observed in the surface. This is an expected result, since the primary source of contaminant release to the marine environment likely ceased in the late 1940s, when the manufactured gas plant operation closed, and un-impacted sediment has been deposited on the surface. This natural depositional process can provide an improvement in surface sediment quality to support benthic organisms while contamination persists in the subsurface.

The concentrations of cPAHs in the pocket beach area range generally from 1,000 µg/kg to 10,000 µg/kg, with multiple instances above this range. At two locations, the cPAH concentration is greater than 100,000 µg/kg (MGP-HS-46, MGP-SB-01), indicating concentrations are greater than 1,000 times the cleanup screening level (86 µg/kg).

5.6 Media of Concern and Indicator Hazardous Substances

Each media which is found to have COPCs in excess of the screening levels is considered a media of concern. This includes soil, groundwater, air, and marine sediment.

In accordance with WAC 173-340-703, a subset of the COPCs detected above Site screening levels will be selected as indicator hazardous substances (IHS). This is useful when multiple contaminants are distributed throughout a Site, but a smaller subset of those provides the most useful metric in assessing distribution, transport, and toxicological characteristics. It is often the case that a subset of primary contaminants is present that are more prevalent and toxic than others at a Site, and are selected by Ecology for the purposes of defining cleanup requirements. Table 18 provides a summary of the evaluation process for selecting IHS for this Site. Table 19 presents the list of IHS, along with proposed cleanup levels for these compounds. The proposed cleanup levels are generally the screening levels already approved by Ecology for this RI. For marine sediment, screening levels included both SCO and CSL values. The proposed cleanup level for sediment in Table 19 is the CSL

value, which represents the regional background value of cPAHs in Bellingham Bay. The following subsections provide a summary of IHS for the media of concern.

The IHS evaluation includes the following:

- Review of the RI screening results for instances where initial screening levels were developed for protection of a transport pathway determined empirically to be protected. For example, if a soil screening level was developed to protect groundwater quality, but groundwater quality is demonstrated to not be contaminated by soil at the existing concentrations, the soil screening level can be adjusted to be protective of the next most conservative screening level. This was the case for some constituents analyzed at the Site, and in those instances as discussed below, the screening level for protection of the direct contact exposure pathway is used to re-screen the RI data (these revised screening values are presented on Table 3). The re-screening process does not remove the original screening results from RI tables or from the figures. A duplicate entry is included in the RI tables for these instances, which are relatively few.
- Statistical evaluation: In some instances, hundreds of samples have been analyzed and only one or two of the results are above screening levels. MTCA provides for a statistical comparison to regulatory criteria which is followed in this evaluation. If less than 10 percent of the results for a particular constituent exceed the screening level, there are no detections greater than 2x the screening level, and if the upper limit of the mean concentration is below the screening level (95% UCL), the data indicate the Site meets the screening level by statistical comparison. There are only a few instances where statistical comparison is used to assess screening levels, as discussed further below.
- Co-location: Some constituents are less toxic or persistent than others. For a Site such as this with many analyzed parameters, there can be some exceedances considered less impactful. For example, when analyzing a sample for PAHs or VOCs, there are many compounds reported that may be present at relatively few locations, and always co-located with other compounds which are more toxic or recalcitrant. As a result, it may be simpler to focus cleanup efforts on the more toxic, prevalent, and environmentally persistent compounds at a Site, if it is likely that addressing those compounds through cleanup efforts will also address the less-impactful compounds detected at the same locations, as provided for by WAC 173-340-703.
- Grouping: Some constituents are reported by the laboratory, which are combined for the purposes of site cleanup and compliance assessment. For example, each of the carcinogenic PAHs may have an individual screening level as well as a TEQ cleanup level based on the most-toxic of the group, benzo(a)pyrene. For these and similar instances, it is useful to retain the grouped value, while excluding individual constituents.

5.6.1 Soil Indicator Hazardous Substances

As part of this evaluation, all soil COPCs that were detected above screening levels are initially considered IHS as summarized in Table 18. The IHS evaluation process as summarized results in the following exclusions:

Empirical Demonstrations

A second screening level for cadmium, copper, mercury, silver, zinc, methylene chloride, styrene, acenaphthene, pyrene, 2,4-dimethylphenol, and phenol were developed for protection of the direct-contact exposure pathway, based on empirical demonstration of groundwater quality (see Tables 3 and 7). Site soil data for these compounds are below the direct-contact screening levels. Since soil is below screening levels for both groundwater protection (by empirical demonstration) and direct-contact, these compounds are not included as IHS for soil.

Statistical Comparisons

In two instances (arsenic and silver), the frequency of exceedances were less than 10 percent and the maximum detections were less than twice the screening level. For these metals, PRO UCL was used to estimate the upper confidence limit of the mean concentration with 95 percent confidence (95% UCL). For both metals, the 95% UCL is less than the screening level, so these are eliminated as IHS based on statistical comparison to screening levels.

Co-Location

Several PAHs exceeded screening levels that were co-located with cPAHs or naphthalene. Because naphthalene and cPAHs represent the most-toxic compounds in the group and based on the mobility of naphthalene, other co-located PAH detections are considered minor in comparison. As a result, 1-methylnaphthalene, 2-methylnaphthalene, fluorine, fluoranthene, and dibenzofuran are eliminated as IHS and will be addressed in the course of achieving cleanup standards based on the co-located cPAHs.

