King County Department of Natural Resources and Parks

Solid Waste Division

Phase 1 – Vashon Island Closed Landfill

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Remedial Investigation Report

VOLUME I

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King County
Department of
Natural Resources and Parks
Solid Waste Division

Waste **Prevention** | *Resource* **Recovery** | *Waste* **Disposal**

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FINAL

REMEDIAL INVESTIGATION REPORT

Vashon Island Closed Landfill

Prepared for: King County Solid Waste Division

Project No. 090057 Task 310.3 • November 6, 2020 Final

Aspect Consulting, LLC in Conjunction with Anchor QEA and BHC Consultants

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Abbreviations

amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
Aspect	Aspect Consulting, LLC
BHC	BHC Consultants, LLC
CFR	Code of Federal Regulations
COC	constituent of concern
COPEC	chemical of potential ecological concern
CSM	conceptual site model
CWA	Clean Water Act
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
EIM	Washington State Department of Ecology Environmental Information Management System
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
GWAC	groundwater advisory committee
GWMP	groundwater management plan
HDPE	high-density polyethylene
HEC	Herrera Environmental Consultants
KCSWD	King County Solid Waste Division
KCWLRD	King County Water and Land Resources Division
LFG	landfill gas
LOEC	lowest observed effect concentration
MCL	maximum contaminant level
MDL	method detection limit
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
MNA	monitored natural attenuation

MSW	municipal solid waste
MTCA	Model Toxics Control Act
NAVD88	North American Vertical Datum of 1988
NOAEL	no observed adverse effect level
NOEC	no observed effect concentration
NRWQC	National Recommended Water Quality Criteria
NTR	National Toxics Rule
NWTPH-Dx	Northwest Total Petroleum Hydrocarbons – Extended Diesel Range Organics
NWTPH-G	Northwest Total Petroleum Hydrocarbons – Gasoline Range Organics
ORP	oxidation-reduction potential
OSS	On-Site Sewage System
PCUL	preliminary cleanup level
PHSKC	Public Health – Seattle and King County
POC	point of compliance
PPM	parts per million
PQL	practical quantitation limit
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RDL	reporting detection limit
RI	Remedial Investigation
scfm	standard cubic feet per minute
SQER	small quantity emission rate
SVOC	semivolatile organic compound
SWANA	Solid Waste Association of North America
SWAP	Source Water Assessment Program
TCE	trichloroethene
TDS	total dissolved solids
TEE	Terrestrial Ecological Evaluation

TOC	total organic carbon
TPH	total petroleum hydrocarbons
UCL	upper confidence limit
USC	United States Code
USGS	United States Geological Survey
VLF	Vashon Island Closed Landfill
VMI	Vashon-Maury Island
VOC	volatile organic compound
WAC	Washington Administrative Code
μg/kg	micrograms per kilogram
μg/L	micrograms per liter

Executive Summary

This Remedial Investigation (RI) Report has been prepared to document the results of the RI at the Vashon Island Closed Landfill (VLF), located on Vashon Island, Washington (Figure 1.1). An RI is conducted to define the distribution of contaminants at a site and the associated potential threat to human health and the environment. For an RI conducted in accordance with the Washington State Model Toxics Control Act (MTCA; Washington Administrative Code [WAC] Chapter 173-340), data is gathered and analyzed to provide an understanding of the hydrogeologic site setting, nature and extent of contaminants, their fate and transport, and the receptors that may be impacted by the contaminants. This information is used to develop preliminary cleanup levels (PCULs) and constituents of concern (COCs). PCULs address all detected constituents in all affected media for which promulgated screening criteria are available. Information collected for the RI enables preparation of a feasibility study (FS). PCULs are considered preliminary as the final cleanup levels are established by the Washington State Department of Ecology (Ecology) in a cleanup action plan, prepared following the approval of the RI and the FS.

King County Solid Waste Division (KCSWD) performs routine monitoring to meet the landfill's permit requirements. One of these requirements is groundwater detection monitoring. The independent RI was conducted as part of a corrective action (pursuant to WAC 173-351 and in accordance with MTCA) that was triggered by statistically significant exceedances of groundwater protection standards (Ecology 2010a, 2010b). This RI Report includes evaluation of data collected since implementation of the recommendations made in "Environmental Review, Investigation, and Evaluation Technical Memorandum – Vashon Island Closed Landfill" (Aspect et al., 2012).

The following provides an overview of the RI findings.

Extent of Solid Waste and Landfill Closure

Solid waste disposal activities occurred at the VLF since the early 1900s. Based on review of historical topographic maps, solid waste was placed in a former valley. The northwest portion of the landfill, approximately 2.3 acres, was closed in 1988 in accordance with WAC 173-304 (Phase 1 Closure Area). During Phase 1 closure, a liner was placed across the central portion of the landfill. The landfill accepted refuse for placement in the lined portion of the landfill until 1999. Final landfill closure (or Phase 2 closure) was completed in 2001 in accordance with WAC 173-351. Site investigations suggest that unlined refuse extends approximately 300 feet south of the Phase 2 closure area, into the South Slope Area.

Landfill environmental controls include a permanent geomembrane cover system across Phase 1 and 2 closure areas, landfill gas (LFG) extraction and treatment, stormwater management, and leachate collection. The VLF facility includes a transfer and recycling station, LFG treatment facilities, and a scale house.

Hydrogeology

VLF geology is composed of glacially derived sediments, with surficial geology being primarily glacial till and advance outwash. The site stratigraphic model categorizes the subsurface into seven primary units, designated A through G, based on interpreted geologic origin. Groundwater in two underlying stratigraphic units (Unit C and Unit D) has been characterized for the nature and extent of COCs at the VLF.

Unit C is glacially derived, consisting of fine-grained soils (Cf) deposited in a low-energy glaciomarine or glaciolacustrine setting and coarser-grained soils (Cc) deposited in a higher-energy glaciofluvial deposit. Subunits Cc2 and Cc3 are considered to be the principal water-bearing layers of Unit C. Borings completed at the VLF indicate limited hydraulic interconnection between Cc units, which is consistent with the characteristics of their glacial depositional environment. The Cc units are separated from one another by fine grained soils (Cf).

Groundwater with concentrations of COCs exceeding PCULs is limited to Unit Cc2. Groundwater flow in Unit Cc2 is westerly and discharges from seeps located on the steep hillslope on the western side of the VLF property.

Unit D is a fluvial deposit exhibiting a wide range in texture consistent with varying energy in a fluvial environment, including sandy gravel channel deposits to fine-grained overbank deposits. In all deeper borings completed onsite, a fine-grained portion of Unit C was observed separating the water-bearing portions of Unit C from the Unit D aquifer. Groundwater COCs have not been detected above PCULs in Unit D, whether in on-property monitoring wells or off-property domestic drinking water wells monitored by KCSWD. Unit D is not considered to be impacted by landfilling processes.

A beneficial use survey was conducted to assess drinking water sources for residents in the vicinity of the VLF. Thirty-three wells and one spring were identified in the vicinity of the VLF. Twenty-eight of the wells reviewed for the beneficial use survey were determined to be located within the Survey Area. This includes one Group A system (85 Acres), seven Group B systems, and 21 single-family wells. Nine of the thirty-two wells have been sampled previously by KCSWD during the 2002 well survey. Two wells, Paquette and 85 Acres Water Systems, continue to be monitored by KCSWD semi-annually. No evidence of contamination originating from the VLF has been identified in historical and ongoing sampling of these water sources. Section 7 of this RI Report presents the summary of the beneficial use survey.

Extent of Impact

The following presents the conclusions of the RI.

- Groundwater impacts are limited to Unit Cc2. Groundwater COCs include dissolved metals (arsenic and iron), volatile organic compounds (VOCs; vinyl chloride, benzene, 1,2-dichloropropane, and trichloroethene [TCE]), and semi-volatile organic compounds (SVOCs; bis(2-chloroethyl) ether).
    - Groundwater exceeds the PCUL for vinyl chloride at the southern property boundary.

- Surface water impacts at the VLF are limited to surface water locations downgradient of Unit Cc2 groundwater discharge points along the West Hillslope of the VLF property. Surface water COCs include dissolved metals (arsenic, iron, manganese) and VOCs (vinyl chloride and benzene).
    - Surface water exceeds PCUL for vinyl chloride at the western property boundary; however, no exceedances are present at sampling point SW-E at Robinwood Creek.
- LFG is the primary source of groundwater impact. Residual leachate impacts to groundwater have diminished overtime.
- Lateral control of LFG is maintained by active LFG collection infrastructure. No off-property migration of LFG has been observed since at least 1998.

MTCA defines “Site” or “Facility” as everywhere that contamination has come to be located. The VLF MTCA Site includes those areas delineated on Figure 10.1 where COCs exceed PCULs. More specifically, the VLF MTCA Site is bounded to the north by the edge of the Phase 2 final cover and by MW-4 and MW-36, and to the east by the estimated extent of unlined refuse and MW-20. To the south, vinyl chloride exceeds PCULs at the southern property boundary; however, COC concentrations at MW-21 are expected to continue to decline with the expansion of the LFG collection system within the South Slope Area. At the west property boundary, only vinyl chloride in surface water exceeds PCULs; however, downgradient of the VLF, concentrations of vinyl chloride do not exceed PCULs at a surface water sampling location 1,600 feet west of the VLF in Robinwood Creek.

Exposure Pathways and Receptors

The following exposure pathways and receptors were identified as potentially complete for humans:

- **Direct contact with groundwater.** Direct contact of current and potential future on-property VLF staff and construction workers (above- and below-ground) is an exposure pathway mitigated by landfill safety procedures.
- **Direct contact with surface water.** This exposure pathway is potentially complete for current and future off-property residents and off-property recreational users. On-property exposures are mitigated by landfill safety procedures.
- **Ingestion of aquatic organisms.** Off-property, this exposure pathway is complete for current residents and recreational users and potentially complete for future residents and recreational users, driven by ingestion of aquatic organisms exposed to bioaccumulative compounds (i.e., vinyl chloride) originating from groundwater discharge to surface water.

- **Direct contact with refuse and soil.** Potential exposure pathways for soil include direct contact with shallow refuse or soil and impacted groundwater (on-property only).
- **Inhalation of fugitive LFG.** Human exposure to LFG is mitigated on-property by landfill safety procedures. There is no evidence of LFG migration off-property.
- **Landfill gas explosions.** Exposure to current and potential future on-property above- and below-ground VLF staff and construction workers is mitigated by landfill safety procedures and routine monitoring that are in place for staff and worker protection.
- **Direct contact with fugitive leachate.** Human exposure to leachate is mitigated on-property by landfill safety procedures. There is no evidence of leachate migration off-property.

Ingestion of groundwater by off-property residences is a potentially complete exposure pathway; however, there is no risk to humans because COCs do not exceed state or federal drinking water MCLs off-property.

Section 8 of this RI Report presents a summary of the terrestrial ecological evaluation conducted on the West Hillslope. Dissolved metals are the COCs for ecological receptors. The following ecological exposure pathways and receptors were identified as potentially complete:

- **Ingestion of surface water.** While the pathway for ecological exposure to impacted surface water is complete on-property along the West Hillslope, no exceedances of dissolved metals are present at the VLF property boundary therefore there the pathway is not complete off-property.
- **Direct contact of refuse.** The exposure pathway of direct contact by terrestrial receptors is considered incomplete based on depth to refuse and presence of a geomembrane liner and geotextile fabric.
- **Direct contact and ingestion of soil.** The exposure pathways of direct contact and ingestion of soil by terrestrial and burrowing organisms are complete for on-property receptors based on the concentrations of select metals in excess of terrestrial ecological screening levels. However, there is no elevated risk present due to detected concentrations consistent with area-wide background concentrations.
- **Ingestion by biotic uptake (plants and prey).** The exposure pathway of ingestion biota that have taken-up COCs is complete for on-property terrestrial and burrowing organisms. However, there is no elevated risk present due to detected concentrations consistent with area-wide background concentrations and no plant impacts were observed during the wetland survey.

Data Gaps

Through the course of this RI data gaps have been identified that are to be addressed during the Feasibility Study, in accordance with WAC 173-340-350(7). These data gaps are as follows:

- **GW-11 water source.** The source of water recharge to GW-11, seasonally obscuring the well screen, affecting LFG extraction is unknown.
- **Extent of vinyl chloride along south property boundary.** Additional investigations are necessary to define the extent of vinyl chloride south of the property.

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1 Introduction

This Remedial Investigation (RI) Report has been prepared to document the results of the RI at the Vashon Island Closed Landfill (VLF), located on Vashon Island, Washington (Figure 1.1). An RI is conducted to define the distribution of contaminants at a site and the associated potential threat to human health and the environment. For an RI conducted in accordance with the Washington State Model Toxics Control Act (MTCA; Washington Administrative Code [WAC] Chapter 173-340), data is gathered and analyzed to provide an understanding of the hydrogeologic site setting, nature and extent of contaminants, their fate and transport, and the receptors that may be impacted by the contaminants. This information is used to develop preliminary cleanup levels (PCULs) and constituents of concern (COCs). PCULs address all detected constituents in all affected media for which promulgated screening criteria are available. Information collected for the RI enables preparation of a feasibility study (FS) and remedy selection to address contamination. PCULs are considered preliminary as the final cleanup levels are established by the Washington State Department of Ecology (Ecology) in a cleanup action plan, prepared following the approval of the RI and the FS.

King County Solid Waste Division (KCSWD) performs routine monitoring to meet the landfill's permit requirements. Statistically significant exceedances of groundwater protection standards triggered corrective action requirements for the landfill pursuant to WAC 173-351. As outlined in communication with Ecology in 2010, KCSWD pursued an independent RI (pursuant to WAC 173-351 and in accordance with MTCA) to satisfy components of the corrective action (Ecology 2010a, 2010b). In response to a written request by KCSWD to modify the list of groundwater analytes required for detection monitor (King County, 2014), the Washington State Department of Ecology (Ecology) and Public Health – Seattle & King County (herein referred to collectively as the Agencies) stated that additional data and evaluation were needed before a reduction in the analyte list could be authorized (Ecology, 2014). This RI satisfies some of the additional data and evaluation requested by Ecology to support the demonstration. This RI Report includes evaluation of data collected since implementation of the recommendations made in "Environmental Review, Investigation, and Evaluation Technical Memorandum – Vashon Island Closed Landfill" (Aspect et al., 2012). These recommendations included updates to the hydrogeologic conceptual model; contaminant source evaluation; groundwater and surface water monitoring system improvements; leachate monitoring; and landfill gas (LFG) monitoring investigations.

1.1 Objectives and Purpose

The objective of this RI Report is to evaluate and document data by which to characterize the environmental conditions associated with the VLF. Ultimately, this RI will be used to prepare a FS to enable the selection of a cleanup action in compliance with MTCA regulations (WAC 173-340-350 through 173-340-390). Specifically, the RI objectives included:

- Provide an up-to-date summary of completed investigations conducted at the VLF since landfill closure.
- Update the existing hydrogeologic conceptual site model (CSM) with data through December 2019.
- Characterize the nature and extent of impacted media (i.e., groundwater and surface water) at the VLF and define the “Site” in accordance with MTCA.
- Identify the potential for vertical migration of LFG and the need for LFG controls beyond what is already in place.
- Identify the potential for migration of landfill leachate and the need for leachate controls beyond what is already in place.
- Identify PCULs for affected media that are not contained within the footprint of landfill refuse.

1.2 Report Organization

This RI includes 10 sections. The main text is organized as follows:

- **Section 1 – Introduction** presents information regarding the objectives and approaches for the VLF RI.
- **Section 2 – Site Setting** provides information on VLF location, history, and closure.
- **Section 3 – Environmental Setting** summarizes environmental information relevant to the VLF RI, including topography, surface water features, climate, and hydrogeology.
- **Section 4 – Previous Investigations** describes the purpose and scope of earlier investigations conducted at the VLF.
- **Section 5 – Proposed Preliminary Cleanup Levels** are identified for the purposes of comparing chemical concentrations and identifying potential site-specific pathways to human and ecological receptors. Chemical data are compared to potential screening levels to determine COCs.
- **Section 6 – Nature and Extent of Contamination** summarizes data on the chemical quality of groundwater, surface water, LFG, and leachate and compares the concentrations to PCULs.
- **Section 7 – Beneficial Use Survey** provides a summary of the survey completed to identify drinking water sources in the vicinity of the VLF.
- **Section 8 – Terrestrial Ecological Evaluation** summarizes the wetland survey and activities performed as part of the terrestrial ecological evaluation for the West Hillslope.

- **Section 9 – Conceptual Site Model** provides a discussion of fate, transport, and attenuation processes. It describes the mechanisms of contaminant transport through groundwater, discusses the processes of chemical attenuation, and evaluates potential exposure pathways.
- **Section 10 – Remedial Investigation Conclusions** summarizes the main conclusions presented in the RI, presents the MTCA "Site" boundary, identifies ongoing interim actions, and discusses potential data gaps resulting from the RI.
- **Section 11 – References** are provided at the end of the main report text.

This RI includes 12 appendices (A – L), as presented in the Table of Contents, that support the analyses and discussions presented in the main body of the text and tables.

2 Site Setting

This section provides descriptions of the Site location and surrounding area, and a summary of the Site history, including historical operations and phased landfill closure.

2.1 Site Location and Surrounding Area Description

The VLF property encompasses 54.3 acres of land within the west-central portion of Vashon Island, King County, Washington (Figure 2.1). Westside Highway SW divides the landfill property into two unequal parts. The 39.1-acre area east of the highway is primarily unwooded open space and consists of 10.3 acres of municipal solid waste (MSW) inside the Phase I and 2 landfill closure areas, 2.3 acres of unlined MSW in the South Slope Area, 0.5 acres of MSW west of the Phase I closure area and the remaining 26 acres contain landfill facilities. This eastern portion is currently secured with perimeter fencing and locked access gates. The 15.3-acre area west of the highway is steep, undeveloped, forested land, commonly referred to as the West Hillslope. The VLF property is bounded by Westside Highway SW and rural residential land to the northwest, by Southwest 184th Street to the north, by forested land and rural residential land to the east, and by rural residential land to the south. Figure 2.2 presents the land use and parcel map for the landfill and surrounding properties.

The VLF property is zoned RA-5 (Rural Area, one dwelling unit per 5 acres). Adjacent land to the north, south, and east are also zoned RA-2.5 and RA-5 (Rural Area, one dwelling unit per 5 acres). The Island Center Forest, a King County park, adjoins the landfill along parts of its east and north borders.

Facilities at the VLF include a transfer and recycling station, LFG treatment facilities, a scale house, a perimeter road, perimeter stormwater ditches, a leachate lagoon, a south siltation pond, a south detention pond, an east pond, transfer station storm ponds, and a borrow area with associated pond. These facilities are shown on Figure 2.3.

2.2 Site History

The following section provides a history of site use as a landfill, extent of solid waste and details about landfill closure activities in 1988 and 2001.

2.2.1 Historical Operations

Solid waste disposal activities have occurred at the VLF since the early 1900s. KCSWD assumed operations during the late 1950s (R.W. Beck and Associates, 1983), at which time routine record-keeping practices were initiated. The northwest portion of the landfill east of Westside Highway SW was closed in 1988 and a liner was placed across the central portion of the landfill. A summary of closure activities including liner placement are detailed in Section 2.2.2. The facility accepted refuse for placement in the landfill until 1999 (King County, 2011b), when the transfer and recycling station was completed. Since then, waste generated on the island has been trucked off-island to the Cedar Hills Regional Landfill (Berryman & Henigar and UES, 2006a).

2.2.1.1 Depth and Extent of Solid Waste

None of the subsurface explorations at the VLF have encountered the bottom of the solid waste in the central portion of the landfill, outlined as 1988 and 2001 final cover areas on Figure 2.3, and a high-resolution pre-landfill topographic map is not available. However, given the general site setting, it is suspected solid waste was placed in a former valley running approximately north-south, the southern extent of which can be seen at the South Slope Area located at the south end of the landfill, east of the Leachate Lagoon. Based on review of historical topographic maps, it is suspected that the solid waste reaches a maximum thickness of 20 to 40 feet near the center of the former valley and thins towards the outer margins of the landfill (Golder Associates, 1986). While a high-resolution pre-landfill topographic map is not available, pre-landfill closure maps from 1979 and 1986 are provided in Appendix A.

The horizontal extent of solid waste, including areas without a bottom liner located within the northwest corner of the landfill closed in 1988 and the South Slope Area, is shown on Figure 2.4. The extent of unlined refuse (enclosed by dotted red line in Figure 2.4) is based on multiple lines of evidence: visual observations in 1987 (Golder Associates, 1987), geophysical investigations (Aspect and Duoos, 2018), subsurface explorations, and LFG occurrence. Figure 2.4 also depicts the landfill closure areas (discussed in the next section) and the portions of the unlined refuse areas at the south end of the landfill where a geotextile cover was placed. The leachate lagoon, also located at the south end of the landfill, was constructed with a geomembrane liner and it is unknown if solid waste underlies this feature. Landfill closure areas (Phases 1 and 2 cover areas depicted in Figure 2.4) cover a 10.3-acre area. Solid waste located outside these final cover areas include 2.8 acres in the South Slope Area and 0.5 acres west of the Phase 1 area.

2.2.2 Landfill Closure

The VLF was closed in two phases: a partial closure in 1988 in accordance with WAC 173-304 (herein referred to as Phase 1) and a final closure in 2001 in accordance with WAC 173-351 (herein referred to as Phase 2). The following subsections summarize specific activities performed during the two closure phases.

2.2.2.1 Phase 1 Closure Activities

In 1988, the northwest portion of the landfill area (approximately 2.3 acres) was closed in accordance with then-applicable regulations, Minimum Functional Standards for Solid Waste Handling (WAC 173-304). The closure included installation of cover, a liner below the lateral expansion area, surface water management, leachate collection, and LFG collection systems.

Cover System Installation

The cover system installed in 1988 spanned the existing waste as well as locations planned for lateral expansion east and south sides of the existing refuse mounds (referred to as the “lateral expansion area”). The composite lining system consists of the following components, listed from top to bottom:

- Seed

- Topsoil (6 inches)
- Vegetative soil (6 inches)
- Drain sand (12 inches)
- Strip drain
- High-density polyethylene (HDPE) geomembrane (80 mil [0.08 inches] thick)
- Low-permeability soil (24 inches)
- Geotextile
- Foundation material/natural soil liner (6 inches)
- Gas collection gravel (12 inches)—existing refuse mound only, not placed in lateral expansion area

Refuse placed in the ravine between the south toe of the lined area and the south stormwater facilities (also referred to as the “South Slope Area”) was stabilized using geotextile and a native soil cover as depicted in Figure 2.4 (Berryman & Henigar and UES, 2006a).

Approximately 10 acres were covered or lined (Berryman & Henigar and UES, 2006a). Figure 2.3 depicts the northwest refuse area covered in 1988 and the lateral expansion area where the bottom liner was placed in preparation for future refuse placement (identified as the “Phase 2 - 2001 Final Cover” area).

Surface Water Management System Installation

The initial surface water collection and conveyance system was installed from 1986 to 1990 during closure of the northwest corner of the landfill (King County, 2018). The surface water management systems installed at that time included ditches, culverts, and siltation and detention ponds. Surface water collection features are illustrated on Figure 2.5.

Leachate Collection System Installation

To bring the VLF into compliance with state and local solid waste regulations, a leachate collection system was installed in 1988 after placement of the cover system. Leachate collection features are illustrated on Figure 2.6. The process of installing the collection system included:

- Installation of a gravity leachate collection system within the landfill footprint.
- Construction of a lined, aerated, pretreatment and storage lagoon (“Leachate Lagoon” on Figure 2.6).
- Construction of discharge pump station and leachate tank truck loading station.
- Installation of a perforated toe collector and pump station at the base of the South Slope Area of the VLF that discharges to the leachate conveyance system.

LFG Collection System Installation

The information summarized in this section regarding the initial 1988 and expanded 1996 LFG collection system installation is based on Harper-Owes et al. (1988), CH2M HILL (1997a, 1997b), and Berryman & Henigar and UES (2006a). A detailed description of these activities is provided in "Vashon Island Closed Landfill Environmental Evaluation" (henceforth the Environmental Evaluation Report) (Berryman & Henigar and UES, 2006a). The existing LFG collection system is illustrated on Figure 2.7.

In 1988, KCSWD installed a passive LFG collection system using horizontal perforated piping connected to independent elevated flares (including EF-1, EF-2, EF-3, and EF-4), in addition to the gas collection gravel placed beneath the 1988 closure cover system. This system was designed to control LFG along the edges of waste (EF-1, EF-2, and EF-3), and within the covered waste area (EF-4).

In 1996, KCSWD converted the passive LFG collection system to an active system by installing a blower and treatment system, connecting EF-1 through EF-4 to a gas conveyance pipe header, and decommissioning the elevated flares. The collected LFG was not flammable, and LFG was treated using granular activated carbon. Condensate from LFG conveyance piping was pumped or drained into leachate pipes for conveyance to the lined Leachate Lagoon.

KCSWD also expanded the LFG collection infrastructure in 1996 by installing:

- Vertical gas wells GW-1 through GW-8 across the bottom two-thirds of refuse thickness in the 1988 closure area (CH2M HILL, 1997b).
- Horizontal trench collectors T-1 and T-5 along the northern and western edge of unlined waste in the gas collection gravel placed above the refuse and beneath the 1988 closure cover system.
- Horizontal trench collector T-2 along the eastern edge of unlined waste in reworked "natural soil material" beneath the 1988 bottom liner geomembrane (no waste had yet been placed above the liner in this area).
- Horizontal trench collectors T-3 and T-4 in what was then uncovered refuse above the bottom liner at the south end of the landfill, within the Phase 2 landfill area.

2.2.2.2 Phase 2 - Final Closure Activities

The placement of material in the "lateral expansion area" was discontinued in August 1999 and a temporary plastic cover was placed over the refuse. Final closure in accordance with WAC 173-351, Criteria for Municipal Solid Waste Landfills, was completed between 1999 and 2001. Closure activities began with expansion of the existing surface water management infrastructure and improvements to accommodate flows following installation of the final cover system. The second stage of closure involved installation of an impermeable cap over the refuse, and upgrades to the other environmental control systems. The combined Phase 1 and Phase 2 landfill closure area is approximately 10.3 acres. Final closure record drawings were presented by Berryman & Henigar et al. (2001).

Surface Water Management System Installation

Surface water drainage features are illustrated on Figure 2.5. During the late 1999 upgrades to the surface water management system, a detention pond (the "East Pond") was installed at the southeast corner of the property and an underground drain system including the North Landfill Drain was installed along the landfill perimeter (King County, 2011b). The North Landfill Drain is a 12-inch diameter storm drain system that extends along the east side of the landfill along the perimeter road between the two east-side catch basins, and ultimately discharges to the East Pond. During the final closure phase in 2001, surface water control features within the landfill perimeter were further modified; these modifications included installation of the West Landfill Drain and the South Landfill Underdrain at the south toe of the landfill (Berryman & Henigar and UES, 2006a). The South Landfill Underdrain was installed below and parallel to the ditch along the south face of the landfill. Ultimately, stormwater from the VLF is discharged via an outfall from the South Detention Pond into an unnamed, natural, ephemeral drainage course tributary to Judd Creek.

After final landfill closure, the surface water management system included the following features:

- Vegetated, rock, and asphalt ditches
- Drainage structures and piping
- South Siltation Pond
- Borrow Area Pond
- East Pond
- South Detention Pond
- Transfer Station Storm Ponds

A detailed description of the VLF surface water management system is provided by Berryman & Henigar and UES (2006a).

Final Cover System Installation

The final cover system installed in 2001, designed and constructed in accordance with WAC 173-351, consisted of the following components from top to bottom:

- Seed
- Vegetative Soil (6 inches)
- Topsoil (6 inches)
- Granular drain material (18 inches)
- 60-mil HDPE geomembrane
- Natural low-permeability soil liner (24 inches)
- Geotextile

- Gas collection gravel drainage layer (1 inch)

The topsoil, vegetative soil, and low-permeability soil were all obtained from source onsite at the borrow area (Berryman & Henigar and UES, 2006a).

Leachate Collection System Installation

Leachate collection features are illustrated on Figure 2.6. The leachate collection and conveyance system were expanded before cap placement during the Phase 2 closure, and the Leachate Lagoon was constructed. At landfill closure, the VLF leachate control system consisted of drainage material placed above the bottom liner of the landfill, a network of collection and transmission pipes, two pump stations, and the Leachate Lagoon (Berryman & Henigar and UES, 2006a). Leachate either flows by gravity or is pumped by Pump Station 2 to the flow control vault, and then to Manhole 3. From Manhole 3, leachate flows by gravity to the Leachate Lagoon for pretreatment by aeration. Pump Station 1 pumps the treated leachate from the lagoon to tanker trucks for discharge off-site at a King County wastewater treatment plant.

The sanitary sewer and leachate flows from the tipping floor of the transfer station are conveyed to the VLF leachate system for pretreatment. A detailed description of the leachate system is provided by Berryman & Henigar and UES (2006a).

Landfill Gas Collection System Installation

This section summarizes the LFG collection system installation after 1996 and prior to final Phase 2 closure in 2001. A more detailed description is provided in the Environmental Evaluation Report (Berryman & Henigar and UES, 2006a). Figure 2.7 maps the existing LFG collection system.

During landfilling activities after 1996 and before 1999, horizontal trench collectors FT-1 and FT-3 were connected to the leachate collectors at the base of waste and above the bottom liner. FT-2 and FT-4 were installed between refuse lifts and connected to the existing active LFG collection system. In 2001, horizontal trench collectors FT-5 and FT-6 were installed just below the 2001 closure cover system and connected to the existing active LFG collection system.

2.3 Site Survey

Features at the VLF have been surveyed on an ad hoc basis since landfill closure. Historically, drawings and basemaps developed for past deliverables were created by compiling survey data and features digitized from construction drawings and/or as-builts where survey data was not available.

To ensure consistency in the vertical datum across the site and to verify the location of select features, the VLF was surveyed by King County Roads Service Division in May 2019 and by True North Surveying in June and July 2019. Features that were surveyed included monitoring wells, LFG gas probes, LFG extraction wells, LFG risers, stormwater pipes, ditches, and catch basins. The horizontal datum used by both surveyors is Washington State Plane Coordinate System, North Zone (NAD 83/11) and the vertical datum is NAVD88. As part of the resurvey, the nomenclature for select LFG features were updated at the request of KCSWD as follows:

Old Naming Convention	New Naming Convention
NP-1 through NP-8	GP-01D/I/S through GP-08D/I/S
VTP-1S/D through VTP-11S/D	TP-1S/D through TP-11S/D
Gas Probe 1 and Gas Probe 2 (aka GP-1 and GP-2)	GP001 and GP002

The new survey data and naming convention have been incorporated in the text, tables, and figures of this RI Report.

3 Environmental Setting

This section describes the topography, climate, and geology/hydrogeology conditions of the landfill. In addition, a summary of LFG generation and components is provided.

3.1 Topography and Surface Drainage

The topography at the VLF property is gently rolling at elevations ranging from 300 to 400 feet above mean sea level (amsl). The VLF is located within the Judd Creek drainage area. Surface water from the VLF generally drains toward the south into a tributary of Judd Creek; however, the undeveloped West Hillslope portion of the property drains westward into an unnamed tributary of Robinwood Creek and eventually into Colvos Passage. Robinwood Creek is a fish-bearing waterbody. Judd Creek flows approximately 3 miles to the southeast and discharges into Quartermaster Harbor (King County, 2018). Streams near the VLF are identified on Figure 2.1.

3.2 Climate

King County has a mild climate tempered by southwesterly winds. Summers are cool and dry, and winters are moist and mild. King County's Water and Land Resources Division (KCWLRD) has maintained a weather station—the West Judd Creek Rain Gage (28Y)—at the VLF since October 2004. Routine monitoring (to the quarter hour) has occurred since 2004 for precipitation; since 2007 for air temperature; since 2010 for barometric pressure; and since 2011 for solar radiation. The data for the West Judd Creek Rain Gage were provided by King County's Hydrologic Information Center (http://green2.kingcounty.gov/hydrology/DataDownload.aspx).

The monthly average precipitation ranges from 0.5 inches in July to 7.7 inches in November. The annual total precipitation received ranged from 30.9 inches in 2013 to 56.5 inches received in 2006. The single rainiest month on record was November 2006, with 18.2 inches of rain recorded.

The daily average temperature for the period of record (2007-2014) ranged from 48 to 54 degrees Fahrenheit, while the daily maximum temperature ranged from 68 to 84 degrees Fahrenheit, and the daily minimum temperature range from 19 to 32 degrees Fahrenheit.

3.3 Regional Geology and Hydrogeology

This section provides a detailed summary of the regional geology and hydrogeology to provide broader context and scale for relevant VLF stratigraphy and contaminant extent discussed in Section 3.4.

3.3.1 Geologic Setting

Vashon Island geology is composed of glacially derived sediments deposited during several glacial episodes. Surficial geology is primarily glacial till (or till-like units), (approximately 68 percent of the island), and glacial and alluvial outwash (the remaining 32 percent) (King County, 2005). A regional perspective of the geologic setting is shown by cross section A-A´ (Figures 3.1 and 3.2). Figure 3.1 illustrates the location of borings used for interpretation of geologic contacts including off-property wells monitored by KCSWD (DW prefix in well identification). Refer to Section 6.1.4 for a discussion of groundwater monitoring results from off-property wells. The regional cross section is based on unpublished work from the University of Washington (used by permission; Troost, 2004).

The following descriptions are based on a U.S. Geological Survey (USGS) geologic map of Vashon and Maury Islands (Booth, 1991). Data suggest that tills representing at least three separate glacial advances occur on Vashon Island. The most recent of these was deposited during the Vashon Stade of the Fraser Glaciation, which reached its maximum southerly extent near Olympia about 17,000 years ago. A stade is a short period of time characterized by climatic conditions associated with maximum glacial extent. The Vashon till (Qvt) mantles most of the island and is widespread throughout the Puget Lowlands. Surficial geologic materials in the VLF area consist of Quaternary (Vashon) till and advance outwash. Although Vashon ice contact deposits mantling the till east of the VLF have been mapped, these materials were not identified in explorations completed at the landfill (see boring logs compiled in Appendix B).

The till is underlain by advance outwash (Qva) soils formed by water flowing in front of the approaching glacier; these outwash deposits were subsequently overridden and compacted by glacial ice and till. The advance outwash deposit tends to grade downward from gravelly sand to uniform fine to medium sand. The USGS map (Booth, 1991) shows Vashon advance outwash as occurring at or below the 300-foot elevation west and south of the VLF. At the VLF, sands directly beneath the till are presumed to be advance outwash. The upper (gravelly) advance outwash was not encountered at the VLF; soils directly beneath the advance outwash are typically a poorly graded fine sand or slightly silty sand.

Distribution of pre-Vashon and pre-Fraser deposits beneath the advance outwash is complex. The base of the advance outwash is defined by the uppermost appearance of interglacial silts or clay or oxidized non-glacial clasts. Exposures of the Quaternary pre-Fraser fine-grained facies (Qpff) unit are mapped on the steep bluff just west of the landfill at elevations at or below 200 feet. A small outcrop of older pre-Fraser clay and silt has also been identified at the base of the sea cliffs southwest of the VLF property. All VLF soils beneath the uppermost (“advance outwash”) sands are presumed to be pre-Fraser in age and laterally continuous with those soils mapped west of the landfill. For the VLF, these soils include alluvial, fluvial, and lacustrine or glaciolacustrine sediments.

3.3.2 Regional Hydrogeology

Groundwater flow on Vashon-Maury Island (VMI) is largely radial and downward, flowing outward from the island’s central uplands towards the surrounding Puget Sound (King County, 2005). Groundwater is recharged from precipitation. In areas with glacial till surficial soils, infiltration rates are low compared to those with coarser grained surficial soils derived from glacial outwash. Rainwater either infiltrates or flows overland into lakes or streams that ultimately discharge to the Puget Sound. Surface water may also infiltrate, if for example, the stream flows through an area with coarse soils.

Regional hydrogeology has been examined over the years by the following studies: a 1983 water resources study, frequently referred to as the Carr Report (Carr/Associates, 1983); VMI Ground Water Management Plan (VMI Ground Water Advisory Committee [GWAC], 1998); and VMI Water Resources Evaluation 2004-2010 (multiple reports). The broader purpose of those studies was to evaluate different components of the island's water budget, water supply sustainability, and water quality.

The Carr Report (Carr/Associates, 1983) identified two primary aquifers used as Vashon Island's water supply source: the Principal Aquifer generally located above sea level yielding moderate amounts of water to wells, and the Deep Aquifer at depths of about 100 to 300 feet below sea level capable of yielding larger quantities of water. By inference to its position above sea level, Carr's Principal Aquifer would include the advanced outwash (Qva) aquifer.

The 1998 groundwater management plan (GWAC, 1998) defined four hydrostratigraphic zones based on water level data and completion depths from 25 wells. Broadly speaking, Zones 1 and 2 are within the Principal Aquifer and Zones 3 and 4 are within the Deep Aquifer identified in the Carr Report. In both studies, groundwater flow in the shallower aquifers was to the east and west from a topographic high that extends in an approximate north-south axis along the island, with steeper gradients along the west side.

Groundwater modeling completed as a component of the Water Resources Evaluation confirmed this aspect of groundwater flow on the island (King County, 2005). Research for the groundwater modeling found that groundwater use is fairly evenly divided among the shallow advance outwash, upper deep, and lower deep aquifers. What the groundwater modeling report refers to as "deep aquifers" are stratigraphically below the pre-Fraser fine-grained facies referred to in the previous section. Refer to Section 7 for a summary of the beneficial use survey completed as part of the RI to assess drinking water sources for residents in the vicinity of the VLF.

3.4 Site Geology and Hydrogeology

This section provides a summary of the updated hydrogeologic conceptual model for the VLF. Initially developed by Berryman & Henigar et al. (2000), Berryman & Henigar and UES (2004, 2006a), and King County (2011b), the updated hydrogeologic conceptual model described below reflects data collected since 2014.

3.4.1 Site Stratigraphic Model

The site stratigraphic model categorizes the subsurface into seven primary units, designated A through G, based on interpreted geologic origin. The principal stratigraphic units for the current site model are summarized below from shallowest to deepest. Monitoring wells installed on the VLF property and their assigned completion units are shown on Figure 3.3 and in Table 3.1. Cross sections, whose positions are noted on Figure 3.3, are shown on Figures 3.4 through 3.6. Stratigraphic interpretations provided in the cross sections are a refinement of work completed by King County in 2012 (King County, 2012; included in Appendix C of this report). Cross section D-D' (Figure 3.6) extends off-property to illustrate drinking water wells and borings south of the landfill. Refer to Figure 3.1 for the D-D' cross section location.

3.4.1.1 Unit A

Unit A consists of low-permeability Vashon Till that mantles the landfill property east of the Westside Highway SW. Soils in this unit typically consist of very dense, gravelly, silty sand. The till ranges in thickness from 15 to 50 feet, except where it has been eroded or removed by landfill-related activities. As illustrated on cross section C-C′ (Figure 3.5) and Figure 2.4, the area where till is known to be absent is at the south end of the VLF property. Groundwater has not been identified in Unit A and no monitoring wells are completed in this unit.

3.4.1.2 Unit B

Underlying the till is an advance outwash sand designated as Unit B. This unit has been encountered in all borings that extend beyond Unit A and ranges in thickness from about 40 to 50 feet. The advance outwash is typically comprised of sands with trace amounts of silt and gravel.

3.4.1.3 Unit C

Unit C consists of variable fine-grained glacially derived sediments approximately 100 to 120 feet thick. Groundwater that has been impacted by the VLF occurs within Unit C coarse-grained material; therefore, the depositional environment is discussed in more detail compared to other units and subunits have been defined.

The fine-grained portions of Unit C (indicated by Cf for Unit C fine-grained) act as an aquitard and consist of interbedded sandy silts, silts, and clays. Incised within the fine-grained soil are coarser sand deposits (indicated by Cc for Unit C coarse-grained). The Cf soils were deposited in a low-energy glaciomarine or glaciolacustrine setting and the Cc sediments are a higher energy glaciofluvial deposit. Glaciofluvial deposits are typically less laterally extensive than non-glaciofluvial deposits and appear to represent subglacial meltwater channel deposits and possibly eskers (sinuous ribbons of sand and gravel deposited in meltwater tunnels at the base of the ice). Glaciofluvial sand can also be deposited in a meltwater channel below floating or grounded glacial ice.

Three coarser units have been identified within Unit C, designated from shallowest to deepest as Cc1, Cc2, and Cc3. Surface outcrops of Units Cc2 and Cc3 were observed during a survey completed of the steep West Hillslope located on the west side of the property (King County, 2011a). Figure 3.7 is a geologic map depicting these outcrop observations. Seeps discharging from Unit C along the West Hillslope are overlain on the geologic outcrops depicted on this figure. Refer to Section 3.4.2 for further discussion of groundwater occurrence and point of discharge.