Similarly, some VOCs (toluene, ethylbenzene, xylenes, 1,2,4-trimethylbenzene) and petroleum hydrocarbons (gasoline and diesel-range) were detected above screening levels that were co-located with benzene. Because benzene represents the most-toxic of the group, it acts as a representative indicator of where the impacts are present and require remediation.

Grouping

Individual cPAH compounds (benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene) are excluded individually as IHS based on inclusion of the analytical group of cPAHs, which is retained.

Summary

Based on these adjustments, 6 individual IHS are retained for soil: lead, selenium, benzene, naphthalene, cPAHs, and cyanide.

5.6.2 Groundwater Indicator Hazardous Substances

The IHS evaluation process was conducted in the same manner described above for groundwater. The following paragraphs summarize the resulting exclusions:

Empirical Demonstrations

For two compounds (acenaphthene and anthracene), initial screening levels were developed to be protective of sediment quality. Based on empirical demonstration that sediment quality is protected for these constituents, the groundwater screening levels were adjusted to be protective of the next most conservative exposure scenario: consumption of organisms in surface water. Only one sample result of 40 for acenaphthene exceeded secondary screening level and the 95% UCL is well below screening level. These compounds are eliminated as IHS based on a combination of empirical demonstration and statistical evaluation.

Statistical Comparisons

No COPCs were eliminated based strictly on statistical assessment, except as noted above for acenaphthene.

Co-Location

One PAH (fluoranthene) exceeded screening levels that were co-located with cPAHs and naphthalene. Because naphthalene and cPAHs represent the most-toxic compounds in the group and based on the mobility of naphthalene, the fluorine exceedances at this Site were considered relatively minor in comparison based on prevalence and toxicity. As a result fluoranthene is eliminated as an IHS and will be addressed in the course of achieving cleanup standards based on the co-located compounds.

Similarly, some VOCs (toluene, ethylbenzene, xylenes, 1,2,4-trimethylbenzene) and petroleum hydrocarbons (gasoline and diesel-range) were detected above screening levels that were co-located with benzene. Because benzene represents the most-toxic of the group, it acts as a representative indicator of where these impacts are present and require remediation.

Grouping

As noted above, individual cPAH compounds are excluded as IHS based on inclusion of the analytical group of cPAHs, which is retained.

Summary

Based on these adjustments, six individual IHS are retained for groundwater: selenium, benzene, naphthalene, cPAHs, and cyanide (total and WAD).

5.6.3 Marine Sediment Indicator Hazardous Substances

The IHS evaluation process was conducted in the same manner described above for sediment. The following paragraphs summarize the resulting exclusions:

Empirical Demonstrations

No COPCs were eliminated based on empirical demonstration.

Statistical Comparisons

No COPCs were eliminated based on statistical assessment.

Co-Location

LPAHs, HPAHs, 2-4-dimethylphenol, and benzoic acid were eliminated based on co-location with cPAHs based on the greater toxicity and recalcitrant nature of cPAHs. It is anticipated that cleanup of the Site cPAHs will address the co-located compounds.

Grouping

As noted above, individual cPAH compounds are excluded as IHS based on inclusion of the analytical group of cPAHs, which is retained.

Contaminants Unrelated to Site Releases

Two metals are excluded from consideration as IHS based on being unrelated to Site releases: mercury and lead. Additionally, benzyl alcohol is eliminated based on consideration of the USACE discussion of the prevalence of benzyl alcohol in the sediments of Puget Sound. There were only 4 exceedances of screening levels for this compound, and 2 of those are co-located with cPAH contamination. Based on the distribution of the 4 exceedances, it is not clear that the benzyl alcohol is present due to Site releases. The 2 locations that are not co-located with cPAH contamination only slightly exceeded the screening levels. And, since benzyl alcohol rapidly biodegrades to benzoic acid which has a much higher screening level it is not anticipated that these exceedances pose a significant environmental risk in comparison to cPAH.

Summary

Based on these considerations, cPAHs are the sole IHS for Site sediment.

5.7 Site Boundary

The boundary of a cleanup site is defined in WAC 173-340 as the area in which hazardous substances have been deposited, stored, disposed of, placed, or otherwise have come to be located. This definition is not dependent on screening or cleanup levels, and is true for soil, groundwater, and sediment. However, for practical purposes, screening levels and cleanup levels are developed to

assess RI data to determine where contaminants have come to be located that are at concentrations considered to present a threat to human health or the environment. This section reviews the nature and extent of contamination—which was described holistically in Sections 5.1 through 5.5—in the context of Site-related COPC concentrations that exceed applicable screening levels.

5.7.1 Extent of Soil Contamination

This section evaluates the extent of soil contamination and, in combination with data from other media, helps to establish the Site boundary. All analytical results for the 6 soil IHS are presented on Figures 32 through 43, providing for the evaluation of both horizontal and vertical concentration gradients.

As shown on the figures, cPAHs, benzene, naphthalene, and cyanide are largely distributed throughout the Site. Metals contamination was infrequently detected and only in isolated areas. The distribution of selenium indicates the source of selenium impacts are likely due to poor fill quality in the Lower Park Area and not from Site releases. There were only a few instances of lead present at concentrations above the SLs resulting in it being established as an IHS for the Site. These detections are limited to the immediate vicinity of the historical MGP operations and an isolated location in the Lower Park Area which does not appear connected to Site operations or releases.

The following paragraphs describe the rationale for establishing a Site boundary in each of the cardinal directions.