In the drainage extending from the south VLF property boundary, surface outcrops of geologic Units B, Cc1, and the underlying Cf have been observed. Based on the elevations where Unit Cc2 is observed at the VLF, it is inferred that Unit Cc2 likely outcrops on private property south of the VLF near Southwest Cemetery Road. Further definition of the extent of Unit Cc2 on the drainage south of the landfill is considered a data gap to be addressed in the FS, as discussed in Section 10.2.

As depicted in the cross sections, the Cc units are not continuous across the VLF property. For example, Unit Cc3 was not observed in borings completed north of the VLF closure area. Unit Cc2 was not observed in borings southeast and northwest of the VLF closure area.

Borings completed at the VLF indicate limited hydraulic interconnection between the three Cc units, consistent with what is known of their glacial depositional environment. These units are separated from one another by highly variable Cf units, with finer-grained clays noted with depth, as discussed in detail below:

- Cf between Unit B and Cc1 includes silt, sandy silt, and laminated silt ranging between 4 to 20 feet thickness.
- Cf between Cc1 and Cc2 includes 10 feet of silt or silt with fine sand layers below which the unit has interlayers of silt, sandy silt, and silty sand. This Cf ranges between 20 and 38 feet in total thickness.
- Cf between Cc2 and Cc3 consists of interlayers of silt, sandy silt, silty sand, and clay ranging between 8 to 20 feet thickness.
- Cf between Cc3 and Unit D consists of interlayers of sandy silt, silt, and gravelly silt. In borings MW-19, MW-29 and MW-36, Cf is noted to be clay, silty clay to clayey silt above Unit D. The Cf between Units Cc3 and D has been identified in all borings that extend to Unit D or deeper.

3.4.1.4 Unit D

Unit D is comprised of fluvial deposits exhibiting a wide range in texture consistent with varying energy in a fluvial environment. Textures range from sandy gravel channel deposits to fine-grained overbank deposits, and the unit exhibits a corresponding range of hydraulic properties. Thickness of Unit D ranges from about 25 to 65 feet and has been encountered in all deeper borings.

3.4.1.5 Unit E

Unit E is a lacustrine unit approximately 40 feet thick, underlies Unit D and is thought to be continuous beneath the site. This unit is mainly comprised of silt and acts as an aquitard between the water-bearing fluvial deposits in Unit D and Unit F.

3.4.1.6 Unit F

Unit F consists of Pre-Vashon fluvial deposits of widely varying texture, similar to those of Unit D. The thickness of Unit F ranges from 30 to over 90 feet.

3.4.1.7 Unit G

Unit G is the oldest and deepest unit encountered in soil borings at the VLF and is a dark gray, varved clay thought to be regionally extensive and over 50 feet thick.

3.4.2 Site Hydrogeology

The following sections present information on the site-specific hydrogeology based on observations from monitoring wells completed at the VLF. Details on the groundwater-bearing units and aquifer characteristics, including flow direction, recharge, and hydraulic conductivity identified at the VLF, are presented below.

3.4.2.1 Groundwater Occurrence

Four principal water-bearing units were identified based on existing hydrogeologic data: Unit Cc2, Unit Cc3, Unit D, and Unit F. Three criteria were developed to interpret the principal water-bearing units:

- The relationship of groundwater occurrence to specific geologic units.
- Water level elevations (i.e., wells with similar water level elevations were grouped together).
- Water level response to recharge (i.e., wells with similar water level changes were grouped together).

Table 3.1 provides a well completion summary for groundwater monitoring wells completed at the VLF, organized by the stratigraphic unit in which the well is completed.

Units B and Cc1 are not considered principal water-bearing units. While occasional groundwater has been measured in wells completed in these units, the saturated zone is thin to dry and with strong seasonal variability. Wells MW-1 (decommissioned in 2015), MW-3, and MW-4, completed in Unit Cc1 are seasonally dry.

With the exception of MW-20, MW-33, and MW-36, water levels in the Units Cc2 and Cc3 are below the top of the unit indicating unconfined groundwater conditions; however, as discussed further below, barometric effects suggest some degree of confinement is present in the Cc2 and Cc3 wells. Groundwater elevations in wells MW-20 and MW-33, at the southern portion of the property, and MW-36 at the western portion of the property are above coarse-grained portions of the unit indicating confined conditions. Similarly, water levels in Unit D indicate unconfined conditions with the exception of well MW-34, where water levels are approximately 25 feet above the top elevation of Unit D.

Units C, D, and F have been evaluated in light of previous Vashon Island regional aquifer classification systems (Berryman & Henigar and UES, 2006a), which were developed for a King County water resource study (Carr/Associates, 1983) and the Vashon-Maury Island Groundwater Management Plan (GWAC, 1998). These regional classification systems are simplified characterizations of the regional geology, and the hydrostratigraphic classification at the landfill generally correlates with them. Unit C corresponds to the upper portion of the Principal Aquifer in the Carr Report (Carr/Associates, 1983) and “Zone 1” of the Vashon groundwater management plan (GWMP; GWAC, 1998). Both Units D and F correspond with the Principal Aquifer in the Carr Report and “Zone 2” of the Vashon GWMP. These correlations are based on geologic unit and stratigraphic descriptions provided in the reports.

Refer to Section 7 for a summary of the beneficial use survey which was completed to assess drinking water sources for residents in the vicinity of the VLF, including a discussion of the inferred geologic unit of completion for the off-site wells.

3.4.2.2 Aquifer Characteristics

Local groundwater flow direction, recharge, and hydraulic conductivity are summarized here.

Groundwater Flow Direction

Groundwater potentiometric surface maps for Unit Cc2 from the first and third quarters of 2019 are presented on Figures 3.8 and 3.9, respectively. The map incorporates water levels measured in all Cc2 monitoring wells. Beginning in August 2019, MW-30 was added to the routine Unit Cc2 water level monitoring program to confirm westerly groundwater flow direction in the water bearing unit and this well has been incorporated into the potentiometric maps.

Groundwater has been shown to flow in a westerly direction with Unit Cc2 discharge occurring from a series of springs and seeps located on the steep slope on the west side of Westside Highway SW (King County, 2011a). Figure 3.7 illustrates seep discharge from the Cc2 aquifer, in relation to Cc and Cf unit outcrops. Groundwater flow is westward at an average gradient of 0.019 with discharge occurring at the West Hillslope springs (Figures 3.8 and 3.9). Flow direction showed only minor variation between the first quarter (Figure 3.8) and third quarter (Figure 3.9). Seeps have not been observed to discharge in the drainage at the south property boundary where Unit Cc1 outcrops have been observed on VLF property (King County, 2007). Investigations to date have not included a survey of potential groundwater discharge points from Unit C in the drainage located south of the VLF (Figure 2.1). Based on review of existing geologic information, these potential points of discharge are inferred to be located on private property in the area of Southwest Cemetery Road. A seep assessment in this south drainage area has been identified as a data gap to be addressed in the FS, pending access from property owners.

Monitoring well MW-20 is the most upgradient monitoring well completed in Unit Cc2. This well is upgradient of the South Slope Area and slightly crossgradient of the 2001 closure area. Monitoring wells MW-33, MW-35, and the West Hillslope springs (24S and 18S) are downgradient of the South Slope Area, while monitoring wells MW-2 and MW-21 lie crossgradient from the South Slope Area (Figure 3.8).

Groundwater potentiometric surface maps for Unit D from the first and third quarters of 2019 are presented on Figures 3.10 and 3.11, respectively. Groundwater flow direction in Unit D is strongly influenced by high water levels in MW-34 and MW-7 which create a groundwater divide in the Unit D aquifer beneath the 2001 closure area. Groundwater flow is generally southerly to the south of the divide and northwesterly to northeasterly north of the divide. The groundwater gradient south of the divide is less steep than that north of the divide. This variation in groundwater gradient may be related to a permeability change within Unit D or other stratigraphic controls. Monitoring well MW-7 consistently exhibits the highest water levels in Unit D and is upgradient of the landfill refuse. Unit D wells downgradient from the landfill include MW-12 to the south and MW-19, MW-26, MW-28, MW-29, and MW-25 to the north. Monitoring well MW-34 is cross-gradient from the refuse.

The screen interval of MW-27 was initially interpreted as a Unit D well but was reinterpreted to be screened within Unit Cc3, based on the continuous soil core collected from adjacent well MW-34. MW-27 had a pea gravel backfill section beneath the screen interval that extended into Unit D. Because of this potential interconnection of Units Cc3 and D, monitoring well MW-27 was decommissioned in July 2016 by overdrilling using sonic drilling methods. A memorandum documenting the decommissioning is included in Appendix B.

Recharge

Hydrographs for selected monitoring wells completed in Units Cc1, Cc2, Cc3, and D are shown on Figure 3.12 along with precipitation data from King County's West Judd Creek Rain Gage (28Y). The lag time between precipitation events and response in groundwater elevation ranges from 4 weeks (Unit Cc1) to 8 weeks (deeper Unit D wells). Lowest groundwater elevations typically occur in November following relatively dry summer/fall months, and maximum groundwater elevations occur in March/April. As shown on Figure 3.12, MW-3 completed in Unit Cc1 was likely dry from July until late November 2015. The response time in the Cc1 aquifer may be less than 4 weeks as shown on Figure 3.12 as there is a time lag between water level rise in the aquifer in response to the beginning of the wet-season precipitation and the water level response observed in monitoring well MW-3, which is completed higher than the base of Unit Cc1.

It is further hypothesized, based on seasonally dry conditions in most of the Unit Cc1 wells and the hydrograph presented on Figure 3.12, that the residence time of groundwater in this unit is short and that the presence of groundwater in Unit Cc1 wells is likely a transient reflection of downward migration of recharge.

The hydrographs indicate that recharge diminishes with increasing depth. The greatest water level increase during the 2016 wet season, depicted on Figure 3.12, occurred in Unit Cc1 with over 5 feet of water level increase. Seasonal water level rise in the deeper aquifers was generally less than 2 feet. Moreover, the magnitude of the seasonal fluctuation declines with depth, with Unit D aquifer showing the smallest wet season water level increase.

Superimposed on the water level trends are short-duration fluctuations attributed to variations in barometric pressure. Barometric pressure effects are typically observed in confined aquifers. Thus, the water level data suggest some degree of confinement for Unit Cc2 and deeper aquifers and an unconfined condition for Unit Cc1. The confinement revealed by the barometric affects was not apparent based on evaluation of water levels relative to the top of aquifer. Under confining conditions, changes in barometric pressure cause inverse changes in water levels in the confined aquifer.

Hydraulic Conductivity and Groundwater Velocity

Aquifer testing was completed to estimate hydraulic conductivity and update groundwater flow velocity estimates for the principal water-bearing units. Hydraulic conductivity estimates are compiled in Table 3.2. Groundwater flow velocity estimates are provided in Table 3.3.

Estimated hydraulic conductivity for Unit Cc1 ranges from 0.43 to 8.79 feet per day, with a geometric mean of 2.69 feet per day. However, because this unit is generally dry seasonally, horizontal migration of groundwater is expected to be limited in Unit Cc1.

In Unit Cc2, estimated hydraulic conductivity ranges from 1.61 to 46.1 feet per day, with a geometric mean of 8.21 feet per day. Horizontal gradient is estimated at 0.014 to 0.024 (Figures 3.8 and 3.9). If effective porosity is assumed to be 0.20, the calculated groundwater velocity in Unit Cc2 property-wide is 0.11 to 5.5 feet per day, with an average of 0.78 feet per day. For the South Slope Area, groundwater velocity is calculated to be 0.11 to 1.7 feet per day, with an average of 0.46 feet per day. The springs discharging from the West Hillslope near the VLF property boundary are approximately 900 feet from the refuse source on the South Slope Area. Given this distance and estimated average velocity, the travel time from source to spring is approximately 1 to 22 years (5 years based on the average).

Estimated hydraulic conductivity for Unit Cc3 ranges from 3.53 to 23.04 feet per day, with a geometric mean of 11.6 feet per day. Insufficient data are available for this unit for the purpose of estimating horizontal gradient and therefore, groundwater velocity.

Unit D estimated hydraulic conductivity ranges from 4.4 to 46.1 feet per day, with a geometric mean of 10.2 feet per day. With a gradient of 0.02 south of the divide and an effective porosity of 0.20, the calculated groundwater velocity in Unit D south of the divide is 0.4 to 4.6 feet per day, with an average of 1 foot per day. With a gradient of 0.03 to 0.04 north of the divide and an effective porosity of 0.20, the calculated groundwater velocity in Unit D north of the divide is 0.7 to 9.2 feet per day, with an average of 1.8 feet per day.

3.5 Landfill Gas

LFG is generated at the VLF during decomposition of MSW. The LFG generation rate depends on many factors, for example:

- Volume – greater waste volume results in greater LFG generation rates.
- Age – LFG generation rates decrease with increasing age of waste.
- Waste type – LFG generation is greater for organic waste (such as food waste) than inert waste (such as concrete or fiberglass).

The primary components of LFG are methane and carbon dioxide. Methane is generated from anaerobic decomposition, while carbon dioxide is generated from aerobic and anaerobic decomposition. LFG also includes small concentrations of VOCs which may come from the waste itself (for example Freon from disposed refrigerators) or from decomposition (for example ketones from fat decomposition).

Methane is potentially explosive in air and is not to exceed the lower explosive limit in compliance gas probes (Code of the King County Board of Health, Section 10.09.050 and WAC 173-351-200 (4)). The lower explosive limit for methane is 5 percent by volume in air. While there is no regulatory criterion for carbon dioxide, it is also an indicator of LFG migration. Background carbon dioxide concentrations are due to naturally occurring soil respiration.

4 Previous Investigations

Hydrogeology, water quality, and environmental investigations have been conducted at the VLF since 1983, led by R.W. Beck and Associates and Sweet, Edwards and Associates (1984), Harper-Owes (1986), Harper-Owes, et al. (1988), CH2M HILL (1995, 1996), Berryman & Henigar et al. (2000, 2001), Berryman & Henigar and UES (2004, 2006a), King County (2010), and Aspect (2012). Figure 4.1 provides a visual representation of the investigation timeline within the context of landfilling and landfill closure activities. Table 4.1 lists historical explorations at the VLF and bibliographic references. KCSWD has sampled groundwater and seeps since 1986 and monitored LFG and leachate at the VLF since environmental monitoring infrastructure was first installed in approximately 1988.

The following sections provide a summary of the investigations completed at the VLF, organized by media (groundwater, surface water, LFG, and leachate). Findings of these investigations are presented in Section 6 to describe the nature and extent of contamination and Section 9 to support the conceptual site model. All exploration locations are depicted on Figure 4.2, including borings, test pits, probes, wells, and surface water sampling locations. VLF groundwater monitoring well locations are illustrated on Figure 4.3, color-coded by the aquifer monitored. Off-property groundwater and surface water sampling locations are mapped on Figure 4.4. On-property surface water sampling locations are shown on Figure 4.5.

4.1 Groundwater

The following sections document groundwater investigations that have been completed at the VLF. The monitoring well network is illustrated on Figure 4.3. Boring logs are provided in Appendix B.

4.1.1 Initial Characterizations

The first four groundwater monitoring wells at the landfill were installed in 1983. Piezometers P-1/1A/1B and P-2/2A, located within the refuse area on the east side, were decommissioned in 1988. Piezometers MW-13 (originally numbered P-3) and MW-24 (originally numbered P-4) were installed in 1992. MW-13 is now used as a monitoring well for water level measurements and geochemical sampling. MW-24 is used only for groundwater level monitoring (King County, 2011b).

Monitoring wells MW-1 through MW-4 were installed in 1983. Wells MW-5 and MW-6 were installed in 1986. These wells were installed in the early to mid-1980s as part of a site assessment completed to determine how to best bring the landfill into compliance with state and local solid waste disposal regulations. Wells MW-1, MW-5, and MW-6 have since been decommissioned (refer to Section 4.1.6 for details).

Eight additional monitoring wells (MW-7, MW-8, MW-9, MW-10, MW-11, MW-12, MW-14, and MW-19) were installed in summer 1995. MW-20 and MW-21 were installed in fall 1998 to further evaluate Unit Cc2 groundwater (King County, 2011b). Wells MW-11 and MW-14 have since been decommissioned (refer to Section 4.1.6 for details).

Four wells (MW-26 through MW-29) and one piezometer (MW-25) were installed during summer 2003 to expand the monitoring network. However, MW-28 has been dry since installation (King County, 2011b). Well MW-27 has since been decommissioned (refer to Section 4.1.6 for details).

4.1.2 West Hillslope Investigation

KCWLRD completed a hydrogeologic investigation focusing on the West Hillslope, west of the closed landfill area and west of Westside Highway. The scope of work included a reconnaissance of the West Hillslope to help design a stratigraphic model for the VLF (King County, 2006). This 2005 survey provided a better understanding of the spatial orientation of saturated geologic units that outcrop on the steep slope (King County, 2011a). A copy of the report is provided in Appendix C.5.

With a better understanding of where the Cc aquifers outcrop on the West Hillslope, the KCWLRD completed an extensive water sampling program assessing the nature and extent of contamination along the hillslope relative to upgradient VLF wells. Work included:

- Installation of wells MW-30 through MW-32 in hand-augered borings.
- Installation of weirs downgradient of seeps (SW-W4 through SW-W7).
- Water quality sampling of hillslope seeps and weirs and of existing VLF wells (Unit Cc2: MW-5D, MW-9, and MW-21; Unit D: MW-12, MW-19, and MW-27).

Findings and conclusions from that investigation (King County, 2011a) have been incorporated into this RI Report.

4.1.3 Landfill Gas and Leachate Effects on Groundwater

In 2005, an analysis of groundwater and leachate data was completed to determine whether LFG or leachate was the primary source of contamination in Unit Cc2 groundwater (Berryman & Henigar and UES, 2006b). Data from the period 1987 through 2005 on general water quality parameters and volatile organic compounds (VOCs) were used for the analysis. Unit Cc2 wells MW-2, MW-5D, and MW-21 represented impacted groundwater and well MW-20 represented background groundwater quality. Landfill gas data used in the evaluation was collected in October 2003. The findings of this investigation are discussed in Section 9.2 of this RI Report (Contaminants and Source Analysis).

4.1.4 South Hillslope Investigation

In 2007, KCWLRD completed a hydrogeologic study of the southern portion of the VLF to identify where the coarse-grained units of Unit C outcrop on the hillslope and if any saturated outcrops were present. The study was focused to the VLF property, not extending offsite to private property to the south.

The investigation included an array of 27 shallow pits (less than 2-feet deep) to complete a lithologic description. No chemical analytical sampling was completed in this investigation. Sample locations were located along the west property boundary starting west of the Leachate Lagoon area then southward to the property southwest corner and then continue along the south property boundary across the south drainage that connects to Judd Creek. Findings and conclusions from that investigation (King County, 2007) have been incorporated into this RI Report, primarily Section 3.4. A copy of the report is provided in Appendix C.6.

4.1.5 Monitoring Well Installation, MW-33 though MW-36

Four groundwater monitoring wells (MW-33 through MW-36) were installed in spring 2015. Sonic drilling methods were used for these installations and provided continuous soil samples to aid in the refinement of the hydrostratigraphy. MW-33 was drilled at the South Slope Area of the landfill through the unlined refuse zone, targeting Unit Cc2. MW-34 was drilled into the Unit D near MW-27 to investigate anomalous groundwater elevations in MW-27. MW-35 was installed in Unit Cc2 as a replacement for MW-5D, which was decommissioned (see Section 4.1.6). Since MW-35 was installed to replace MW-5D, these wells are herein referred to as a single well “MW-5D/MW-35” for data analysis purposes, but they are not contemporaneous. MW-36 was installed in Unit Cc3 as a replacement for MW-14, which was decommissioned (see Section 4.1.6). New monitoring wells MW-33 through MW-36 were developed following installation.

4.1.6 Monitoring Well Decommissioning

Piezometers P-1/1A/1B and P-2/2A, located within the refuse area on the east side, were decommissioned in 1988. MW-11 was damaged in the February 2001 Nisqually earthquake and was not sampled after that event. MW-6S and MW-6D were also damaged during the earthquake. These wells were decommissioned in 2003 and no new wells were installed to replace them (King County, 2011b).

Work conducted in spring 2015 included decommissioning MW-1, MW-5S/5D and MW-14. Having not yielded groundwater samples for several years, MW-1 was not a useful monitoring well. MW-5S/5D was completed in 1986 but did not meet current monitoring well standards and was subsequently replaced by MW-35. Therefore, both wells were over-drilled with a sonic drill rig and decommissioned by sealing the borehole with bentonite chips.