West and East: For the purposes of simplicity, the extent of soil contamination is bounded to the west by Bellingham Bay (any contamination farther west is discussed in the marine sediment section).

In the Upper Park Area, soil contamination is bounded to the east by South State Street. South State Street is upgradient and uphill from historical Site operations, so fate and transport mechanisms did not provide any means for the migration of contaminants in soil any further east than South State Street.

South: In the southern portion of the Lower Park Area, lower levels of cPAHs are present beyond the upland Site boundary shown on the figures; those cPAHs are associated with other offsite sources (e.g., treated wood), and are not attributable to releases from the Site's MGP operations. Figure 2 shows the locations of historical nearby operations discussed in Section 2, including a lumber mill and log dump, a lumber wharf, and lumber waste conveyor. Processing, handling, or storage of treated wood commonly results in cPAH contamination. Additionally, hundreds of timber piling associated with the former lumber mill shown in aerial photographs in Appendix A are present in the subsurface along with miscellaneous fill and burned wood debris which likely results in the presence of cPAHs. Based on a review of the building plans and existing grading, and inspection of the crawl space for the nearby Spinnaker Condo building, it appears that several feet of soil above bedrock was removed for construction of the nearby condominium, which is directly adjacent and south of the former

operations area at the property line. Based on historical excavations at this location and the lack of a direct southward fate and transport mechanism, it is assumed that the property line is the approximate boundary of the southern extent of contamination in the Upper Park Area.

Based on the presence of these offsite cPAH sources, the Site boundary is established at the extent of contamination associated with releases from the MGP operations. This is identified by the presence of other significant Site COPCs, such as benzene and cyanide along with the cPAHs. Benzene and cyanide are directly attributable to Site releases, are relatively mobile in the environment (so should conservatively indicate the extent of migration), and do not have other known nearby sources. As a result, the Site boundary to the south is based on encompassing the extent of these IHS.

North: The northern Site boundary is based on the estimated extent of operations, chemical concentrations, and the presence (or absence) of soil above the bedrock. The Site boundary is identified beyond the northernmost soil sample collected, which has IHS at concentrations above the SLs. Additional samples were not collected farther north based on observations of exposed bedrock in that direction and a lack of soil to sample from the thin veneer above bedrock. In addition to precluding further soil sampling in the area of exposed bedrock to the north, the lack of soil substrate also acts as a physical geologic barrier to potential migration of Site contamination to soil further north. The extent of contamination in this direction is not perfectly clear, although it is sufficient for developing and evaluating cleanup alternatives. During remedial design, it is anticipated that further delineation will be needed in this direction in order to provide detailed design plans for implementing the cleanup action.

5.7.2 Extent of Groundwater Contamination

The extent of groundwater contamination is largely defined by the presence or lack of presence of groundwater within the area already defined by the extent of soil contamination. Bedrock elevations are closer to the surface in the eastern portion of the Site (Figure 9). The bedrock effectively reduces the aquifer thickness in this area by redirecting groundwater elsewhere and as a result, there is no measureable groundwater in some areas of the Site. Groundwater was not observed in soil borings or a monitoring well installed in the northern portion of the Lower Park Area (GP-01, GP-26, HS-26, HS-43, and MW-58). And during collection of water samples at WP-01 and WP-02, the poor recharge rate indicated a lack of groundwater recharge from the uplands.

Similarly, groundwater is present only in limited quantities in the Upper Park Area, where it is perched on the bedrock. As a result, the extent of groundwater contamination to the north and east is bounded by the lack of groundwater presence. As with soil, the eastern Site boundary in the Upper Park Area is identified as South State Street. South State Street is upgradient and uphill from historical Site operations, so fate and transport mechanisms did not provide any means for the migration of contaminants in groundwater any further east than South State Street.

Figure 44 presents the analytical results for all IHS from ***the most recent monitoring events at each monitoring well***. Selenium is retained as a Site IHS but is not shown on Figure 44 because it had no exceedances during the most recent groundwater monitoring event from each monitoring location. As shown on the figure, there are more IHS present, and detections were highest in groundwater in the Upper Park Area than in other areas of the Site. Throughout much of the Lower Park Area south of the pocket beach, cyanide is the only IHS present in excess of the screening level. Near the pocket beach area, near the pedestrian bridge, and just down-slope from the former operations, other IHS are present but at concentrations much lower than the Upper Park Area. The concentration gradients indicate significant attenuation in groundwater concentrations moving outward from the presumed source areas (former operations and pocket beach area where releases are reported to have occurred).

To the south, the extent of cyanide exceeding the SLs provide a useful means of identifying the extent of Site-related contamination because, as discussed above, some non-Site related cPAHs are present in soil within and beyond the Site boundary in the Lower Park Area. The Site boundary to the south encompasses all of the cyanide and benzene groundwater concentrations that exceed SLs. cPAH exceedances of groundwater screening levels are generally limited to the former operations area, the area directly downgradient at the toe of the slope, and near the pocket beach.

The extent of groundwater contamination to the west is the point of subterraneous discharge to Bellingham Bay.

5.7.3 Extent of Sediment Contamination

The marine Site boundary is established at the estimated extent to which Site-related cPAH contamination has migrated at concentrations above the regional background level. Near the pocket beach area of the marine portion of the Site, concentrations of cPAHs are significantly elevated, and a decreasing concentration gradient is evidenced moving outward into Bellingham Bay from this location. This is consistent with the understanding that historical MGP operations were located upslope of the pocket beach, including a drain pipe that extended from the former gas holders to a ditch on the east side of the railroad tracks(Figure 2).