MW-14 was decommissioned because the dedicated pump got stuck above the screen. KCSWD obtained video footage downhole above the pump and attempted—unsuccessfully—to loosen the pump. Drilling subcontractors were also unsuccessful in their attempts to remove the pump. MW-14 was over-drilled with a sonic drill rig and decommissioned by sealing the borehole with bentonite slurry.

MW-27 was decommissioned in 2016. The memorandum documenting the MW-27 decommissioning is included in Appendix B.

4.1.7 2015 Monitoring Well Redevelopment and Maintenance

In preparation for the aquifer hydraulic testing, existing monitoring wells were redeveloped while the drilling contractor was mobilized at the landfill for the installation of MW-33 through MW-36 in spring 2015. The existing monitoring wells that were redeveloped included: MW-2, MW-3, MW-4, MW-7, MW-8, MW-9, MW-10, MW-12, MW-13, MW-19, MW-20, MW-21, MW-24, MW-25, MW-26, MW-27, and MW-29.

Observations during redevelopment indicate improved connection between the well and the surrounding aquifer. Pumps and tubing showed signs of biofouling, which was also, presumably, on the inside of the well screen. Surging with a tight-fitting surge block removed biofouling from the well screen, and the pump screens were cleaned with non-phosphate detergent (Alconox®) scrub, potable water rinse, and distilled water rinse. Deteriorated pump tubing was replaced in MW-7, MW-8, MW-9, MW-10, and MW-19. Pump bladders were replaced in wells MW-8, MW-9, MW-10, and MW-12.

4.1.8 Downhole Monitoring Well Geophysical Survey

A geophysical survey of MW-7, MW-19, and MW-27 was conducted on February 5, 2015 (Duoos, 2015). A copy of the report is provided in Appendix C. The geophysical survey was conducted using natural gamma and electromagnetic (EM) induction logging to evaluate down hole stratigraphy at each well location. Stratigraphic units across the VLF were correlated to the geophysical survey findings to further refine the hydrogeological conceptual model. In summary, the geophysical survey found:

- Natural gamma logs are not reliable indicators of silt or clay at the VLF, likely due to the overburden materials in which the wells are installed and the bentonite grout used to fill the annulus of the wells.
- EM conductivity responded well to the stratigraphy and there appears to be good correlation with the material descriptions in the geologic boring logs. In general, shallow sand and gravels had lower EM conductivity than deeper silt layers, and the fat clays correlated with the highest conductivity values.
- Steel centralizers used in well construction adversely affected the EM responses. The steel centralizers are identifiable on the EM conductivity log by the bands of high magnitude erratic response and appear approximately every 50 feet in MW-7 and MW-19.

4.1.9 Aquifer Hydraulic Testing

Eleven wells in Units Cc1, Cc2, Cc3, and D were selected for aquifer hydraulic testing to estimate hydraulic conductivity and to update groundwater flow velocity estimates. For Unit Cc2, groundwater flow velocities calculated from previous hydraulic conductivity estimates (mean value of ~0.002 ft/day) are inconsistent with facility impacts observed in the West Hillslope springs. Travel time calculated from the previous conductivity data is on the order of 500 years but the earliest waste placement occurred about 100 years ago.

The new tests were conducted to confirm previous work and refine groundwater flow velocities in Unit Cc2. Hydraulic conductivity testing was conducted on MW-2, MW-13, MW-20, MW-21, MW-24, MW-25, MW-26, MW-33, MW-34, MW-35, and MW-36. Two of the existing wells initially selected for testing (MW-1 and MW-5S) were dry and were therefore not tested. Results of the aquifer hydraulic testing and comparison to previous results have been integrated into Section 3.4.2 and are compiled in Appendix D.

The completion of Unit D well MW-25 includes a 3-inch-diameter screen inserted into a 4-inch-diameter screen that was broken during well installation. Because of the abnormal well completion, hydraulic conductivity test results on MW-25 are not representative of the aquifer but show that flow is restricted from entering the well. For this reason, results from MW-25 were excluded when calculating Unit D hydraulic conductivity estimates discussed in Section 3.4.2.

4.1.10 Continuous Water Level Measurements

In 2015/2016, nine wells, in Units Cc1, Cc2, Cc3, and D, were instrumented with a Schlumberger Water Services Micro-Diver pressure transducer (Diver) to measure water levels over time. Divers were installed in the following wells:

- Unit Cc1 – MW-3
- Unit Cc2 – MW-2, MW-9, MW-20, MW-33, MW-35
- Unit Cc3 – MW-8
- Unit D – MW-12, MW-34

Divers record water pressure with a range of 10 meters and an accuracy of ± 1.0 cm of water. The Divers were set to record water levels in the well every 15 minutes, and the water levels were adjusted for barometric pressure using a Schlumberger Water Services Baro-Diver installed in the well casing of MW-12. Data from King County's West Judd Creek Rain Gage (28Y) were used to compare precipitation to water level trends. Water levels measured with the transducers were consistent with the quarterly water level measurements collected by the KCSWD, as presented in Appendix E. Results have been incorporated into Section 3.4.2.

4.1.11 Geochemical Evaluations

In 2015/2016, Anchor QEA (2017) completed a geochemical investigation with two primary objectives:

- Identify the transport pathways for VOCs detected in Unit Cc2 (e.g., via infiltration of landfill leachate or interaction with LFG).
- Evaluate mobilization of metals and attenuation of VOCs and metals in groundwater downgradient of the landfill.

Selected wells (MW-2, MW-20, MW-21, MW-33, and MW-35) and weirs (SW-W1, SW-W2, and SW-W3; see seep locations on Figure 1 in Appendix C.1[1]) were sampled in September 2015 (dry season) and February 2016 (wet season). Samples were also collected from the leachate system during both sampling events. Analyses included isotopic measurements of carbon, oxygen, hydrogen, sulfur, arsenic III/V speciation, and atmospheric chlorofluorocarbons.

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[1] Anchor QEA cited chloride concentrations at "SW-2", which is inferred to be weir SW-W2 based on location coordinates presented in the report. All weirs referenced in the Anchor study as SW-1, SW-2, and SW-3 are inferred to represent the weirs labeled by KCSWD as SW-W1, SW-W2, and SW-W3, respectively.

Details and results are included in Appendix C. A summary of the findings to the primary objectives is provided in Section 9.2 (Contaminants and Source Analysis).

4.1.12 Groundwater Sampling

KCSWD performs routine groundwater monitoring to meet the landfill's permit requirement for detection monitoring. The monitoring is conducted in accordance with the "Environmental Monitoring Sampling and Analysis Plan and Quality Assurance Project Plan for Vashon Island Closed Landfill" (King County, 2016). The following tasks are completed by KCSWD:

- Quarterly groundwater sampling for Appendix I and II analytes plus dichlorodifluoromethane, as per detection monitoring requirements set forth in WAC 173-351-430 and WAC 173-351-990.
- Periodic[2] groundwater sampling for Appendix III analytes defined by WAC 175-351-440 as a condition of assessment monitoring.
- Quarterly water level measurements to assess groundwater flow conditions.

Results of the routine groundwater monitoring are presented in Section 6.1.

4.2 Refuse Extent Investigations

In 2018, investigations were completed to meet two objectives:

- Define the extent of refuse beyond the main landfill refuse footprint in the West Perimeter Road and South Slope Area.
- Further characterize LFG within and adjacent to these delineated areas, including the source of LFG currently being extracted in the South Slope Area.

Results from a surface geophysical investigation (Aspect and Duoos, 2018) were used to refine the locations of the borings completed in April 2018—B-6 through B-12 and LFG probe installations TP-7 through TP-11D.[3] Findings from this investigation have been included in the discussion on the extent of refuse (Section 2.2.1.1). While LFG characterization is ongoing, investigations completed to date are discussed in Section 4.4 (Landfill Gas).

4.3 Surface Water

This section describes the VLF surface water management and monitoring systems.

4.3.1 Surface Water Management System

Prior to 1979, the surface water management system at the VLF consisted of ditches, culverts, and natural drainage paths, with surface water runoff flowing to the southern

[2] Prior to 2005, groundwater samples were analyzed for Appendix III analytes annual. Post-2005, this list of analytes is only analyzed periodically (e.g. 2011, 2012, 2018, and 2019).

[3] Temporary probes TP-7 through TP-11D were originally called VTP-7 through VTP-11D.

extent of the landfill and off-property via an unnamed tributary to Judd Creek. After a 1986 storm caused off-property deposition of sediment in the unnamed tributary, a sediment control pond (South Siltation Pond) and stormwater detention pond (South Detention Pond) were constructed in the ravine at the southern VLF property boundary. During subsequent developments, additional surface water conveyance and control infrastructure were built, including leachate control facilities, a landfill liner, the transfer station, and other stormwater improvements (Berryman & Henigar, 1999).

Surface water generated at the VLF continues to discharge off property to the south via the unnamed tributary to Judd Creek. The following infrastructure, shown on Figure 2.5, provides detention and conveyance to the outfall (SW-B).

Flows generated from former borrow material areas to the north of the VLF and from the transfer station are conveyed to a series of four unlined ponds that discharge through a conveyance pipe to the outfall. An overflow structure is included in the conveyance pipe at the South Detention Pond.

Surface water from the capped landfill, asphalt-lined ditches around the closed landfill, and the area east of the capped landfill are directed to a lined detention pond (East Pond) southeast of the refuse area. Flow from the East Pond is also directed to the outfall at the southern end of the VLF.

All other surface water generated at the VLF consists of overland flow from the South Slope Area to the South Siltation Pond or runoff from the VLF entry area that is collected in surface ditches and directed to the south ponds.

A 2012 investigation of the VLF surface water management system (Aspect et al., 2012) yielded three recommendations for improvement:

- South Siltation Pond – Convert the pond from a sediment control feature (no longer required because landfilling had ceased) to a detention pond. Design the detention pond to prevent permanent standing water and associated mosquito-related public health concerns.

- Northwest Landfill Drainage Improvements – Maintain the grass-lined ditches to prevent low spots and ponding due to settlement in an area above an unlined portion of the landfill.

- Asphalt Ditch Maintenance – Remove vegetation and debris from the asphalt-lined ditches surrounding the capped landfill to maintain clear flow paths and prevent ponding.

4.3.2 Surface Water Monitoring

Surface water has historically been routinely monitored at five locations on the VLF property (Figure 4.5): one at the northeast corner (SW-D), one at the south end (SW-B) and three weirs on the West Hillslope (SW-W1, SW-W2, and SW-W3) west of Westside Highway SW.

Results of a 2012 site visit and evaluation of the existing surface water monitoring at the VLF (Aspect et al., 2012) are summarized in the following sections and discussed in Section 6.2 (Surface Water).

4.3.2.1 Borrow Area Stormwater Pond (SW-D)

Former surface water sample point SW-D was located at the outfall from the series of borrow area stormwater ponds. This sample location was monitored beginning in 2000 to provide water quality information for flows from the transfer station and borrow areas prior to mixing with other surface water sources. Sampling of this surface water location was discontinued in 2013.

4.3.2.2 Vashon Landfill Outfall (SW-B)

Combined surface water from the VLF is conveyed off-property to an unnamed tributary to Judd Creek. Former surface water sample location SW-B was located immediately upstream of the southern property boundary. Samples for SW-B were collected beginning in 1991 from a surface water conveyance structure and considered representative of the entire property. Sampling of this surface water location was discontinued in 2013.

4.3.2.3 West Hillslope

Groundwater springs along the West Hillslope west of Westside Highway SW produce surface water flows that discharge off-property. Surface water sampling on the West Hillslope began in 1992 and is conducted upstream of the west property boundary at weirs constructed downslope of the Unit Cc2 springs and seeps. Weirs SW-W1, SW-W2, and SW-W3 are currently monitored. Groundwater seeps along the West Hillslope (SW-S1 through SW-S6 and SW-24S) were periodically sampled from 2007 through 2010. An additional point, SW-E, added in 2012, is monitored in Robinwood Creek approximately 1,500 feet from the VLF property. Alternatives to improve sample collection of the West Hillslope spring flows were provided (Aspect et al., 2012). These alternatives will be further evaluated in the FS.

4.4 Landfill Gas

This section describes previous and ongoing investigations of LFG migration control and collection system inspections and improvements, and LFG monitoring activities.

4.4.1 Landfill Gas Probe Installations

Compliance gas probes to evaluate LFG migration control were installed between 1986 and 1995 in soils around the refuse perimeter, near the property boundary. Temporary gas probes were installed between 2014 and 2018 in or near refuse to assess the performance of the LFG collection system. Construction details are tallied in Table 4.2 and probe locations are shown on Figure 2.7.

4.4.1.1 Compliance Probes

In 1986, probes P-1 and P-2 were installed, with the top of screen interval at approximately 3 and 5 feet below ground surface (bgs), respectively. Probes GP-05 and GP-06 were also installed, with the top of screen approximately 3 feet bgs. GP-05 was installed within the same borehole as monitoring well MW-5S/D and GP-06 was installed within the same borehole as monitoring well MW-6S/D. Although all four probes had

2-foot-long screens, the filter pack intervals extended below the gas probes to depths ranging from approximately 85 to 116 feet bgs.

In 1992, LFG probes GP001 and GP002 were installed, with the top of screen approximately 20 and 25 feet bgs, respectively, and the bottom of screen at approximately 30 feet bgs. Each probes' filter pack extended 6 feet below the bottom of screen.

In 1995, eight LFG probe sets were installed (originally named NP-1 through NP-8; currently named GP-01 through GP-08), each with three completion intervals across the vadose zone. Depending on location, the tops of screen were set 10 to 12 feet bgs for the shallow probes, 30 to 49 feet bgs for the intermediate probes, and 65 to 95 feet bgs for the deep probes.

Starting in 2010, monitoring wells MW-13 and MW-24 have been monitored routinely for LFG concentrations, and have indicated no LFG near the water table (see Section 6.3). These groundwater monitoring wells are located next to gas probe set GP-3.

4.4.1.2 Temporary Probes

In 2014, temporary probes TP-1S, TP-2S, and TP-2D were installed to assess LFG conditions inside the property boundary. (These temporary probes have been renamed "TP-", but were originally named "VTP-"). TP-1S was installed in native soils west of the EF-3 horizontal collector to assess potential LFG migration (location not shown on Figure 2.7). Its screen interval was typically submerged by perched groundwater, and no LFG was measured; this probe was decommissioned in 2016. TP-1D was installed to a greater depth in the underlying advance outwash unit to assess the extent of methane at that location. TP-2S and TP-2D were installed in the South Slope Area, the former in the gravel gas collection layer above refuse and the latter in refuse.

In August 2016, two temporary probe pairs (TP-3S/TP-3D and TP-4S/TP-4D) were installed to supplement existing probes TP-2S and TP-2D, assess the extent of LFG migration, and monitor the performance of LFG extraction well GW-9 at controlling LFG migration during an "influence test" conducted from September 14, 2016, through March 1, 2017. Shallow probes (TP-3S and TP-4S) were installed within the waste, and deep probes (TP-3D and TP-4D) were installed in native soils below the waste. Installation of extraction well GW-9 is discussed in Section 4.4.2.2.

In January 2017, two additional temporary probe pairs (TP-5S/TP-5D, and TP-6S /TP-6D) were installed during the influence test to further investigate the extent of refuse, assess the potential for methane migration (methane is an indicator of LFG), and help determine the radius of influence of GW-9.

In April 2018, four temporary probes and one temporary probe pair (TP-7, TP-8, TP-9, TP-10, and TP-11S/TP-11D) were installed during an investigation of refuse extent. Temporary probes TP-7 through TP-10 were installed in the South Slope Area, and TP-11S and TP-11D were installed outside the northwest corner of the perimeter road.

4.4.2 Gas Collection System Inspections and Improvements

Since closure of the VLF in 2001, LFG collection system performance has been evaluated through camera surveys, blockage removals, and satellite gas extraction well installation.

4.4.2.1 Camera Survey and Blockage Removal

A camera survey was conducted in June 2015 to assess potential blockages within laterals EF-1, EF-2, EF-3, and T-2 (Herrera Environmental Consultants [HEC], 2015). These horizontal collectors were characterized by lower flow rates and LFG concentrations than anticipated, indicating potential blockage. Although limited gravel debris was found inside the horizontal collectors, no blockages were identified (HEC, 2015). Relative to the design drawings, the location of EF-1 appeared to be shifted approximately 10 feet to the south, and EF-2 appeared to be shifted approximately 30 feet to the west and not beneath the landfill liner (HEC, 2015). The functionality of lateral EF-1 was thought to be compromised, as excavation inspection and the camera survey revealed fine-grained material in the pipe-bedding, which could limit or impede vacuum influence through the material.

4.4.2.2 Extraction Well Installation

In August 2016, a vertical LFG extraction well (GW-9) was installed to initiate LFG collection in the South Slope Area (Figure 2.7). GW-9 was completed across the refuse, except for the bottom seal and the top annular seal. The aboveground wellhead was connected to the active LFG collection system with an aboveground lateral. A valved monitoring assembly was installed to adjust flow, and to measure flow, gas concentrations, and static pressure. GW-9 has been in operation since September 2016.

In June 2018, two vertical LFG extraction wells (GW-10 and GW-11) were installed to supplement LFG collection in the South Slope Area. In September 2018, GW-10 and GW-11 were incorporated into the active LFG collection system, the activities for which included a well location survey, connection to the active LFG collection system, and influence testing. GW-10 and GW-11 have been in operation since September 2018.

Condensate management at GW-9, GW-10, and GW-11 began in January 2019, and GW-11 has been pumped dry each month since. However, the water levels in GW-11 were not significantly affected by condensate management, which indicates a secondary source of water recharge to this extraction well. Water in GW-11 has fully submerged the screen seasonally during winter and spring months, limiting LFG collection at these times. During summer and fall months, a portion of the screen is unsaturated and the well is able to collect LFG.

4.4.3 Landfill Gas Monitoring

KCSWD performs routine LFG monitoring to meet the landfill’s permit requirement. Current LFG compliance probe monitoring (see Figure 2.7) is conducted quarterly in accordance with the “Environmental Monitoring Sampling and Analysis Plan and Quality Assurance Project Plan for Vashon Island Closed Landfill” (King County, 2016).

Routine LFG operations monitoring is conducted in accordance with the “Vashon Island Closed Landfill Plan of Operations and Post-Closure Plan” (Berryman & Henigar, 2005).

KCSWD monitors the LFG collection system locations (see Figure 2.7) on a monthly basis for LFG concentrations (methane, carbon dioxide, and oxygen), temperature, static pressure, and flow rate.

Influence testing of extraction wells GW-9, GW-10, and GW-11 included monitoring temporary gas probes in the South Slope Area and was conducted in accordance with work plans (Herrera, 2016; Aspect, 2018a). Findings and recommendations were provided in influence test reports (Aspect, 2017b; Aspect and Herrera, 2019). KCSWD continues to monitor gas extraction wells and temporary probes in the South Slope Area on a monthly basis.

The LFG monitoring data were analyzed and summarized in "Landfill Gas System Evaluation Summary Report" (Aspect and Herrera, 2019; Appendix H), and are presented in Section 6.3.

4.5 Leachate Management System

Leachate evaluations at the VLF fall into two categories: those completed prior to installation of the leachate collection system and those completed after. Both sets of evaluation assessed the potential impacts and influence of VLF leachate on surrounding groundwater and surface water, as summarized in the following sections.

4.5.1 Evaluations Prior to Leachate System Installation

The most relevant pre-1988 evaluations are listed below with abbreviated summaries.

- "Groundwater Geology/Quality Investigations for the Rural Landfills" (R.W. Beck and Associates and Sweet, Edward and Associates, 1984) – This investigation included installation of four monitoring wells, a groundwater sampling and analysis program, and identification of potential impacts. Results were inconclusive regarding the influence of solid waste disposal activities on groundwater. Recommended measures included establishing routine monitoring and further investigation into impacts on surface water, particularly Judd Creek.
- "Technical Memorandum, Vashon Landfill Leachate Control, Task 1A: Conceptual Alternatives Development" (Harper-Owes, 1985) – This memorandum recommended leachate control alternatives, which were further investigated and superseded by the 1986 Task 1B Technical Memorandum (next bullet).
- "Technical Memorandum, Vashon Leachate Control, Task 1B: Geotechnical and Water Quality Investigations" (Harper-Owes, 1986b) – This memorandum reported additional investigations that resulted in the following recommendations for future leachate control:
  - Provide facilities to minimize leachate migration (e.g., interceptor drains, liner/cover systems).
  - Close the southern area and continue operation of the northern area.
  - Monitor the West Hillslope springs.

- Install a collection system at the springs, initiate remedial action for impacted wells if any are identified, or both.

4.5.2 Evaluations After Leachate System Installation

Installation of the leachate collection system and associated lining and cover systems during Phase 1 landfill closure led to a significant change in leachate generation and flow. The evaluations conducted after leachate system installation are listed below with abbreviated summaries.

- "Vashon Island Landfill Hydrogeologic Report" (Berryman & Henigar et al., 2000) – This report was written to satisfy requirements of WAC 173-351-490 and includes a water balance and water quality analysis.
  - The lined portions of the landfill "are not relevant [for the water balance] … as they assume liner competence and therefore generate negligible values of infiltration and leachate generation."
  - A small portion of refuse area (i.e., the South Slope Area of the VLF) is included in the water balance, even though it is served by an engineered leachate collection system draining to pump station PS-2.
  - Groundwater chemistry data indicated that leachate from the VLF was not impacting either the regional aquifer or the perched groundwater beneath the VLF. Impacts may have occurred prior to the Phase 1 lining, cover, and leachate collection system improvements.
  - Leachate was not currently impacting stormwater discharging from the VLF.
- "Vashon Island Landfill Hydrogeologic Report Update" (Berryman & Henigar and UES, 2004) – This update to the 2000 VLF Hydrogeologic Report documents investigations performed between 2000 and 2004. Groundwater monitoring recommendations are updated, but earlier conclusions about potential leachate impacts on groundwater remain unchanged.
- "Vashon Island Closed Landfill Environmental Evaluation" (Berryman & Henigar and UES, 2006a) – The purposes of this evaluation were to summarize the existing environmental control systems, inventory potential source areas for LFG and leachate, and review the effects of these potential sources on surface water and groundwater.
  - Two likely sources were identified, each an unlined refuse area without a geomembrane cover: the northwest portion of the waste placement area and the southern portion of the VLF. Neither source area was identified as producing significant leachate volume.
  - Two recommendations were provided to further reduce potential leachate impacts:

  - Repair west perimeter ditches to improve surface water drainage and limit infiltration.
  - Improve the cover on the South Slope Area.

- "Vashon Island Closed Landfill: Potential Effects of Landfill Gas and Leachate on Vashon Landfill Groundwater and Springs" (Berryman & Henigar and UES, 2006b) – This investigation concludes that while leachate may have been a dominant factor influencing groundwater and spring quality in the past, its influence appears to have become minimal. LFG appears to have been the dominant factor controlling the water quality characteristics in recent years.

- "Vashon Island Closed Landfill: Environmental Investigations, Monitoring, and Remediation Services" (Aspect et al., 2012) – The purposes of this evaluation of the environmental monitoring system at the VLF were to further refine groundwater flow paths and LFG and leachate source areas, and to recommend improvements for environmental monitoring. The leachate portion of the report focuses in the South Slope Area and source sampling. Two modifications to leachate sample collection were recommended:
  - Add a sample location at pump station PS-2.
  - Revise the sample collection protocol at the leachate vault (sample point LVB) to collect leachate directly from the leachate pipes.

- "Vashon Island Landfill Leachate System Flow Characterization" (BHC, 2014; see Appendix C) – This document identifies primary contributors to leachate constituent loading by source and majority source of flow (direct precipitation on the Leachate Lagoon accounts for 46 percent of total flow). Three options were offered to reduce the frequency and cost of leachate hauling: discharge to the Vashon Island wastewater treatment plant, on-site treatment, and installation of a cover for the Leachate Lagoon.

4.5.3 Leachate Monitoring

In accordance with the "Environmental Monitoring Sampling and Analysis Plan and Quality Assurance Project Plan for Vashon Island Closed Landfill" (King County, 2016), KCSWD routinely monitors leachate to meet the landfill's permit requirement for detection monitoring. Leachate monitoring is conducted quarterly, and findings are reported quarterly. Results of the routine leachate monitoring are presented in Section 6.4 (Leachate).

4.6 Landfill Cover System

The landfill cover system has been evaluated on multiple occasions. These evaluations include routine inspections by KCSWD Operations staff, investigations of the leachate and LFG systems, and settlement surveys. Two investigations that included cover system evaluations are summarized below:

- "Vashon Island Closed Landfill Environmental Evaluation" (Berryman & Henigar and UES, 2006a) – Areas containing refuse outside of the landfill cap were identified. Improvements to the cover system in the South Slope Area were recommended as a method of controlling sources of LFG and leachate.

- "Vashon Island Landfill Site Visit: Site Visit Report and Photo Log" (Aspect et al., 2011) – Based on visual observations, the cover appeared to be in good condition, with no indication of differential settlement or a compromised cover system.

Landfill settlement surveys at 29 permanently established points across the cover were conducted in June 2017 as a baseline event, again in December 2017, and in August 2019. These surveys were conducted to comply with Ecology (2011) guidelines recommending surveys of fixed points at least 2 years apart to assess landfill settlement, whether during or after the post-closure period (WAC173-304-100(59)). At the time this report was written, the landfill had not reached the end of its 30-year post-closure period. Final results of the settlement survey program will be presented under separate report.

5 Proposed Preliminary Cleanup Levels

This section identifies potentially applicable environmental regulations and PCULs for media, potential receptors that may require protection, and potential exposure pathways which may require protection per environmental regulations. In Section 6, chemical concentrations detected in the VLF area are compared to PCULs to identify COCs.

5.1 Potentially Applicable Regulatory Requirements

The following potentially applicable or relevant and appropriate requirements (ARARs) based on local, state, and federal laws apply to the VLF:

- Washington Model Toxics Control Act (MTCA, WAC 173-340).
- Washington State statute on Chemical Contaminants and Water Quality (Chapter 70.142 RCW), Washington State statute on Water Pollution Control (Chapter 90.48 RCW), and implementing regulations (Water Quality for Surface Waters, WAC 173-201A).
- Washington State primary maximum contaminant levels (MCLs) for drinking water (WAC 246-290-310).
- Clean Water Act (CWA) (33 United States Code [USC] Section 1251 et seq.), including National Recommended Water Quality Criteria (NRWQC) for protection of human health and aquatic life and Washington State-specific human health criteria (water and organisms) promulgated by the U.S. Environmental Protection Agency (EPA) under Section 303(c) (EPA, 2016).[4]
- Criteria for Municipal Solid Waste Landfills (WAC 173-351), landfill operation and closure requirements.
- Resource Conservation and Recovery Act (RCRA) and Subtitle C regulations, to the extent that hazardous wastes are discovered during the remedial action.
- Washington Hazardous Waste Management Act and Dangerous Waste regulations (70.105 RCW and WAC 173-303), to the extent that dangerous wastes, as defined under these regulations, are discovered during any remedial action.
- Federal, State, and Local air quality laws and regulations (Clean Air Act 42 USC 7401 et seq.; 40 CFR 50; 70.94 RCW; WAC 173-400; WAC 173-460; Regulations I and III of the Puget Sound Clean Air Agency) to the extent that air emissions are generated during interim measures and long-term remedies (i.e., LFG flares, soil vapor extraction, and vapor mitigation).

[4] On July 23, 2019, the EPA proposed a rule to withdraw federal water quality standards for certain human health criteria promulgated in 2016. These 2016 human health CWA criteria remain ARARs until they are removed from the Federal Register.

- King County's Construction Standards for Methane Control, Title 10, Board of Health Solid Waste Regulations, 10.09.060, detailing requirements for construction to prevent methane migration on or within 1,000 feet of a landfill that generates methane at or above its lower explosive limit.

5.2 Applicable or Relevant and Appropriate Requirements for Development of Preliminary Cleanup Levels

MTCA relies on a risk-based evaluation of potential human health and environmental exposures to COCs. Part of the process includes development of cleanup standards, which consist of preliminary cleanup levels with a chemical- and medium-specific location where the PCUL must be met. These locations are known as "points of compliance" (POC) and by MTCA definition are throughout the site. MTCA allows for establishing conditional POC if it can be demonstrated that it is not practicable to meet PCULs throughout the site (173-340-720 through -760 WAC); however, the conditional POC cannot extend beyond the property boundary.

The PCUL for a given constituent in soil, groundwater, surface water, or air must be at least as stringent as established state or federal standards, if available, or other requirements (i.e., ARARs) developed for human health and environmental protection. If a state or federal standard is available, that ARAR is evaluated to ensure that it is protective under MTCA. If the ARAR is not protective, the PCUL is adjusted to ensure its protectiveness.

The PCUL for one medium must also be protective of the beneficial uses of other affected media. PCUL development, as outlined in WAC 173-340-720 (groundwater), -730 (surface water), -740 (soil), and -750 (air), includes specific rules for evaluating cross-media protectiveness.

MTCA and Water Quality Standards for Surface Waters (WAC 173-201A) were of primary consideration in developing PCULs for the VLF. Washington State freshwater surface water standards (WAC 173-201A) are considered potentially applicable. Federal surface water criteria under the CWA and NTR are also considered potentially applicable.

Landfill closure and post-closure requirements in WAC 173-351 were considered during development and evaluation of cleanup standards. The post-closure period lasts 30 years, or longer, if necessary for the facility to stabilize (i.e., no longer a threat to human health or the environment at the point of exposure). During this time, monitoring of groundwater, surface water, and LFG is required, as is maintenance of the facility, facility structures, and monitoring systems. Constituents for which detection monitoring samples must be analyzed are listed in Criteria for Municipal Solid Waste Landfills (WAC 173-351), but modifications are possible if certain requirements specified in WAC 173-351-450 are met. Per *Criteria for Municipal Solid Waste Landfills* (WAC 173-351), the POC must be located no more than 150 meters (492 feet) from the boundary of the waste management unit.

RCRA Subtitle C and Washington state Dangerous Waste regulations are not expected to apply unless dangerous wastes as defined under these regulations are discovered or generated during the remedial action.

5.3 Potential Exposure Pathways

According to MTCA, an exposure pathway is: "…*the path a hazardous substance takes or could take from a source to an exposed organism. An exposure pathway describes the mechanism by which an individual or population is exposed or has the potential to be exposed to hazardous substances at or originating from a site.*"

Listed by media, the potential current and future exposure pathways for both human and ecological receptors at the VLF are:

Groundwater:

- Direct human contact with impacted groundwater.
- Human ingestion of impacted groundwater.
- Human inhalation resulting from soil vapor discharge and intrusion to indoor and ambient air; soil vapor caused by volatilization of VOCs in shallow groundwater has the potential to migrate.
- Groundwater discharge to surface water (see surface water pathway below).

Surface water:

- Discharge of impacted groundwater to surface water.
- Direct human contact with impacted surface water.
- Direct exposure of ecological receptors (aquatic and terrestrial) to impacted surface water.
- Human consumption of aquatic organisms exposed to impacted surface water.

Landfill gas:

- Inhalation by occupants of current and future structures of indoor air impacted—via vapor intrusion—by VOCs originating from fugitive LFG.
- Direct human contact from explosions of fugitive LFG.
- Human inhalation of air impacted by fugitive LFG vapors.
- Fugitive landfill gas discharge to groundwater (see groundwater pathway above).

Leachate:

- Human contact with fugitive leachate.
- Fugitive leachate discharge to groundwater (see groundwater pathway above).

Refuse:

- Direct human contact by below-ground workers to shallow refuse.
- Direct contact by burrowing terrestrial organisms to shallow refuse.

Soil:

- Direct contact and ingestion by terrestrial organisms (e.g. plants, soil invertebrates, birds, and mammals) and burrowing terrestrial organisms (e.g. voles) into soil.
- Direct contact by humans (e.g., worker exposure of excavated soils).

Biotic uptake (plants/prey):

- Ingestion of plants and/or prey by burrowing terrestrial organisms (e.g. shrew and voles).

Direct exposure to air contaminated by LFG is addressed in the LFG discussion above and may occur during facility operations and maintenance activities, but these activities are performed with worker protection controls in place. These potential exposure pathways are evaluated in Section 9 (Conceptual Site Model).

5.4 Potential Receptors

Both human and ecological receptors may be exposed at the VLF:

- **Human Receptors:** for evaluation of human exposure, MTCA allows for consideration of various exposure scenarios depending on land use (173-340-708 WAC).
    - Residential occupants of structures off-property under current and potential future development scenarios.
    - VLF staff and future construction workers (above- and below-ground); KCSWD maintains internal controls to ensure that VLF staff receive appropriate training and monitoring. Off-property workers include commercial occupants of structures under current and future land use scenarios as well as above- and below-ground workers (e.g., utility and construction workers).
    - Recreational and other users of property adjacent to but outside of the VLF boundary; property access restrictions preclude recreational users on the VLF property as potential receptors.
- **Ecological Receptors:**
    - Aquatic organisms.
    - Terrestrial organisms including plants, soil invertebrates, birds, and mammals

These potential receptors are evaluated in Section 9 (Conceptual Site Model).

5.5 Development of Preliminary Cleanup Levels for Detected Chemicals

Preliminary cleanup levels (PCULs) for detected chemicals are described in the following sections. Final cleanup levels will be selected by Ecology and presented in the Cleanup Action Plan. The value and source of groundwater and surface water PCULs are presented in Table 5.1.

PCULs for soil were not developed for this site as it is a Site characterized by groundwater impacts. In accordance with WAC 173-340-747(3)(f), it is anticipated that compliance with soil cleanup levels will be demonstrated empirically based on compliance with the groundwater cleanup standards. Any applicable soil cleanup levels, if deemed necessary, will be presented in the FS and/or the Cleanup Action Plan.

5.5.1 Groundwater

PCUL values for groundwater were obtained from the following chemical-specific regulatory criteria for Washington State:

- State primary MCLs (WAC 246-290-310) protective of the human health ingestion pathway.
- Cleanup levels (WAC 173-340-740) protective of the human health ingestion pathway established by MTCA Method A (table values for 25 to 30 of the most common hazardous substances in soil or groundwater) or calculated by MTCA Method B (using standard or generic default assumptions).
- Surface water cleanup standards as detailed in the next section.

Per MTCA, groundwater PCULs shall be based on estimates of the highest beneficial use. For most sites, including the VLF, use of groundwater as a source of drinking water is the beneficial use. Furthermore, Vashon-Maury Island was designated a "sole source aquifer" by the EPA in June 1994, meaning the aquifer is the principal source of drinking water for the island. The sole source aquifer boundary is coincident with the shoreline of the island and includes all potable aquifers, regardless of depth (EPA, 1994). MTCA may require more stringent PCULs in situations when protection of other beneficial uses is necessary. For the VLF, groundwater discharges to surface water, so the development of groundwater PCULs accounted for the protection of surface waters (WAC 173-340-720(1)(d)).

For carcinogens that also have a state or federal MCL, MTCA allows for modification of the cleanup level to a target excess lifetime cancer risk of $1x10^{-5}$ (1 in 100,000). The calculations presented in WAC 173-340-720 were used to adjust the MTCA Method B values for selected carcinogenic COCs and the adjusted values were compared to state MCLs (WAC 246-290-310).

When a natural background value was available, it was used as the PCUL instead of risk-based values. Based on Ecology publication *Natural Background Groundwater Arsenic*

Concentration in Washington State, the background concentration for Puget Sound is 8 micrograms per liter (µg/L) (Ecology, 2015a).

5.5.2 Surface Water

For surface water, possible PCUL values were obtained from the following federal and state chemical-specific applicable regulatory criteria (Table 5.1):

- Washington State-specific and EPA human health criteria (water and organisms) promulgated under CWA Section 303(c) (EPA, 2016).
- National recommended water quality criteria pursuant to CWA Section 304(a) for human health and freshwater aquatic life.
- Water quality standards for surface waters of the State of Washington (WAC 173-201A) that are protective of the human health ingestion and ecological health pathways (freshwater standards).
- Washington State MTCA surface water cleanup levels (WAC 173-340-730) calculated using Method B (standard formula values) that are protective of the human health ingestion and the ecological health pathways (freshwater standards).

Regulatory criteria for certain metals are hardness-dependent. PCULs for these metals were derived from the site-specific hardness-corrected chronic freshwater criteria.

For arsenic, the most stringent level is EPA's (2016) Washington State-specific CWA criterion of 0.018 µg/L, based on human consumption of fish. However, according to the Governor's 2014 surface water policy brief (Inslee, 2014), the fish consumption criterion for arsenic "is not attainable and essentially meaningless because it is set below levels that occur naturally in much of our surface water and groundwater." Therefore, the surface water PCUL for arsenic has been adjusted to 8 µg/L—background for Puget Sound (Ecology, 2015a).

5.5.3 Landfill Gas

For LFG, PCUL values were obtained from WAC 173-351-200 (Criteria for Municipal Solid Waste Landfills, Operating Criteria) and in the Code of the King County Board of Health, Title 10 (see Section 10.09.050).

6 Nature and Extent of Contamination

For this RI, data from 2001 through 2019 were selected for discussion and analysis. In the following sections, site-specific data are compared with the PCULs identified in the previous section. The purpose of screening using the regulatory criteria is to identify parameters requiring further evaluation. For each environmental media, the constituents retained after screening (i.e., COCs) are identified. The nature and extent of COCs are then discussed.

6.1 Groundwater

6.1.1 Data Screening and Constituent of Concern Selection

This section provides a summary of groundwater data collected from monitoring wells located on VLF property and off-property drinking water wells sampled by KCSWD. Groundwater samples were analyzed for hundreds of parameters, as summarized in Tables 6.1 (VLF wells) and 6.2 (off-property drinking water wells) and all groundwater data (2001 through 2019) are fully tabulated in Appendix F. Groundwater data from VLF wells were compared to the most stringent screening level based on protection of groundwater as drinking water and for the highest beneficial use for the protection of surface water for ecological receptors. Data from off-property drinking water wells were compared to the most stringent screening level based on protection of groundwater as drinking water.

Tables 6.1 and 6.2 provide the minimum, maximum, and average detected concentrations for each analyte and the number and frequency of PCUL exceedances. Of the 252 parameters for which samples were analyzed, 57 were detected in more than one sample. The detected compounds included metals (total and dissolved), a suite of VOCs, field parameters, and conventional groundwater quality parameters. Of the 57 compounds detected, 17 were found at concentrations above their respective PCUL, but only in groundwater quality samples collected from VLF monitoring wells, not off-property wells:

- Conventional parameters – nitrate
- Metals – arsenic, cadmium, copper, lead, iron, manganese, mercury, selenium, silver, zinc
- Semivolatile organic compounds (SVOCs) – bis(2-chloroethyl) ether, bis(2-ethylhexyl) phthalate
- VOCs – 1,2-dichloropropane, benzene, TCE, vinyl chloride

The next step in the COC selection process is to further evaluate the compounds with PCUL exceedances. The specific factors used to evaluate whether a compound is retained as a COC is based largely on exceedance frequency and time elapsed since last exceedance.

Nitrate had a detection frequency of 62 percent but exceeded the PCUL in a single sample: MW-27 at 10.3 mg/L in March 2015, slightly above the 10 mg/L PCUL. Therefore, nitrate is not considered a COC.

Of the metals detected at concentrations above their respective PCUL, only arsenic, iron, and manganese are retained as COCs, as these compounds exceeded PCULs in more than 10 percent of samples. The other seven metals exceeded their respective PCUL in only 0.1 to 1 percent of samples. Cadmium, copper, lead, mercury, selenium, silver, and zinc are therefore not considered COCs.

For VOCs, vinyl chloride has the highest exceedance frequency at 21 percent. While other VOCs exceedance frequencies are low, ranging between 1 to 7 percent, they have been retained as COCs because detections are recent and are located within the vinyl chloride plume, as discussed below.

SVOCs have only been sporadically analyzed in groundwater, so the dataset is not as robust as other constituents. Bis(2-chloroethyl) ether has an exceedance frequency of 15 percent, with exceedances as recent as 2019 noted at MW-33 and MW-35 and has been retained as a COC. Bis(2-ethylhexyl) phthalate has an exceedance frequency of 8 percent with two detections and has not been retained as a COC. These exceedances of bis(2-chloroethyl) ether and bis(2-ethylhexyl) phthalate PCULs have occurred recently in 2018 and 2019 when a lower reporting limit was achieved by the laboratory. However, the reporting limit remains an order of magnitude higher than their respective PCULs.

6.1.2 Groundwater Quality

This section describes the nature and extent of impacted groundwater at the VLF. Refer to Section 9, Conceptual Site Model, for a discussion of the contaminant extent and transport. The COCs for groundwater include dissolved arsenic, dissolved iron, 1,2-dichloropropane, benzene, TCE, and vinyl chloride. Table 6.3 provides a summary of groundwater PCULs for COCs. While several VOCs are considered COCs, the focus of the RI is on vinyl chloride as an indicator compound because the other VOCs and SVOCs are co-located within the vinyl chloride plume.