Due to the presence of multiple waterfront cleanup sites in the Bellingham Bay area and non-point source urban discharges, it is anticipated that concentrations of cPAHs near the shoreline throughout much of Bellingham Bay are elevated above the regional background concentration, which is 86 µg/kg. The marine Site boundary was drawn to encompass sample locations above this regional background value. This results in the Marine portion of the Site extending several hundred ft from the shoreline and elongating toward the north (Figure 31). Elevated cPAH concentrations may be present beyond the northern nearshore marine Site boundary and may be indicative of non-point source concentrations associated with urbanized areas around the Puget Sound. In addition to the non-point sources, several potential historical sources known to have existed north of the Site include overwater

features such as the log-dump tracks and other railroad features (overwater trestles and upland railroad tracks along the shoreline), coal bunkers, a round house, waste fires, and an overwater rail at the south end of the Bellingham Bay Improvement Company sawmill. These features are noted on 1904, 1913, and/or 1950 Sanborn maps (Appendix A) and in Section 6.1.

6.0 FATE AND TRANSPORT CONSIDERATIONS

The following sections present a summary of fate and transport considerations for contaminants detected at the Site. This section provides a discussion of potential contaminant sources, physical and chemical characteristics that affect transport, and a summary of physical transport mechanisms.

6.1 Contaminant Sources

As discussed in Section 2.1.3, the following list of products or byproducts are associated with historical usage of the property as a manufactured gas plant in the Upper Park Area from about 1890 to the late 1940s, and may have been released at the Site:

- Coal tar/oil tar
- Tar/oil/water emulsion
- Tar decanter sludge
- Coke and coal residue
- Wastewater treatment sludge
- Petroleum hydrocarbons stored in oil/fuel tanks
- Surface run-off and outfall(s).

The release of these products or byproducts appears to have resulted in PAHs (including cPAHs), VOCs, TPH-D, and some metals affecting the environment. Based on the understanding of historical operations and based on the distribution of contamination observed at the Site, these releases are thought to have occurred from leakage of residual contamination from the former tar wells, separators, gas holder tanks and/or underground piping left in place at the Site, or discharges to the ground surface and the toe of the Slope Area from an historical drain pipe and other activities associated with the former operations.

Unrelated activities on and near the Site may also be sources of contamination observed during the RI (Appendix A). Other potential sources of contamination include:

- Environmental releases associated with lumber mill operations in the lower portion of the Site from 1884 to 1925
- Environmental releases associated with a fire that destroyed the lumber mill in 1925 or other waste fires north of the Site
- Environmental releases associated with operation and maintenance of the railroad at the toe of the slope area of the Site from 1890 to the present date, and overwater “log dump” tracks (rail) adjacent to the Site shoreline from at least 1913 to 1950
- Environmental releases associated with overwater trestles or coal bunkers just north of the Site, or a former round house located closer to downtown Bellingham

- Environmental releases from an overwater rail at the south end of the Bellingham Bay Improvement Company sawmill
- Placement of fill materials with undocumented chemical composition in the lower portion of the Site from the 1930s to the 1970s
- Discharges of urban stormwater runoff through two outfalls conveying untreated stormwater to Bellingham Bay in the pocket beach at the Site
- Contaminated sediment migration with current and wind movement.

After the lumber mill closed due to fire in 1925, a large area of the shoreline was filled with various construction and wood waste materials as documented on historical aerial photographs of the Site. The fill materials could be a source of cPAHs in soil and groundwater in the lower portion of the Site and the nearby marine sediment.

Activities associated with the existing BNSF railroad tracks and the historical rail lines that bisect the Site could be a source of benzene and cPAHs to all media in the vicinity of the tracks. Oily products (e.g., creosote) are commonly used to treat the wood in the ties, and may have been used to control vegetation along the tracks.

Outfalls convey nonpoint source runoff from the parking lot in the lower park and from South State Street and the surrounding neighborhood to Bellingham Bay. The outfalls could be a source of cPAHs, and copper in the marine environment from vehicular activities and general urban runoff.

6.2 Physical and Chemical Characteristics of Contaminants of Potential Concern

There are several factors that affect contaminant transport or migration through media at any site. These include the unique geological and hydrogeologic setting, and also physical and chemical characteristics of the contaminants themselves. This section presents a summary of the physical and chemical characteristics considered in understanding fate and transport at the Site.

The primary physical and chemical properties that govern contaminant fate and transport at this Site include the organic carbon-water partitioning coefficient (Koc), the distribution coefficient (Kd), the Henry's Law constant (Hcc), and the aqueous solubility (S). Table 20 presents these parameters for the contaminants detected at the Site with these parameters available in Ecology's CLARC Information System (Ecology 2015c). The following sections summarize the importance of these characteristics and how they affect fate and transport of contaminants in the environment.

Soil Organic Carbon-Water Partitioning Coefficient (Koc)

This parameter describes the degree of partitioning between the soil matrix and the aqueous phase based on the amount of organic carbon in the soil. The coefficient represents the ratio of the mass of contaminant adsorbed to the soil (per unit mass of organic carbon in the soil) to the equilibrium

concentration of the contaminant in aqueous solution. The parameter is useful in estimating the contaminant concentration of groundwater based on adjacent soil contaminant concentrations. Higher Koc values correlate to organic chemicals that bind well to soil, and lower Koc values correlate to those which partition more to groundwater and are therefore more mobile in the environment.

Soil-Water Distribution Coefficient (Kd)

This coefficient similarly describes the equilibrium relationship between the contaminant concentrations in soil or water. This parameter more directly describes the relationship of a chemical's adsorbed concentration to dissolved concentration. For organic contaminants, Kd can be calculated by multiplying the Koc value by the mass fraction of organic carbon in the soil (foc). Table 20 presents the Kd values for metals.

Volatility – Henry's Law Constant (Hcc)

This parameter describes the ratio of a contaminant's concentration in air to the equilibrium concentration in water. The Hcc value is used in estimating the concentrations in soil vapor based on concentrations in ground water using three- and four-phase equilibrium partitioning models at a given temperature.

Aqueous Solubility (S)

The aqueous solubility describes the degree to which a contaminant will dissolve into water. The parameter is use determine maximum saturation limits, as the value represents the maximum concentration in groundwater that could be imparted by the presence of free product or NAPL.

6.3 Transport Mechanisms

This section provides a background for understanding potential contaminant transport mechanisms.

6.3.1 Dissolved Phase Transport in Groundwater

Contaminant transport in the dissolved phase in groundwater is the result of advection, hydrodynamic dispersion, and biological/chemical reactions (including oxidation, biodegradation, sorption, etc.). Dissolved-phase constituents may also volatilize into the vadose zone. The following subsections discuss advection, hydrodynamic dispersion, and sorption in groundwater.

Advection

Advection is the movement of groundwater as a result of a hydraulic gradient. Advection is described by Darcy's law, which states that the flow rate through a porous medium is proportional to the hydraulic gradient (Eq. 1 below). Advection is essentially the average linear groundwater velocity without dispersion or chemical reactions.

The average linear velocity is defined by the following relationship:

$$\text{Eq. 1} \qquad v_{ave} = (-K/n)*(dh/dl)$$

Where *n* is the effective porosity (unitless) and *dh/dl* is the hydraulic gradient (unitless).

Hydrodynamic Dispersion

Mechanical dispersion and molecular diffusion are commonly combined into a quantity called hydrodynamic dispersion because they cannot be evaluated independently in flowing groundwater (Fetter 1993). Dispersivity is a mixing length and is an intrinsic property of the porous medium. It results from variations in flow velocity at the pore and field scales (Wang and Anderson 1982). If dispersion did not occur, there would be an abrupt interface between the solute and uncontaminated groundwater (i.e., the solute would move like a plug). Molecular diffusion is a result of concentration gradients. Solutes in water spontaneously travel from areas of high concentrations toward areas of low concentration. This effect is intensified at the point of groundwater discharge tidally-influenced surface water bodies. Mechanical dispersion within the soil pore space where groundwater discharges to the surface water is caused by pumping action as the tide rises and lowers, mixing seawater and the groundwater prior to discharge. When soils in the transition zone between groundwater and surface water are permeable, the tidal exchange results in a significant reduction in groundwater contaminant concentrations prior to discharge.

Sorption

Sorption-desorption retard the velocity of contaminant transport relative to the groundwater flow velocity. Chemicals that are not retarded are transported at the rate of groundwater flow.

A retardation factor, R_d, quantifies the contaminant transport velocity relative to the groundwater flow. R_d is estimated by the following equation:

$$\text{Eq. 2.} \qquad R_d = 1 + (\rho_b K_d)/n$$

Where ρ_b is the dry bulk density of the aquifer material, K_d is the partition coefficient, and n is the porosity.

The bulk dry density and porosity are properties of the aquifer media. K_d describes equilibrium partitioning between the water and the aquifer material. K_d depends on the contaminant chemical properties, soil properties (particularly organic carbon content), temperature, and pH. The retardation factor is 1.0 for chemicals that are not retarded.

The K_d for partitioning of organic contaminants in soil (sediment) and groundwater correlates to the organic carbon content of the soil. K_d can be estimated as:

$$\text{Eq. 3.} \qquad K_d = f_{oc} \times K_{oc}$$

Where f_{oc} is the mass fraction of organic carbon, and K_{oc} is the soil organic carbon partition coefficient.

K_{oc} is a measure of an individual chemical's tendency to partition into organic carbon in soil and sediment. The K_d value for the bulk soil (or sediment) is a function of the organic carbon fraction of the soil, f_{oc}, which is expressed as a ratio. If the K_{oc} of a compound and the organic carbon content of the aquifer are known, then K_d can be calculated.

6.3.2 NAPL Transport in Soil and Groundwater

The movement of NAPL in the subsurface is driven by gravity and pressure forces. The most important process influencing the downward migration of the liquid is movement due to a potential gradient. In the vadose zone, the NAPL may partition into the air as a vapor phase (Fetter 1993). If the NAPL is partially soluble in water, a dissolved phase may also be present.

When NAPL is released to soil, it will typically travel downward through the vadose zone (if present) to the capillary fringe zone (tension saturated zone where the pressure head is less than atmospheric pressure). At the top of the capillary fringe, light NAPL (LNAPL), which has a density less than water, will spread laterally. At the bottom of the capillary fringe, DNAPL, which has a density greater than water, will displace the soil porewater and continue to migrate downward to the saturated zone.