This discussion also evaluates water quality parameters that, while not identified as COCs, represent landfill-related indicators signifying impacts other than PCUL exceedances. Appendix G.2 provides water quality time-series plots for the following parameters at select wells. The combined set of parameters evaluated in water quality trend plots and as part of the nature and extent discussion includes:

- Arsenic (dissolved)
- Iron and Manganese (dissolved)
- Chlorinated VOCs – TCE and Vinyl Chloride
- Other VOCs and SVOCs – Benzene, 1,2-dichloropropane, and bis(2-chloroethyl) ether
- Water Quality Parameters – Alkalinity and Chloride

The lowest PCULs for arsenic and iron are based on protection of surface water for ecological receptors. The following discussion of metals exceedances are for dissolved fraction only, as this fraction is more toxic to ecological receptors compared to the total fraction.

6.1.2.1 Arsenic

Arsenic is a naturally occurring, nonconservative metal in groundwater that has been detected above the PCUL in both upgradient and downgradient monitoring wells at the VLF. A parameter is considered nonconservative when its concentrations depend on the geochemical environment. Arsenic mobility in groundwater is enhanced by alkaline pH and by moderately reducing conditions.

The extent of dissolved arsenic exceeding the PCUL in Units Cc2 and D from 2002 through 2019 is illustrated on Figures 6.1 and 6.2, respectively. Analytical results are compared to the Puget Sound background level of 8 µg/L (Ecology, 2015a), as detailed below.

- Unit Cc1 – Dissolved arsenic concentrations range between 0.12 and 5 µg/L in Unit Cc1 wells. Unit Cc1 is not considered to be impacted by arsenic from landfilling processes.
- Unit Cc2 – As illustrated on Figure 6.1, the highest arsenic concentrations were found at the south end of the VLF; the maximum concentrations were reported at well MW-33, located in the South Slope Area, and at MW-35, located approximately 200 feet downgradient of MW-33. Dissolved arsenic concentrations at these wells range between 22.9 and 57.2 µg/L, with values at the higher end of the range from MW-33. By contrast, concentrations at upgradient well MW-20 range between 1 and 5 µg/L.
- Dissolved arsenic concentrations decrease downgradient of wells MW-33 and MW-35, to the west, likely due to attenuation and distance from geochemical changes to groundwater caused by landfill processes. Specifically, arsenic (among other metals such as barium, iron, and manganese) occur naturally in soil, and their occurrence in groundwater can depend on local groundwater oxidation-reduction (redox) conditions. Although not directly sensitive to redox, arsenic is strongly adsorbed to iron oxides and oxyhydroxides or manganese oxides and can be released under reducing conditions.
- As discussed in Section 6.2.2, seeps attributed to Unit Cc2 groundwater, discharge from the West Hillslope, and flow downslope to weirs SW-W2 and SW-W3 at the west property boundary. Dissolved oxygen increases along this flow path leading to metals precipitation and a decrease in dissolved arsenic concentrations at these weirs to below 8 µg/L. Arsenic does not exceed PCULs at the western property boundary. Figure 6.1 also demonstrates that arsenic concentrations do not exceed PCULs at the southern property boundary.
- Unit Cc3 – Dissolved arsenic concentrations range between 0.45 and 3.5 µg/L in Unit Cc3 wells. Unit Cc3 is not considered to be impacted by arsenic from landfilling processes.

- Unit D – Dissolved arsenic concentrations range between 1 and 9 µg/L in Unit D wells (Figure 6.2). A similar range has been measured at upgradient well MW-7 (2.1 to 9 µg/L). One elevated concentration was detected at well MW-19 (27 µg/L) in October 2004. All other data from this well (73 total data points) have been comparable to other Unit D wells, so the detection of 27 µg/L is considered anomalous.

  Dissolved arsenic concentrations greater than 8 µg/L have been measured in wells in the Vashon-Maury Island area, especially in aquifers corresponding to Unit D or deeper (King County, 2013). Dissolved arsenic concentrations in Unit D are not attributable to releases at the landfill, but rather to naturally occurring conditions in regional soils. The Unit D is not considered to be impacted by arsenic from landfilling processes.

Time-series plots for dissolved arsenic depict a remarkable decrease in arsenic concentrations after landfill closure.

6.1.2.2 Iron and Manganese

Iron and manganese are naturally occurring, nonconservative metals in groundwater that has been detected above the PCUL in VLF groundwater. Because of its nonconservative nature, dissolved iron and manganese are common when geochemical processes (water-rock interactions) cause reducing groundwater conditions. Conversely, in oxidized groundwater, iron forms hydroxide (rust-like) mineral grain coatings. Manganese is commonly found with iron as part of that mineral oxide coating. The concentrations of iron and manganese relative to background values helps reveal whether groundwater is undergoing geochemical changes.

The extent of dissolved iron in Units Cc2 and D from 2002 through 2019 is illustrated on Figures 6.3 and 6.4, respectively.

- Unit Cc1 – Dissolved iron concentrations range between 8.1 and 490 µg/L in Unit Cc1 wells (PCUL is 1,000 µg/L). Unit Cc1 is not considered to be impacted by iron resulting from reducing conditions from landfill processes.

- Unit Cc2 – As illustrated on Figure 6.3, exceedances (maximum concentration of 26,000 µg/L) occur south of the Phase 2 closure area in wells MW-21, MW-33, and well MW-5D/MW-35. At other Cc2 wells, dissolved iron concentrations range between 5.9 and 510 µg/L. Concentrations at the upgradient well MW-20 range between non-detect and 510 µg/L. Over the past 10 years, dissolved iron has remained below PCULs at the southern property boundary (MW-2 and MW-21) except one slight exceedance at well MW-21 in September 2015 (1,120 µg/L).

- Unit C groundwater flows west and discharges as seeps on the West Hillslope. As discussed in Section 6.2, dissolved iron concentrations in surface water are below PCULs at the western property boundary. Therefore, dissolved iron exceedances in Unit Cc2 do not result in impacts beyond the VLF property boundary.

- Unit Cc3 – Dissolved iron concentrations range between 7 and 300 µg/L in Unit Cc3 wells. Unit Cc3 is not considered to be impacted by dissolved iron from landfilling processes.
- Unit D – Dissolved iron concentrations range typically between 10 and 420 µg/L in Unit D wells, with upgradient well MW-7 having a much narrower range (10 to 100 µg/L). Despite the higher concentrations in well MW-29 (290 to 975 µg/L), values remain below the PCUL for protection of surface water (1,000 µg/L) and the drinking water MCL (11,000 µg/L). Figure 6.4 depicts the Unit D PCUL exceedances for dissolved iron. Unit D is not considered to be impacted by dissolved iron from landfilling processes.

The time-series plots for dissolved iron depict a general decrease in concentrations in MW-5D and MW-21 since landfill closure (after an initial modest uptick in concentration) and MW-33 appears stable to decreasing; however the plot for MW-35 appears to depict some increasing detections. See the statistical analysis discussion in Section 6.1.3 for further evaluation.

Dissolved manganese exceedances (PCUL 750 µg/L) are located within the same footprint of dissolved iron exceedances. South of the Phase 2 closure area in wells MW-21, MW-33, and MW-5D/MW-35, concentrations of dissolved manganese range between 165 and 2,560 µg/L. Outside this area, two exceedances are reported from well MW-19 at 1,290 and 1,350 µg/L (11/8/2010 and 8/9/2010); however, dissolved manganese was detected between 728 and 310 in all other samples from this well (69 data points).

Time-series plots for dissolved manganese indicate a general decrease in concentration at MW-5D and MW-21 since landfill closure, and MW-33 appears stable to decreasing; however, the plots for MW-35 appears to depict some increasing detections. See the statistical analysis discussion in Section 6.1.3 for further evaluation.

6.1.2.3 Chlorinated Volatile Organic Compounds

Chlorinated VOCs are of anthropogenic origin that occur in both landfill leachate and LFG. They are commonly present in LFG because of their high vapor pressure and low solubility. Vinyl chloride and TCE are the two chlorinated VOCs identified as COCs for the VLF.

The extent of vinyl chloride in Units Cc2 and D from 2002 through 2019 is illustrated on Figures 6.5 and 6.6, respectively. Exceedances of vinyl chloride (PCUL of 0.02 µg/L) have been found in Unit C wells only, primarily within Unit Cc2, as detailed below:

- Unit Cc1 – In two samples, vinyl chloride concentration was greater than the PCUL: 0.5 µg/L at well MW-4 in May 2007 and 0.02 µg/L at well MW-13 in February 2008. Vinyl chloride was not detected in any other Unit Cc1 groundwater sample (including those from these two wells) with all other results reported as non-detect. These data indicate there are no ongoing vinyl chloride impacts to the Unit Cc1.
- Unit Cc2 – As illustrated on Figure 6.5, exceedances occur at the south end of the property, with the highest concentrations reported in the South Slope Area at MW-33 (24.3 to 53.1 µg/L, since its installation in 2015). Concentrations of vinyl

chloride decrease in the downgradient direction from well MW-33, to the west. Groundwater seeps attributed to Unit Cc2 discharge from the West Hillslope. Surface water sampling results for the seeps are discussed in Section 6.2.

Vinyl chloride concentrations in Unit Cc2 groundwater exceed PCULs at the south property boundary at wells MW-2 and MW-21, cross-gradient from MW-33. Concentrations at MW-2 and MW-21 are significantly lower than those detected at MW-33, ranging between 0.04 and 0.13 µg/L over the past three years. While these concentrations exceed the PCUL, the PCUL is based on protection of surface water as the beneficial use. In terms of the drinking water as the beneficial use, vinyl chloride concentrations at MW-2 and MW-21 do not exceed the drinking water standard for vinyl chloride (0.29 µg/L).

- Unit Cc3 – One vinyl chloride sample exceeded the PCUL: 0.04 µg/L at well MW-14 in February 2008. Vinyl chloride was not detected in any other Unit Cc3 sample, including those from well MW-14. Unit Cc3 is not considered to be impacted by vinyl chloride from landfilling processes.
- Unit D – As depicted in Figure 6.6, vinyl chloride has not been detected in Unit D above the reporting detection limit (RDL). In May 2019, the laboratory reported a qualified detection of vinyl chloride in a sample collected from MW-19 at a concentration (0.0101 DJT µg/L) less than the RDL (0.02 µg/L). The detection of vinyl chloride has not been substantiated, as all previous and subsequent samples from MW-19 have been non-detect. The unsubstantiated detection is, therefore, not considered further in the RI.

TCE exceedances (PCUL 0.3 µg/L) are within the area of vinyl chloride exceedances with higher concentrations located at well MW-5D/MW-35 where concentrations from 2001 to present range between 0.25 to 1.22 µg/L.

The TCE detected in one sample from Unit D well MW-12 (0.4 µg/L, 5/6/2004) is considered an anomalous data point. This was a single, anomalous detection from over 15 years ago, well below the TCE drinking water MCL, 5 µg/L. TCE was not detected in any other sample from well MW-12 (73 total data points). Unit D, a source of drinking water, is not considered to be impacted by TCE from landfilling processes.

The time-series plots for vinyl chloride and TCE are presented in Appendix G. Since landfill closure, the detected concentrations of VOCs in monitoring wells largely appear to be decreasing, with the exception of recent (2019) variability in concentrations detected at MW-21, MW-33, and MW-35. See the statistical analysis discussion in Section 6.1.3 for further evaluation.

6.1.2.4 Other Volatile Organic Compounds and Semi-Volatile Compounds

Of anthropogenic origin, benzene and 1,2-dichloropropane are VOCs that can occur in both landfill leachate and LFG (Solid Waste Association of North America [SWANA], 2000). These other VOCs have been detected above their respective PCULs, but only in Unit Cc2 at the south/southwest portion of the VLF property. Units Cc1, Cc3, and D are not considered to be impacted by benzene or 1,2-dichloropropane from landfilling processes. Benzene data for Units Cc2 and D from 2002 through 2019 are illustrated on Figure 6.7 and 6.8, respectively.

The highest benzene concentrations were detected at well MW-33 (0.98 to 1.8 µg/L) (PCUL 0.44 µg/L). Concentrations decrease at downgradient well MW-5D/MW-35 (0.25 to 1.6 µg/L).

Exceedances and detections of 1,2-dichloropropane (PCUL 0.71 µg/L) are co-located with benzene exceedances at wells MW-33 and MW-5D/MW-35. Concentrations at MW-33 (0.24 and 13 µg/L) are higher than those at downgradient of well MW-5D/MW-35 (non-detect to 2.3 µg/L).

Similarly, exceedances of bis(2-chloroethyl) ether (PCUL 0.02 µg/L) were detected at well MW-33 and MW-35, ranging between 1.06 and 3.16 µg/L. These detections also appear to be collocated with benzene and concentrations decrease in the downgradient direction from MW-33 to MW-35.

6.1.2.5 Water Quality Parameters

Alkalinity and chloride are two key indicator parameters that are used to identify landfill impacts on groundwater. Alkalinity is a measurement of the ability of water to neutralize (buffer) an acid. Bicarbonate alkalinity in groundwater can form from dissolution of carbonate and silicate minerals in aquifer material by dissolved carbon dioxide gas (carbonic acid) from either landfill leachate or LFG.

Chloride is a naturally occurring, conservative ion that is also found in landfill leachate. Dissolved chloride concentrations remain relatively unchanged by natural chemical processes in groundwater (except for mixing).[5] More typically present in landfill leachate, chloride is not a significant component of LFG and thus not indicative of LFG impacts. Chloride in groundwater above background levels could originate from landfill leachate.

Both parameters can be elevated in leachate, and LFG can increase alkalinity. Data from upgradient wells are provided for Units Cc2 and D, units where sufficient information is available to establish horizontal gradient, thus identify upgradient wells.

- Unit Cc1 – Alkalinity concentrations range between 18 and 170 mg/L (average 59 mg/L) in Unit Cc1 wells. Chloride concentrations range between 1 and 19 mg/L (average 3.5 mg/L).
- Unit Cc2 – At upgradient well MW-20, alkalinity ranges between 58.5 and 94.9 mg/L and chloride ranges between 3 and 4.1 mg/L. Corresponding ranges in the southern portion of the VLF, where COC impacts are noted above, are 116 to 496 mg/L (average 258 mg/L) for alkalinity and 2.1 to 15.2 mg/L (average 3.9 mg/L) for chloride.

[5] In contrast, nonconservative ions change concentrations as the result of natural chemical processes such as water-rock interactions.

- Unit Cc3 – Alkalinity concentrations range between 46.5 and 160 mg/L (average 66 mg/L) in Unit Cc3 wells. Chloride concentrations range between 2.8 and 6.23 mg/L (average 4.2 mg/L).
- Unit D – At upgradient well MW-7, alkalinity concentrations range between 58 and 100 mg/L; chloride ranges between 2.7 and 5 mg/L. Corresponding concentrations in Unit D wells are 3 to 110 mg/L (average 78 mg/L) for alkalinity and. 2.7 to 7 mg/L (average 4 mg/L) for chloride.

The time-series plots for alkalinity and chloride are presented in Appendix G. Since landfill closure the detected concentrations of both water quality parameters in monitoring wells largely appear to be decreasing. See the statistical analysis discussion in Section 6.1.3 for further evaluation.

The alkalinity concentrations observed in Unit Cc2 are in stark contrast to the upgradient well, MW-20, and alkalinity concentrations detected in the other water bearing units at the VLF. However, chloride concentrations appear relatively consistent across the VLF. These results indicate that LFG may be the primary source impacting Unit Cc2 groundwater on the south side of the VLF.

6.1.2.6 Dissolved Gases

Dissolved methane, ethane, and ethene were analyzed in select groundwater samples in 2015, 2016, and 2019 for geochemical source investigation and monitored natural attenuation (MNA; Table F.1). Methane is an indicator of strongly reducing conditions and can also be an indicator of the presence of LFG. Ethane and ethene, also indicators of reducing conditions, are the products of reductive dichlorination of chlorinated ethenes and ethanes and can be indicators of the natural degradation of chlorinated solvents.

Wells included in the dissolved gas analysis included MW-2, MW-3, MW-4, MW-7, MW-8, MW-9, MW-10, MW-12, MW-13, MW-19, MW-20, MW-21, MW-26, MW-29, MW-33, MW-34, MW-35, and MW-36. A preliminary summary of dissolved gas analysis for data collected in 2015 and 2016 was presented in the Geochemical Evaluations (Anchor QEA, 2017; presented in Appendix C). The key findings from the additional dissolved gas analysis in 2019 are:

- The highest dissolved methane occurred in MW-33 and MW-35, where concentrations were significantly higher than other wells (by two orders of magnitude). These wells are located near the South Slope Area where methane dissolution into groundwater is expected.
- The elevated dissolved methane concentrations coincide with the area of greatest groundwater quality impact.
- Concentrations of methane at MW-35 were less than those measured in MW-33. MW-35 is located down gradient of MW-33 and the South Slope Area.
- Methane concentrations observed at MW-33 and MW-35 show an apparent downward trend from 2015 to 2019. The downward trend appears consistent with the enhanced LFG collection in the South Slope Area.

- The highest ethane and ethene were detected in MW-33 and MW-35, which are also the wells with the highest vinyl chloride concentrations in groundwater. The presence of these degradation end-products confirm anaerobic biodegradation of chlorinated solvents, such as vinyl chloride, through reductive dechlorination and supports MNA demonstration.

6.1.3 Statistical Analysis

A statistical analysis of groundwater for the period from January 2015 through December 2019 included an evaluation of COCs (arsenic, benzene, iron, manganese, TCE, vinyl chloride, and 1,2-dichloropropane) and indicator compounds (alkalinity and chloride). The monitoring locations selected to be part of the statistical analysis represent Unit Cc2 groundwater and included MW-20 (upgradient, unimpacted well), MW-2, MW-21, MW-33, MW-35, SW-W1, and SW-W2. These monitoring locations were selected because they represent the wells within the area of highest groundwater contamination, the surface water receiving locations for Unit Cc2 groundwater seeps, and a cross-section of results along the groundwater flow path. The statistical analysis was conducted using:

- ProUCL was used for outlier detection (Rosner’s and Dixon), verifying data distributions (normal/lognormal/nonparametric), and calculating statistical trends and associated significance (Mann-Kendall and Thiel-Sen).
- WQStat Plus™ was used for seasonality testing (Kruskal-Wallis and Seasonal Kendall).

The statistical analysis focused on exceedances of parameters related to landfill impacts, and not on parameters that could be the result of naturally occurring or background groundwater quality conditions. Appendix G.1 contains a more detailed discussion on the statistical tests performed and includes the raw data outputs and graphics produced by the statistical programs.

Ecology (2018) also recommends trend analysis for sites in ongoing compliance monitoring, such as VLF, for evaluating the trend of existing detections. As such, statistical trend tests have been implemented to identify the current progress in the return of groundwater quality to background conditions.

6.1.3.1 Mann-Kendall and Thiel-Sen

Statistical trend summaries are summarized in Tables 6.8a. This table presents trend evaluations using Mann-Kendall and trend slopes evaluated using a Theil-Sen test. The raw statistical output is presented in Appendix G.1

Results of the analysis indicate statistically significant decreasing trends for all parameters in one or more monitoring locations. At MW-33, every parameter evaluated had a statistically significant decreasing trend. The statistically significant increasing trends were few and included arsenic in MW-20 and MW-35, iron in MW-20 and MW-35, and manganese in MW-2 and MW-35. The remaining data were either non-detect or had trends identified as not statistically significant.

6.1.3.2 Outlier Tests

The results of the outlier tests identified six samples with the potential to be outliers:

- Arsenic, iron, and manganese in SW-W2 on February 25, 2016
- Chloride in MW-2 on March 6, 2015
- Iron in SW-W1 on June 23, 2015
- Vinyl Chloride in MW-20 on May 6, 2016

The chloride detection on March 6, 2015, in MW-2 and the vinyl chloride detected in MW-20 on May 6, 2016, were further vetted as outliers and their exclusion from the trend analyses are discussed in the summary by individual monitoring locations presented in Section 6.1.3.4.

Further evaluation of the 2016 dataset with the arsenic, iron, and manganese potential outliers indicates that there may have been a field or laboratory sampling error where the total and dissolved metals sample bottles were switched. During this February 2016 sampling event, the dissolved fraction detections were higher than the total fraction detections. However, these data were not removed from the dataset as outliers because the initial Mann-Kendall trend analysis indicates an insufficient evidence for a trend.

The iron detection in SW-W1 on June 23, 2015, appears to be an anomalous value. The iron dataset for SW-W1 has great variability throughout the period of record and there were no obvious potential sampling deficiencies noted that may have contributed to this anomalous value. This datum was not removed from the dataset as an outlier because the initial Mann-Kendall trend analysis indicates an insufficient evidence for a trend.