The movement of NAPL in the subsurface is affected by heterogeneities in the soil. Migration may be temporarily slowed, completely halted, or redirected, depending on the heterogeneities that are encountered. Soil heterogeneities that offer resistance to continued downward migration can cause NAPL to spread laterally (assuming capillary resistance to lateral flow is less than that for continued vertical flow).

As NAPL migrates through the soil pores, a portion of the NAPL will be trapped within the soil pores due to surface tension. The NAPL that is trapped in the soil pores is referred to as residual NAPL, and will remain essentially immobile in the soil pores. Downward migration of NAPL will continue until the NAPL source is depleted or until it reaches a barrier layer. If there is a sufficient volume of NAPL, it may continue to migrate downslope on top of the barrier under gravity and pressure forces. The NAPL will continue to migrate until it reaches a topographically low area on top of a barrier layer.

DNAPL migration is generally not affected by groundwater flow, except in those cases in which hydraulic gradients are high enough to overcome the gravity and pressure forces that otherwise dominate the migration of DNAPL.

6.3.3 Contaminant Transport – Surface Water

The water solubility of a chemical partly determines how that substance is transported by surface waters. Because water is a polar solvent, polar covalent and ionic compounds are more likely to dissolve than nonpolar compounds. If a chemical dissolves in surface water, its chemical transport

properties will be identical to those of water. Conversely, an immiscible liquid phase (e.g., NAPL) will either sink or float on water depending on its specific gravity. Non-aqueous-phase liquids with a specific gravity of less than one will tend to remain close to, or "float" on the surface and may become susceptible to attenuation by volatilization and photolysis. Immiscible liquids more dense than water will move along the sediment bottom or become absorbed onto sediment particles.

Substances dissolved in surface waters can also partition out of the dissolved phase to a liquid phase or adsorb onto particles suspended in the water or onto bottom sediment. The latter process transfers the substances from the water to the sediment matrix. Conversely, chemicals may desorb from sediment and enter solution.

Chemicals in Site sediments can be transported to other locations in Bellingham Bay as part of the bed or suspended load, depending on particle size and surface water energy. They may settle and accumulate in sediment (e.g., protected, depositional areas) and become buried over time. Resuspension can occur during large storm events or man-made activities (e.g., vessel prop wash, construction).

Discharge of groundwater from the uplands to a tidally-influenced marine environment occurs within a complex and dynamic hydrogeological, chemical, and biological setting. With tidal influences constantly changing flow conditions, the point of discharge is alternately dominated by a mixture of freshwater or marine water depending on fluctuating tidal and groundwater levels. Contaminants transported to the point of discharge may undergo chemical or biological changes due to the changing redox conditions, oxygenation, massive dilution by seawater, and microbial degradation due to the enhance biological activity in these locations. As a result of the physical, chemical, and biological activity, contaminant concentrations are often reduced significantly prior to groundwater discharge. The attenuation effects are significant, but not well-enough understood to apply a standard reduction factor to account for the anticipated change at the point of discharge, which is often used as a point of compliance. As a result, groundwater monitoring near shorelines often overestimates the actual concentration of contamination entering the marine environment. At this Site, the sediments are heavily impacted by historical releases. As shown in Figure 2, a drain pipe reportedly discharged to a ditch near the rail track location, very close to the marine environment. Groundwater sample data collected close to the point of groundwater discharge may be biased-high due to sample contaminant contribution directly from the sediment.

6.3.4 Contaminant Transport in Sediments

Sediment transport is one of the primary transport mechanisms for cPAHs in the aquatic environment. Because of their low solubilities in water, chemicals such as PAHs tend to be adsorbed to fine-grained organic material in the water column and are either deposited on the bottom or transported by physical processes such as tidal flow or wind-driven currents. After deposition, bottom sediments are subject to resuspension by transport as bedload; mostly fine-grained material will be entrained in the

water column as suspended load. The other important processes that affect long-term contaminant presence are biological, including bioturbation of sediments, bioaccumulation, and biomagnification. Sediment bioturbation will improve degradation rates of PAHs through oxygenation of surface sediments.

6.3.5 Contaminant Transport in Unsaturated Soil

Contaminants in vadose zone soil can migrate by gravity flow of NAPL (described above), by infiltration of chemicals in solution, and by leaching of contaminants in soil by infiltrating precipitation or surface water. Infiltration transport in unsaturated soil is downward with localized lateral movement resulting from heterogeneities in the subsurface.

6.4 Conceptual Site Model

This section presents an overview of the media of concern and impacts from the Site IHS. This includes a discussion of contaminant migration potential exposure pathways to Site receptors based on the RI data presented in previous sections. Table 18 provides a summary of the IHS evaluation, organized by media of concern. This table includes an assessment for all COPCs detected at the Site in excess of the screening levels, and selects a subset for inclusion as IHS. Table 19 provides a summary of those selected as IHS, and for those, presents the proposed cleanup levels. Figure 45 provides a conceptual model of contaminant transport mechanisms, and Figure 46 provides a diagrammatic evaluation of potential exposure pathways.

6.4.1 Migration

Figure 45 presents a conceptual model illustrating how contamination has migrated through affected media at the Site, resulting in the currently observed conditions. The model is based on historical Site usage summarized in Section 2, the environmental setting described in Section 3, the nature and extent of contamination discussed in Section 5, and the fate and transport considerations summarized earlier in Section 6.

Releases

As shown on Figure 2, historical operations of the manufactured gas plant appears to have resulted in releases of contaminants to the soil in the Upper Park Area, and to the marine environment through a pipe which drained waste materials from the Upper Park Area to a ditch near the rail tracks. As shown on the figure, additional sources of contaminants include the fill material, which comprises all of the uplands in the Lower Park Area, historical sawmill activities (including the adjacent rafting area), or contaminants in the stormwater outfall pipes which discharge urban runoff.

The Site releases directly affected soil and groundwater quality in the uplands, and sediment quality in the marine portion of the Site. Downstream effects from the Site releases are discussed further below.

NAPL Transport

The Site releases have migrated through and contaminated the permeable soils to the underlying bedrock, where some residual DNAPL may still be present. Historically, the DNAPL likely migrated along the upper surface of the bedrock to reach some portions of the Lower Park Area. Although observations during the RI indicate residual DNAPL may still be present, it is unlikely to still be present in sufficient quantities to be mobile or hydraulically recoverable. It is unlikely at this time that DNAPL is continuing to migrate at the Site, though it may continue to dissolve and affect groundwater quality in localized areas.

Dissolved Phase Transport

Contaminants in the dissolved phase migrate with groundwater, and may affect downgradient soil and possibly sediment quality. At the Site, some dissolved phase metals, VOCs, and PAHs have been observed in the Upper and Lower Park Areas. In the Upper Park Area, groundwater has been found present only in limited areas, apparently related to a depression in the bedrock surface. However, during rainy periods when the holding capacity of the bedrock depression in the Upper Park Area is exceeded, groundwater movement is likely to be in the westerly direction. Although a clear pathway for groundwater migration from the Upper to Lower Park Areas has not been observed, the observation of Site IHS in the Lower Park Area confirms migration has occurred. Groundwater is not observed in the Slope Area of the Site, since the veneer of soil is very thin and there is no chance for accumulation, only ephemeral transport. As a result, it has not been possible to evaluate water quality in this area.

COPCs in Site groundwater have a large range of physical characteristics which affect dissolved phase transport. As shown in Table 20, the solubility and soil organic carbon-water partitioning factors span several orders of magnitude. A comparison of these parameters for benzene and benzo(a)pyrene with regard to their distribution at the Site provides a good example to illustrate the likely dissolved-phase transport mechanisms. Benzene is over a million times as soluble as benzo(a)pyrene, and has a lower partitioning factor by greater than five orders of magnitude. As a result, benzene dissolves readily into groundwater and can travel a relatively great distance with limited flow-retardation by organic matter in the soil. By contrast, benzo(a)pyrene is nearly insoluble in water, and its transport is significantly retarded by attraction to the organic matter in soil.

At the Site, benzene is observed throughout the Upper Park Area, but is present above SLs at only two locations in the Lower Park Area, at MW-31 near the pedestrian bridge and nearby at MW-28 at the toe of the Slope Area. The limited extent of benzene impacts in the Lower Park Area confirmed by samples surrounding MW-31 and MW28, despite its greater potential for migration, indicates that at present day, transport of contaminants in groundwater from the Upper to the Lower Park Area is likely limited to the immediate vicinity of former operations.

The observation of cPAHs throughout the Lower Park Area in soil is likely due to historical Site-related discharges, historical DNAPL migration, and sources unrelated to Site activities. An ongoing source may be the continuing migration of dissolved-phase cPAHs from the Upper Park Area. However, the exceedances being limited to locations near the former operations and the location near the pocket beach where former waste discharges may have occurred suggests that most of the cPAHs in the Lower Park Area may not have recently migrated there from the Upper Park Area—which may be an important consideration in developing cleanup alternatives for the Site.

Near the shoreline, IHS concentrations are markedly lower than upgradient, indicating some attenuation during transport. Additionally, concentrations are expected to decrease significantly prior to discharge to surface water. Hydrodynamic dispersion at the groundwater to surface water interface where dissolved-phase contamination would enter the marine environment is likely to be quite significant and under-represented by the RI data due to the inherent difficulties of collecting representative samples from within the groundwater/surface water mixing-zone. It is expected that groundwater samples near the shoreline have concentrations of cPAHs significantly greater than would be measured at the actual point of discharge, due to the mechanisms discussed in Section 6.3.3. It is anticipated that if samples could be collected nearer the point of discharge, the concentrations of IHS could be below SLs at some locations, though sediment concentrations are elevated sufficiently to prevent collection of unbiased samples. Shoreline samples collected from the area likely affected by the historical discharges through the former drain pipe to the ditch near the rail tracks (GW-WP-01, GW-WP-02, and MW-46) have concentrations of cPAHs in exceedance of the screening level. These locations are in or very near to heavily contaminated sediment. There are other potential sources of cPAHs in this area including poor quality fill materials and other historical activities previously noted in Section 6.1.

The pathway of sediment partitioning to groundwater/surface water is important in the interpretation of water quality samples collected in the Lower Park Area north of the pocket beach. In this area, it unlikely that the concentrations of IHS observed in water samples is representative of groundwater transport, but more likely that the marine sediment was significantly impacted directly by historical releases and now contamination partitions from sediment to the adjacent groundwater or surface water.