6.1.3.3 Seasonality

Seasonality Tests were used to assess the potential impact of seasonality on groundwater quality, starting with the previously identified trends in Table 6.8a. If results were substantially seasonal, it may indicate a need to adjust for seasonality broadly on all statistics. The results of the seasonality testing are summarized in Table 6.8b and show that only a small subset had statistically significant seasonality. Due to the limited impact of seasonality, it was determined that broader seasonality testing was unwarranted.

Of the 18 well and analyte pairs with statistically significant increasing trends, 15 were not found to be statistically seasonal. Alkalinity in SW-W1 was found to have statistically significant seasonality, but no statistically significant trend when deseasonalized. Arsenic in SW-W1 was found to have statistically significant seasonality, but no statistically significant trend when deseasonalized. Arsenic in SW-W2 was found to have statistically significant seasonality, as well as a statistically significant increasing trend when deseasonalized.

6.1.3.4 Summary of Statistical Analysis By Monitoring Location

The following presents a summary of the statistical analysis for each of the monitoring locations included in the analysis.

MW-20

MW-20 is the upgradient “background” monitoring well for Unit Cc2 and is located to the east of the South Slope Area. Chloride and manganese both had statistically significant decreasing trends. The trend analysis for vinyl chloride was run both with and without the previously identified outlier detection. The results for both trend tests were that there is a statistically significant decreasing trend; however, without the outlier, the results were all non-detect. It is suspected that the decreasing trend might be due to the decrease in laboratory detection limit over time. The results presented in Table 6.8a represent those with the outlier removed.

Arsenic and iron reflect statistically significant increasing trends. Arsenic presents a clear increasing trend at the scale shown on the graph in Appendix G.1; however, the detected concentrations are well below the arsenic PCUL and the variability in concentrations detected may be more indicative of variability in laboratory precision than an actual trend. Nevertheless, this is a trend that should be closely evaluated during future monitoring events. For iron, the last detections may be indicative of decreasing concentrations and do not exceed PCULs, so at this time, the increasing trend is not a concern for exceeding standards. However, this is a trend that should be closely evaluated during future monitoring events.

No statistically significant trends were identified for alkalinity or arsenic. The remaining data were non-detect.

MW-2

Monitoring well MW-2 is located south of MW-33 near the southern property boundary. Alkalinity, arsenic, and chloride all had statistically significant decreasing trends. The chloride trend analysis was run both with and without the previously identified outlier detection. The results for both trend tests were that there is a statistically significant decreasing trend. The results presented in Table 6.8a represent those with the outlier removed.

Manganese had a statistically significant increasing trend. The concentrations of manganese detected in MW-2 have not exceeded PCULs; at this time, the increasing trend is not a concern for exceeding standards. However, this is a trend that should be closely evaluated during future monitoring events.

No statistically significant trend was identified for vinyl chloride. The remaining data were non-detect.

MW-21

Monitoring well MW-21 is located south of MW-33 and MW-35 on the southern property boundary. Alkalinity, iron, and vinyl chloride all had statistically significant decreasing trends. The results of the Mann-Kendall and Thiel-Sen statistical evaluation, coupled with the time-series plots presented in Appendix G.2, demonstrate an overall decline in COCs and indicator parameters in groundwater at MW-21, indicating a general improvement in groundwater quality over time.

No statistically significant trend was identified for arsenic, chloride, or manganese. The remaining data were non-detect.

MW-33

Monitoring well MW-33, located within the South Slope Area in unlined refuse has historically represented the highest concentrations of COCs. All parameters included in the trend analysis had statistically significant decreasing trends in MW-33. The results of the Mann-Kendall and Thiel-Sen statistical evaluation, coupled with the time-series plots presented in Appendix G.2, demonstrate an overall decline in COCs and indicator parameters in groundwater at MW-33, indicating a general improvement in groundwater quality over time.

MW-35

Monitoring well MW-35, located within the South Slope Area in unlined refuse has historically had the second highest concentrations of COCs. The results of the trend analysis indicated that alkalinity, chloride, and vinyl chloride all had statistically significant decreasing trends. These trends are further demonstrated on the time-series plots in Appendix G.2.

Arsenic, iron, and manganese had statistically significant increasing trends for the specified time period used in this analysis. The arsenic concentrations during the last seven monitoring events in 2018 and 2019 have been decreasing and may be indicative of the beginning of decreasing trends. These increasing trends may be related to a change in reducing conditions at this well, which should be closely evaluated during future monitoring events.

No statistically significant trends were identified for 1,2-dichloropropane, benzene, or TCE.

SW-W1

Surface water weir monitoring location SW-W1 is located in the West Hillslope Area and is downgradient from the South Slope Area. Vinyl chloride results from the trend analysis indicate a statistically significant decreasing trend. This indicates that along the groundwater flow path from the South Slope Area to the West Hillslope where Unit Cc2 groundwater is expressed at the surface as surface water, vinyl chloride concentrations are declining.

No statistically significant trends were identified for alkalinity, arsenic, iron, chloride, or manganese. The remaining data were non-detect.

SW-W2

Surface water weir monitoring location SW-W2 is located at the west property boundary and is considered the most downgradient point from the South Slope Area. No statistically significant trends were identified for alkalinity, arsenic, chloride, iron, or manganese. The remaining data (which included the VOCs) were non-detect.

6.1.4 Off-Property Groundwater Monitoring

In 2002, KCSWD sampled groundwater from 11 domestic wells located near the landfill and found no evidence of impacted water quality originating from the VLF. The locations of these wells are depicted on Figure 3.1 and include, from north to south, DW-FL, DW-BA, DW-SE, DW-AV, DW-HU, DW-LO, DW-PA, DW-OR, DW-SS, DW-85, and DW-GE.

KCSWD continued monitoring the Smith-Shiratori well (DW-SS on Figure 3.1) from 2005 through 2008. The Paquette well (DW-PA, located west of the VLF) and 85 Acres

Water Company (DW-85 located south of the VLF) are still monitored routinely by KCSWD and data are available from 2002 through 2019. Shown on cross sections A-A′ (Figure 3.2) and D-D′ (Figure 3.6), these three wells are interpreted to be completed in Unit D or deeper based on the elevation of the well screen or open casing in relation to the inferred hydrostratigraphy.

VOC detections in off-property wells were sporadic and at low levels, below PCULs. VOC detections in off-property wells are likely due to post-sampling cross-contamination of the samples rather than VLF impacts to off-property wells. Detected compounds have included acetone, 2-butanone and chloromethane, which are common lab contaminants. Other detected VOCs included toluene, TCE, bromomethane, and carbon disulfide. These compounds have also been detected in quality control samples (i.e., trip blanks and laboratory blanks).

All data from domestic drinking water wells are compiled in Appendix F. No evidence of contamination originating from the VLF has been found in any of the domestic wells. As summarized in Section 7, a Beneficial Use Survey has been completed as part of this RI to assess groundwater use by the public in the vicinity of the VLF.

6.2 Surface Water

6.2.1 Data Screening

Surface water samples were analyzed for hundreds of parameters, as summarized in Table 6.4 and fully tabulated in Appendix F. Surface water data were compared to the most stringent screening level based on the highest beneficial use for the protection of surface water for human and ecological receptors.

Table 6.4 provides the minimum, maximum, and average detected concentrations for each analyte, as well as the number of detections and a comparison to PCULs. Of the 129 parameters for which samples were analyzed, 88 were detected in more than one surface water sample. The detected compounds included metals (total and dissolved), a suite of VOCs, one pesticide, field parameters, and conventional surface water quality parameters. Of the compounds detected, dissolved arsenic, dissolved iron, dissolved manganese, benzene, and vinyl chloride are retained as COCs with exceedance frequencies greater than or equal to 5 percent. With exceedance frequencies less than 5 percent, mercury, selenium, zinc, 1,2-dichloropropane, and acrylonitrile are thus not considered COCs.

6.2.2 Surface Water Quality

This section describes the nature and extent of surface water quality at the VLF at the following locations: Borrow Area Pond, the VLF outfall, West Hillslope seeps and weirs, and Robinwood Creek. Surface water sampling locations are depicted on Figure 4.5. Table 6.5 provides a summary of surface water PCULs for COCs, while a full summary of analytical data for each monitoring location is presented in Appendix F Table F.3. The lowest PCULs for arsenic and iron are based on protection of surface water for ecological receptors. The following discussion of metals exceedances are for dissolved fraction only, as this fraction is more toxic to ecological receptors compared to the total fraction.

Only one analyte – iron (PCUL 1,000 µg/L) – was identified as a COC at the Borrow Area Pond (SW-D). Concentrations at this location range between 113 and 4,100 µg/L, with an average of 846 µg/L.

No COCs were observed at concentrations above PCULs at the VLF outfall (SW-B).

Along the West Hillslope, groundwater discharges as seeps, flows downhill as overland flow, and is intercepted by weirs. The weirs are located near the western property boundary, except for SW-W1, which is approximately 170 feet upstream of SW-W3. Elevation and visual reconnaissance of outcrops at the surface indicate that seeps sampled on the West Hillslope are groundwater discharging from Unit C. Overland flow of groundwater discharge from Unit Cc2 made it difficult to discern if seepage from Unit Cc3 occurs; however, discharge was noted to increase at lower elevations that are comparable to Unit Cc3 elevation. Unit Cc2 groundwater seeps were more visually apparent than Unit Cc3 as there was little to no upslope groundwater seepage to obscure the Unit Cc2 seep locations.

As discussed in Section 4.3.2, some of the West Hillslope seeps were only sampled during the period from 2007 through 2010 and have not been sampled since. Despite the data from these monitoring locations not being recent, they provide a key insight into the nature and extent of COCs in groundwater seeping from the hillslope and are thus included in the nature and extent discussion.

Four COCs are present in the seep and weir samples.

- Dissolved Arsenic – Concentrations at the seeps range between 0.9 and 34.1 µg/L, with an average of 6.3 µg/L (PCUL 8 µg/L). Surface water from SW-24S and SW-S2 exceeded the PCUL for arsenic. Concentrations at the weirs range between 1.05 and 16 µg/L, with an average of 2.3 µg/L. The arsenic PCUL was only exceeded three times in weirs at SW-W1 (in 2009 and 2010) and SW-W2 (in 2016). The arsenic exceedance at SW-W2 on the property boundary is considered an anomalous result as the remaining detections at this monitoring location have been below PCULs.

- Dissolved Iron – Concentrations at the seeps range between 11 and 27,000 µg/L, with an average of 5,040 µg/L (PCUL 1,000 µg/L). Concentrations at the weirs, located downslope from the seeps, range between 11 and 8,970 µg/L, with an average of 177 µg/L. Dissolved iron concentrations at weirs SW-W2 and SW-W3 are below 1,000 µg/L, indicating iron is below PCULs at the western property boundary, with one anomalous result from SW-W2 in February 2016 (8,970 µg/L, 48 total data points at this location).

- Dissolved Manganese – Concentrations at the seeps range between 2.3 and 6,400 µg/L, with an average of 1,683 µg/L (PCUL 750 µg/L). Concentrations at the weirs range between 1.9 and 3,180 µg/L, with an average of 218 µg/L. Five samples from weirs SW-W1 and SW-W2 exceeded the PCUL with concentrations ranging from 951 to 3,180 µg/L.

- Vinyl chloride – Concentrations at the seeps range between 0.0.03 and 7.4 µg/L, with an average of 1.1 µg/L (PCUL 0.02 µg/L). Vinyl chloride has been detected at seeps SW-24S, SW-S2, SW-S3, SW-S4, and SW-S5 at concentrations exceeding the PCUL. Vinyl chloride was detected only at weirs SW-W1 and SW-W3; concentrations range between 0.01 and 0.14 µg/L, with an average of 0.04 µg/L, which exceeds the PCUL.

  From the property boundary weirs, of which only SW-W3 has exceeded the PCUL, water continues downslope as surface water and enters Robinwood Creek. The sampling station for Robinwood Creek is SW-E. Vinyl chloride has not been detected in surface water sampling location SW-E located approximately 1,500 feet from the VLF property in Robinwood Creek since sampling began in 2012.

- Benzene – Benzene was detected only at the seeps; concentrations range between 0.24 and 3.2 µg/L, with an average of 0.91 µg/L (PCUL 0.44 µg/L).

6.3 Landfill Gas

The “Landfill Gas System Evaluation Summary Report” (Aspect and Herrera, 2019; Appendix H) addressed the following LFG-related topics:

- The LFG collection system performance was analyzed for:
  - LFG migration control
  - Air quality protection
  - Opportunities to optimize the existing system.
- The influence test of landfill gas collection from the South Slope Area was summarized.

The data sets presented in the LFG Evaluation Summary Report were updated through 2019 for this RI Report.

6.3.1 Landfill Gas Compliance Monitoring and Results

This section presents a summary of LFG compliance monitoring, which KCSWD performs routinely to meet requirements of the landfill’s permit. LFG is monitored monthly at 26 gas probes,[6] in accordance with the “Environmental Monitoring Sampling and Analysis Plan and Quality Assurance Project Plan for Vashon Island Closed Landfill” (King County, 2016). Probe monitoring is used to demonstrate lateral control of LFG migration and protection of surrounding properties.

At the VLF, the priority has been, and remains, control of LFG migration. Figure 6.9 illustrates maximum annual methane and carbon dioxide concentrations since 1997 and 1999, respectively. In 1997, the maximum methane concentrations were observed at probe GP-5I (79 percent methane by volume). Since active LFG collection started,

[6] Probe names were modified. See Table 4.2 for original and current naming convention.

maximum annual methane concentrations at all compliance probes have remained consistently below the regulatory threshold of 5 percent by volume. Similarly, carbon dioxide concentrations have been approaching or have reached background levels. Elevated carbon dioxide concentrations observed at GP-8S and GP-8I have been decreasing over time and illustrate the importance of LFG collection at the north end of the VLF. Overall, LFG compliance monitoring results indicate that lateral LFG migration has been and is being controlled.

6.3.2 Landfill Gas Operations Monitoring and Results

The following provides a discussion of the performance of the LFG collection system as a whole in addition to the performance of individual collection points. The extent of methane (both within and outside the closed landfill area) is also discussed below as it further illustrates the performance of LFG controls in terms of methane migration.

6.3.2.1 Overall Landfill Gas System Performance

The LFG collection system has been operated at high flow rates to maximize LFG migration control. The system was designed to provide 360 standard cubic feet per minute (scfm) of total flow rate, and has been operated between 164 and 307 scfm since 2006. In 2019, the LFG collection system operated intermittently during blower repairs. Figure 6.10 shows annual average collection rates in a stacked area chart, with individual values provided in a table below the chart; total collection is the sum of methane, carbon dioxide, oxygen, and balance gas flows. Methane and carbon dioxide are the major constituents of LFG, while oxygen and balance gas are indicators of atmospheric air being drawn into the LFG collection system.

The system flow rate was raised in 2013 to increase LFG collection efficiency. This higher flow rate resulted in greater collection of atmospheric air, not LFG. From 2006 to 2009, methane accounted for about 1/3 of the methane and carbon dioxide collected. From 2016 to 2019, methane accounted for about 1/4 of the methane and carbon dioxide collected. These results indicated that LFG collection efficiency was maximized at total flow rates of less than 200 scfm.

The addition of LFG collection in the South Slope Area in 2016 and 2018 had a small effect on LFG collection rates. Flow rates from the wells in the South Slope Area have been limited by low system pressure and condensate management challenges. Due to the location of wellheads for GW-9, GW-10, and GW-11 at elevations below the perimeter header, condensate management has been a key issue in providing consistent LFG collection in the South Slope Area. Furthermore, the unknown water recharge into GW-11 blocking the well screen seasonally has been identified as a data gap to be investigated during the FS.

Over the long-term, calculated LFG generation and observed LFG collection have trended downward. Figure 6.10 shows the annual average LFG generation calculated using EPA's LFG generation model (LandGEM) as stacked lines for methane and carbon dioxide. Input to the LandGEM model include total waste mass (726,000 tons based on 968,000 cubic yards with a density of 1,500 pounds per cubic yard), the age of waste (uniformly placed from 1950 through 1999), the methane-generating capacity of the waste, and a decay in LFG generating capacity of 5 percent per year (default value). The methane-generating capacity was adjusted from a default value of 170 cubic meters per megagram to 50 cubic meters per megagram so that LandGEM results would more closely match observed gas collection rates. With this adjustment, LFG generation rates (methane and carbon dioxide) were calculated at approximately 32 scfm in 2019, matching the 32 scfm of LFG actually collected. The LandGEM model results are useful for projecting long-term LFG generation rates and will support the FS.

6.3.2.2 Landfill Gas Collection Point Performance

The individual LFG collection points have been operated consistently over time to maximize LFG collection rates. Figure 6.11 displays a set of stacked column charts reflecting performance at each LFG collection point for 2006, 2016 (after GW-9 was installed), and 2018 (after GW-10 and GW-11 were installed). The graphs on the left of Figure 6.11 show LFG concentrations have decreased over time at all locations, and methane concentrations have been less than the lower explosive limit at a majority of locations. The graphs on the right of Figure 6.11 show LFG collection rates. The locations of the LFG collection points are mapped on Figure 2.7. LFG collection has been focused on those locations with greater concentrations of methane and carbon dioxide. Wells in the South Slope Area (GW-9, GW-10, and GW-11) have demonstrated sustained collection of methane and carbon dioxide, along with vertical wells completed in the Phase I Closure area and those trench collectors within the lined landfill (T-3 and T-4).

6.3.2.3 Extent of Methane

The extent of methane outside the lined and covered landfill decreased between 2006 and 2018, particularly in the South Slope Area. Figure 6.12 provides maps with color-coded indicators of methane concentrations at compliance probes, temporary probes, and LFG collection points outside the lined and covered VLF. Elevated methane concentrations were observed in the South Slope Area, but not at the compliance probes. Operation of LFG collection wells in the South Slope Area resulted in lower methane concentrations at nearby temporary probes

6.3.3 Volatile Organic Compounds in Landfill Gas and Air Quality Evaluation

In 1997, KCSWD requested and received a permit from Puget Sound Air Pollution Control Agency (Notice of Construction No. 6513; Registration No. 1104) to treat LFG collected from the VLF using granular activated carbon. LFG treatment is typically required to protect air quality from VOCs identified as toxic air pollutants in air quality regulations (WAC 173-460).

VOC concentrations observed at the blower inlet in 2013 and 2019 were less than typical concentrations observed at MSW landfills provided in *Compilation of Air Pollutant Emission Factors* (AP-42) (EPA, 1995). LFG samples were collected on March 14, 2019, and previously in May 1, 2013, for laboratory analysis of VOCs, sulfur compounds, and major gases (Aspect and Herrera, 2019). Laboratory results are summarized in Table 6.6. Changes in concentrations are attributable to one or more factors, for example:

- The landfill refuse decomposition process was more aerobic in 2019 than in 2013.

- There was a greater proportion of atmospheric air in LFG at the blower inlet in 2019 compared to 2013.
- The LFG collection system included extraction from GW-9, GW-10, and GW-11 in 2019.

The potential to emit toxic air pollutants was assessed by comparing calculated treatment system loading rates using 2019 conditions with regulatory thresholds. The regulatory thresholds for each toxic air pollutant are listed in WAC 173-460-150 (updated in November 2019). For example, the small quantity emissions rate (SQER) for vinyl chloride is 18 pounds per year, the *de minimis* emission rate is 0.92 pounds per year, and the ambient source impact level (ASIL), a concentration-based regulatory level, is 0.11 microgram per cubic meter. If a potential source has an emissions rate below the SQER, then air dispersion analysis is not necessary to ensure that emissions meet the ASIL.

Figure 6.13 compares the observed loading rates and regulatory thresholds in units of pounds per averaging period and shows that air quality is protected. Blue symbols indicate constituents with loading rates less than the SQER and represent a high level of air quality protection. Green symbols indicate constituents with loading rates less than the *de minimis* rate (which is 5 percent of the SQER) and represent a higher level of air quality protection. Black symbols indicate constituents with concentrations below the ASILs and emissions below the *de minimis* rates and represent the highest level of air quality protection. Diagonal dashed lines on Figure 6.13 show the SQER and the *de minimis* thresholds. In all cases, the loading rates for detected constituents were below the SQER threshold.

6.3.4 South Slope Area Influence Testing Results

Based on influence testing results and monitoring through December 2019, the addition of extraction wells GW-9, GW-10, and GW-11 provided sustained LFG collection in the South Slope Area. The zone of influence for these three vertical wells covered the South Slope Area, including in native soil below the refuse (Aspect and Herrera, 2019).