Carcinogenic PAHs have very low solubility in water and strong adsorption properties (see Sections 6.2 and 6.3 above) with the organic carbon in soil and sediment. The strong preference for cPAHs to chemically sorb to these media instead of being mobile in groundwater is indicated by their high partitioning coefficients; for most cPAHs, these coefficients range from approximately 1,000,000 to 3,500,000. This physical property results in soil or sediment concentrations that are 1,000,000 to 3,500,000 times greater than the groundwater concentration at equilibrium, which greatly reduces the ability of these contaminants to be mobile in groundwater. Further, at this Site, the relatively high organic content in soil and sediment due to the presence of wood waste from historical sawmill and log rafting operations significantly reduces the cPAH mobility and potential transport distance,

Transport of Contaminated Soil

Transport of contaminated surface soil to Bellingham Bay is currently not anticipated to be significant in most areas of the Site. Along the shoreline, erosional forces are apparent which have the potential to transport upland soil to the marine environment. This erosion typically occurs slowly with small particles over time from typical wave action. However, during storm events, significantly more and larger soil particles can be eroded from the uplands and deposited as sediment in Bellingham Bay along the shoreline. A storm in early 2017 resulted in erosion which warranted an interim action to stabilize the shoreline to prevent further erosion or migration of potentially contaminated soil.

6.4.2 Exposure Pathways

Figure 46 presents a diagrammatic summary of potential release mechanisms, exposure mediums, exposure routes, and potentially affected receptors. Sources include historical operations at the manufactured gas plant, fill materials in the Lower Park Area associated with the former lumber mill, railroad activities, and stormwater discharges at the permitted outfalls. Receptors considered in the model include recreational park users, park workers, recreational or tribal fishers, and offsite residents.

As shown on the figure, there are several significant exposure pathways that could affect the receptors listed above. This includes direct contact by park workers, visitors, or fishers with soil or sediment, air inhalation (if enclosed structures are constructed), and human or aquatic species consumption of Site fish or shellfish. The FS will develop and evaluate remedial alternatives designed to cleanup contamination and prevent exposures.

7.0 EMERGENCY INTERIM ACTION

Based on a storm event in February 2017, the City and PSE conducted an interim action to prevent potential exposure and migration of contaminated media. The work was completed in accordance with an Interim Action Work Plan (Landau Associates 2017), developed in cooperation with Ecology under an amended Agreed Order.

A storm, which produced relatively high winds, surf, and precipitation, occurred on February 10, 2017 and resulted in bank erosion and damage to the existing public pier. The storm caused shoreline erosion and damaged the existing concrete bulkhead adjacent to the pier on the upland side. The damage was evidenced by visible settlement and cracking in the concrete bulkhead, and sinkholes or eroded channels behind the bulkhead.

The interim action was necessary to effectively contain contamination in the shoreline area of the Site and allow proper implementation of the complete RI/FS process. The interim action was determined to meet the MTCA requirements of an interim action, by reducing the threat to human health and the environment through eliminating or substantially reducing one or more pathways for exposure to a hazardous substance, as well as correcting a problem that may become substantially worse if remedial action is delayed. The interim action contained potentially contaminated soil that might otherwise have been released to marine surface water and sediment but did not achieve cleanup standards.

7.1 MTCA Requirements

MTCA distinguishes an interim action from a cleanup action in that an interim action only partially addresses the cleanup of a site and achieves one of the following purposes (WAC 173-340-430[1]):

- Is technically necessary to reduce the threat to human health and the environment by eliminating or substantially reducing one or more pathways for exposure to a hazardous substance (WAC 173-340-430(1)(a))
- Corrects a problem that may become substantially worse or cost substantially more to address if the remedial action is delayed (WAC 173-340-430(1)(b))
- Is needed to complete a site hazard assessment, RI/FS, or design a cleanup action (WAC 173-340-430(1)(c)).

Under MTCA (WAC 173-340-430(2)), an interim action may:

- Achieve cleanup standards for a portion of the site;
- Provide a partial cleanup (clean up hazardous substances from all or part of the site, but not achieve cleanup standards); or
- Provide a partial cleanup and not achieve cleanup standards, but provide information on how to achieve cleanup standards.

7.2 Description of the Interim Action

The interim action generally included placement of rock along the shoreline and bulkhead wall, and the demolition and removal of the wooden pier and piles to prevent erosion. Coastal Geologic Services (CGS) designed a previously implemented the shoreline protection system for Boulevard Park, constructed in 2013, just south of the Site. The shoreline stabilization conducted in 2017 as an interim action was designed consistent with the previous project, which appeared to be functioning successfully. The following bullets summarize elements included in the action:

- Prepared the exposed soil surface along the shoreline to receive additional rock by carefully moving incidental riprap to the existing riprap armor.
- Placed a separation geotextile over the exposed soil.
- Placed appropriately-sized rock (as determined from wave action modeling) on the separation geotextile and filled the gap formed by erosion to a height established by the design.
- Deployed a silt curtain around the pier demolition area.
- Demolished the public pier wood decking.
- Removed treated timber piles.
- Placed appropriately-sized rock against the water side of the bulkhead wall and backfilled voids on the upland side of the wall with rock.

The interim shoreline stabilization is not anticipated to function as a permanent or long-term stabilization, and thus will require observation and possible ongoing maintenance to continue providing protection until a long-term cleanup solution is identified and implemented for the Site as part of the final remedy. Components of the interim shoreline stabilization feature may be incorporated in the final remedy if cost-effective and compatible with the preferred alternative identified in the FS.

An interim action completion report is provided in Appendix E, which provides additional detail relating to the action, including as-built documentation.

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