It took less than 1 year for GW-9 operation to control methane and carbon dioxide concentrations within the waste and in native soils below the waste, as shown by the graphs on Figure 6.14. The upper graphs on Figure 6.14 show maximum observed LFG concentrations for probes completed in the waste and the lower graphs show maximum observed LFG concentrations for probes completed below the waste. However, operational challenges affected LFG collection in the South Slope Area, including condensate accumulation in the lines, secondary source water recharge at GW-11, and intermittent blower operation starting in June 2019.

- The laterals to LFG collection wells in the South Slope Area were installed above ground and have been subject to condensate generation during periods when the ambient air temperature is lower than the LFG temperature. Because the laterals slope toward the wells, condensate that accumulated above the monitoring assembly prevented system vacuum from reaching the well. Starting in January 2019, condensate management improvements included installing drainage ports. Collected condensate has been discharged to the leachate lagoon.

- Water accumulation in GW-11 was observed and resulted in seasonal submerging of most or all of the perforated section of the well. Starting in January 2019, accumulated water was pumped out on a monthly basis and discharged to the leachate lagoon. Observed refill rates indicated that the effects of pumping lasted less than 1 day. Additional measures, such as continuous and automatic pumping, may be needed to address water observed in GW-11. The source of recharge to GW-11 is unknown.
- The LFG system blower was taken off-line and removed for repairs in June 2019 and reinstalled in September 2019. Following blower repairs and through the end of 2019, the system vacuum for wells in the South Slope Area was low due to dilution air at the blower and wellfield re-balancing.

LFG concentrations rebounded in the South Slope Area during 2019 due to operational challenges discussed above, as illustrated on Figure 6.14; however, no methane was observed at compliance probes in 2019 (Figure 6.9). LFG collection performance in the South Slope Area will be improved by providing condensate management, addressing water recharge at GW-11, and providing continuous system vacuum.

6.4 Leachate

Results of leachate sample analyses are summarized in Table 6.7 and tabulated in Appendix F. The main leachate sample collection locations that were sampled more than twice are depicted on Figure 2.6. The main leachate sample collection locations[7] included the following:

Label	Location	Description
LS-B	Flow Control Vault	Also known as the flow diversion box. Current sample location.
LS-PS1	Leachate Lagoon Pump Station	Pump Station 1. Current sample location.
LS-LVT	Leachate Tank	Leachate Tank at truck loading station. Current sample location.
LS-LVPS	Leachate Lagoon Pump Station	Pump station 1 at Leachate Lagoon. Previously mis-identified.
LS-PS2	Pump Station 2	
LS-PA-D	Leachate Lagoon	3-foot depth from lagoon while aerators on.
LS-PA-S	Leachate Lagoon	Surface of leachate lagoon with aerators on.
LS-PN-D	Leachate Lagoon	3-foot depth from lagoon while aerators off.
LS-PN-S	Leachate Lagoon	Surface of leachate lagoon with aerators off.

Gray shading indicates current sample location.

[7] Locations where routine leachate samples are collected. Does not include LS-BE, LS-CT, and LS-LVPS-2 that were part of a two sample special characterization program in 2013. However, this data is presented in Appendix F Table F.4 and summarized within Table 6.7.

Compounds detected in more than one leachate sample included conventional parameters, 24 metals, 3 chlorinated herbicides, and 14 VOCs.

Unlike groundwater and surface water, regulatory values for leachate are not available, and thus COCs for leachate are not identified. For this RI, constituents detected in leachate were evaluated qualitatively to see if they were also detected in groundwater. Of the constituents detected in leachate, those with a detection frequency greater than 50 percent are barium, calcium, copper, magnesium, nickel, potassium, sodium, and zinc. VOCs and chlorinated herbicides were detected at a frequency less than 15 percent in leachate samples. Anchor QEA performed a geochemical evaluation of groundwater to distinguish leachate from LFG impacts using data from selected Unit Cc2 wells (Anchor QEA, 2017). A summary of this evaluation is presented below in Section 9.2 and a copy of the geochemical analysis is included in Appendix C of this report.

7 Beneficial Use Survey

The following provides a summary of the procedures followed for the beneficial use survey and survey findings. The purpose of the beneficial use survey was to determine the extent of groundwater use by the public in the vicinity of the VLF. A previous domestic well survey was completed by KCWLRD in 2002 for KCSWD. The information and monitoring data gathered in 2002 has been incorporated and updated in this survey.

7.1 Survey Approach

7.1.1 Definition of Survey Area

The Survey Area is based on groundwater flow directions and locations of previously identified and sampled wells. The search radius is presented on Figure 7.1 and is approximately 1/4 mile from the property boundary to the west, north, and south, and 1/8 mile on the east side. There are 69 parcels within the defined radius. The Survey Area depicted in Figure 7.1 was reviewed and approved by the Agencies prior to initiating the survey.

7.1.2 State and County Database Search

Multiple public databases were used to obtain information on property use and drinking water sources within the Survey Area. This data acquisition phase included querying public records databases available online followed up by access of select public records as detailed below.

For wells that service multiple households, Agencies differentiate between Group A and Group B water systems. Group A water systems have 15 or more service connections or serve 25 or more people 60 or more days a year. Group B water systems serve fewer than 15 service connections and fewer than 25 people per day. Both State and local health departments were contacted for information on drinking water sources in the Survey Area.

Washington State Department of Health (DOH)

The Department of Health Office of Drinking Water was contacted for information on water systems registered with the State. Information provided by the State was consistent with the Source Water Assessment Program (SWAP) Mapping Tool, the online database for drinking water systems. Drinking water sources identified include Group A and B systems; however, system locations are based on the center point of the quarter-quarter section of the township range.

Public Health – Seattle and King County (PHSKC)

Prior to 2010, PHSKC was delegated Drinking Water Program responsibilities by DOH. The PHSKC Office of Drinking Water provided GIS data for Group B water systems in the vicinity of the VLF. The search radius used by PHSKC was greater than the Survey Area, to account for parcels within the Survey Area that were connected to systems outside the Survey Area. Well locations provided by PHSKC were consistent with the locations of Group B systems surveyed by the KCWLRD in 2002.

Aspect reviewed public records for the Group B water systems identified in the vicinity of the VLF. Key information provided in the files included well owner, parcel connection information, well depth, and completion date.

While the PHSKC Office of Drinking Water does not maintain files on private water wells, well information is available in their On-Site Sewage System (OSS) Program files. Well locations are provided in as-built OSS drawings that homeowners submit to the OSS Program as part of the permitting process. Aspect reviewed septic system records available online through the OSS website. This information was helpful in determining possible location of wells.

Ecology Well Report Database

Ecology maintains an online database of Ecology Well Reports (Well Report) submitted by drillers for wells completed in the State. The report includes owner name, location of well, well completion details (e.g., depth and screen interval), a well log with lithologic description, and completion date.

Locations in the database are based on quarter-quarter section of the township range (160 acres). Well owner and address, when available, were used to pair Well Reports with parcels; not all Well Reports include an address for the well.

King County Assessor Records

King County Assessor Records were accessed via GIS data available through the King County website and King County iMap, their online search tool. GIS records provide easily tabulated parcel information such as parcel identification number, property owner name, and property use information. King County iMap contains the same information as the GIS data as well as previous property owner names within the past 10 to 20 years. Property owner information was helpful for associating well owners listed in Well Reports with former or current property owners listed in King County iMap.

Ecology Water Resources Explorer

Ecology maintains an online database for water right records. These includes water right claims as well as water resources certificates. These records include groundwater and surface water types of water sources. The search was conducted for parcels that did not have a drinking water source identified based on the 2002 domestic well survey or the other sources listed above.

7.1.3 Beneficial Use Neighborhood Mailer

Properties in the Search Area were contacted via mail by KCSWD. The mailing list was generated using available addresses from the King County Assessor GIS database. A beneficial use survey mailer was sent providing an overview of the private well survey KCSWD was conducting and a request for information about the recipient's water source. A copy of the mailer is provided in Appendix I.

KCSWD mailed 64 mailers and received 13 responses, in addition to 10 mailers returned as undeliverable.

7.1.4 Data Compilation and Additional Research

Data gathered from the above sources has been compiled on Figure 7.1 and in Tables 7.1 and 7.2. Parcels have been assigned an arbitrary Study Reference Number. Parcel and drinking water source information is listed by Study Reference Number in Table 7.1 and locations are identified on Figure 7.1.

In some cases, addresses are not listed on Well Reports, making it difficult to associate the report with property parcels. In four cases listed in Table 7.2 (Study Reference IDs 50, 62, 65, 66), the association between parcel and Well Report was made based on date of well installation and property owner at corresponding time as listed in King County Assessor online records.

One Well Report, Kurt Monier owner with Ecology Well ID 94302, was identified within the Survey Area but could not be associated with a property owner name as listed in King County iMap. To further evaluate where the Kurt Monier well may be located, archived tax records were reviewed at the Puget Sound Regional Archives. The well is listed to have been installed in September 1992. Tax records for the years 1992 and 1993 were reviewed for the eight parcels located within the quarter-quarter section listed as the location on the Well Report. Kurt Monier was not listed as taxpayer on any of the parcels. Note that the parcel with identification number 022202-9085 had no listing, indicating it was created after 1993. The parcels in this quarter-quarter area are either vacant or connected to the 85 Acres Well System. No further assessment was completed to identify the location of the Monier well.

Well locations on Figure 7.1 were based on the KCWLRD's 2002 Survey and PHSKC OSS Program files and/or GIS database. The well location source is listed in Table 7.1.

During the data compilation process, certain parcels and wells were found to have inadequate information to assess drinking water source. The water source for these parcels is listed as "Unknown" in Table 7.1. These parcels are discussed in more detail in the next Section.

7.2 Summary of Findings

The following section provides a summary of findings from the beneficial use survey. Note that wells previously sampled by KCSWD have a unique four-letter identification, which includes the prefix DW. This identification is provided in Table 7.1 and on Figure 7.1

7.2.1 Group A Water System

One Group A water system was identified within the Survey Area – 85 Acres. The 85 Acres Water System is located south of the VLF. The well system manager, Iliad Water Company, LLC, provided KCSWD with a well log and summary of parcels connected to the system. The 85 Acres Water System has 22 parcels connected to the system, 17 of which are located within the Survey Area.

The 85 Acres Water System was identified during the 2002 domestic well survey. The system owners agreed to have KCSWD sample the well water in 2002. KCSWD continues to sample the 85 Acres Water System semi-annually. Data are provided in Table G.2.

7.2.2 Group B Water Systems

Seven Group B water systems were identified in the vicinity of the VLF. Since parcels within the Survey Area may be connected to Group B systems outside the Survey Area, research was expanded to encompass adjacent systems. Twelve parcels in the Survey Area are served by Group B systems.

Two of the Group B systems identified in this beneficial use survey had previously agreed to have KCSWD sample their well water – Paquette Water System (DW-PA) and Dump Road Water System (DW-LO). KCSWD continues to sample the Paquette Water System semi-annually. Data are provided in Table G.2.

7.2.3 Single Family Water Systems

Twenty-one single family water systems were identified within the Survey Area. Seven of these well owners had previously agreed to have KCSWD sample their well water. Data are provided in Table G.2.

7.2.4 Parcels with Limited Information

Twelve parcels in the Survey Area have no identified drinking water source based on the records queried. This includes two parcels which are King County park land (Island Center Forest) and eight parcels which are listed as vacant with no taxable improvements in King County Assessor records. These 10 parcels were not researched further as the property use indicates a water source is unlikely to be present.

Study Reference Number 82 is listed as vacant in assessor records but includes a taxable improvement (192 square-foot cabin). For this beneficial use survey, this property has been identified as having an unknown water source and is located approximately 1,000 feet south of the VLF. Two wells (DW-SS and DW-85) located between the landfill and this parcel have been sampled by KCSWD. A search of the Ecology Water Resources database for this parcel yields one result – a water right certificate for the 85 Acres Group A system, which was correlated based on the associated well log. This has been confirmed to not be in Study Reference Number 82.

A map search in the of the Ecology Water Resources database identifies three additional claims on adjacent Study Reference Number 68, east of and adjacent to Study Reference Number 82. For completeness, these sources are listed in Table 7.1 and on Figure 7.1 as they too may be incorrectly located in the database. These sources include one groundwater claim and two surface water claims for Judd Creek (not certificated rights). No well completion information is available.

Similarly, Study Reference Number 81 is listed as vacant but includes a 2,730 square-foot outbuilding and office. In Table 7.1, the property has been listed as vacant based on review of a King County Hearing Examiner Report dated September 18, 2009 (copy provided in Appendix I). The property is zoned rural residential; however, the appellants in the Examiner report (Zellerhoff Construction, Inc.) had been operating a construction business on the property. The appellant had been seeking a conditional use permit to continue commercial use of the property with one argument being a legal source of water for the property had been problematic; thus, residential occupation was not possible. Drilling a well on the property was not possible due to the 1,000-foot radius from the VLF boundary prohibiting well installation on the parcel. Furthermore, connecting the parcel to Group A or B water systems had not been fruitful. Based on details in the Hearing Examiner Report, no water source is listed for the property.

The final parcel listed with unknown water source is Study Reference Number 47, located 800 feet northwest of the VLF. As discussed in the next section, four wells sampled by KCSWD in 2002 are located between Study Reference Number 47 and the VLF.

7.3 Hydrogeologic Setting of Identified Wells

This section provides an overview of the inferred hydrogeologic setting of drinking water wells in the Survey Area within the context of the VLF site stratigraphic model. The discussion is grouped by location of the wells: North of VLF, West of VLF, and South of VLF. Well Reports outside the Survey Area were reviewed to understand the aquifers being used for drinking water in the area of the VLF, not just those in the Survey Area. In some cases, parcels within the Survey Area are serviced by wells outside the area, as captured in Table 7.1 and Figure 7.1.

Determination of groundwater source for the geologic unit is based on review of well logs (if available), completion depth, and correlation to Cross Sections A-A' and D-D'. Twenty-seven Well Reports were identified within the Survey Area. Information from the Well Reports and the inferred geologic unit are summarized in Table 7.2. Copies of the Well Reports discussed in this section are provided in Appendix I.

With repeated glacial sequences and the lack of detail in the driller’s well log, it can be challenging to determine the geologic unit of completion for a given well. The aquifer completion zones for the off-site wells was inferred from the hydrogeologic unit elevations determined from nearby cross sections and interpretation of the well log. The hydrogeologic unit interpretations will, therefore, be limited by the well elevation accuracy, among other factors (e.g., consistency of geologic units). As discussed in Section 7.1, the location of a parcel’s well has been based on information from the well owner, PHSKC records, or KCWLRD’s 2002 well survey. For a given well location, the surface elevation was then determined via GIS using Lidar data available from Washington Department of Natural Resources.

7.3.1.1 North of Vashon Closed Landfill

Eleven Well Reports were reviewed to assess completion unit for wells north of the VLF. Wells within this area are inferred to be completed in Unit B or just below in the upper Unit C.

Of the eleven wells identified north of the VLF, five were previously sampled by KCSWD as part of the 2002 well survey (DW-BA, DW-FL, DW-LO, DW-SE, and DW-AV), the results of which are presented in in Appendix F, Table F.2.

7.3.1.2 West of Vashon Closed Landfill

Eleven Well Reports were reviewed to assess the completion unit for wells west of the VLF, six of which are located within the Survey Area. Eight of the 11 wells are completed at or below sea level. Review of cross section A-A’ (Figure 3.3) and the well log lithologic descriptions, indicate these deeper wells are completed in either Unit F or deeper. VLF groundwater monitoring data indicates that these deeper aquifers are not impacted by contamination originating from the VLF.

The remaining three wells are located on the west side of Robinwood Creek drainage, only one of which is located in the Survey Area (Study Reference Number 15 or Paquette Water System). Robinwood Creek drainage truncates the impacted unit Cc2 aquifer along the West Hillslope where it discharges; therefore, subsurface migration of impacted groundwater west of Robinwood Creek drainage is not possible. Since the 2002 well survey, the Paquette well (DW-PA) has been sampled by KCSWD semi-annually and the data are presented in Appendix F, Table F.2.

Wells located at Study Reference Numbers 61 and 62 are completed in Unit D and lower Unit C or upper Unit D, respectively. As shallow wells are hydraulically separated by Robinwood Creek from the impacted Unit Cc2 at the VLF, no additional analyses are warranted for these water sources.

7.3.1.3 South of Vashon Closed Landfill

Ten wells and three surface water sources were identified in the area south of the VLF, five of which have Well Reports available for review.

Study Reference Numbers 32, 65, and 66 are completed in Unit D or deeper; this includes 85 Acres Water Source wells (32). The 85 Acres Water System well is inferred to be completed in Unit D. Since the 2002 well survey, the 85 Acres well (DW-85) has been sampled by KCSWD semi-annually and the data are presented in Appendix F, Table F.2.

Study Reference Number 63 (DW-SS) does not have a Well Report available; however, information on well completion depth and lithology was available in KCSWD records from the 2002 well survey. These records indicate well DW-SS is completed in Unit D as well. This well was sampled by KCSWD from 2002 through 2008 and the data are presented in Appendix F, Table F.2.

The Well Report for Study Reference Number 64 indicates the well may potentially be completed in Unit C. The property is located cross gradient from the background well (MW-20) on the VLF, making it unlikely that this well is impacted by groundwater contamination originating from the VLF.

Study Reference Number 68 has two surface water sources, one of which was included in the 2002 well survey (labeled DW-GE). This spring, based on the location from the survey, is located at an elevation of 206 feet (NAVD88), an elevation that corresponds to where Unit Cc3 is observed at the VLF. A well log was not available for review for the groundwater source listed for this parcel in the Ecology Water Resources database.

7.4 Beneficial Use Survey Conclusions

Thirty-three wells and one spring were identified in the vicinity of the VLF. Twenty-eight of the wells reviewed for the beneficial use survey were determined to be located within the Survey Area. Nine of the 33 wells have been sampled previously by KCSWD during the 2002 well survey. Two wells, Paquette and 85 Acres Water Systems, continue to be monitored by KCSWD semi-annually. No evidence of contamination originating from the VLF has been identified in historical and ongoing sampling of these water sources.

8 Terrestrial Ecological Survey

The Terrestrial Ecological Evaluation (TEE) is a risk assessment process that evaluates threats posed by contaminants to terrestrial ecological receptors, as required by MTCA. The requirements are described in WAC 173-340-7490 through 7494, as administered by Ecology. Ecology (2019) guidance for conducting TEEs was consulted for this risk assessment.

The site-specific TEE focused solely on the West Hillslope area because it is undeveloped, forested land with wetlands and seeps discharging from the hillslope that could contaminate soil and be a risk to ecological receptors (Figure 8.1). Groundwater and surface water sampling locations on the West Hillslope included in the RI are presented in Figure 8.1. This TEE included a wetland delineation and soil sampling of the West Hillslope area and screening of surface water and soil data against ecological screening levels.

8.1 Project Area Background

As described in Section 6.1, groundwater contamination is limited to Unit Cc2, and the only surface water contamination was at locations downgradient of Unit Cc2 groundwater discharge points, along the West Hillslope (Aspect, 2018b). Contaminants are present in groundwater and surface water at concentrations exceeding PCULs. VLF-related potential contaminant exposure pathways include groundwater to surface water and groundwater to soil, with the potential for soil and surface water exposure to ecological receptors, as described in Sections 5.3 and 5.4.

8.1.1 Environmental Setting

The West Hillslope is a steep western-facing hillslope located downgradient of the VLF. The West Hillslope area contains high-quality habitat for terrestrial wildlife. The area contains at least 10 acres of mixed lowland forest containing a range of successional native and invasive plant species, including wetland plants, within 500 feet of areas where contamination is located. In a 2006 KCWLRD report (King County, 2006), geologic units in the hillslope outcrop were found to correlate with the underlying units at the VLF (Figure 3.7). The West Hillslope was further investigated by KCWLRD to better understand the location of geologic units and groundwater hydrology (King County, 2011a). The findings of the 2011 KCWLRD report were used to inform the VLF RI.

Groundwater from the South Slope Area flows westerly in Unit Cc2 to the West Hillslope and discharges as seeps. The West Hillslope area has not been impacted by landfill solid waste, and no filling or dumping has occurred in this area. The source of landfill-related contamination to the West Hillslope is entirely via groundwater transport that expresses as seeps that contribute to overland flow and soil inundation.

Another potential source of contamination to West Hillslope soils is historical atmospheric deposition from the former Asarco Tacoma smelter in Ruston, which was located on the shoreline of Commencement Bay, south of Vashon Island and Maury Island. The smelter operated for more than 90 years until closing in 1986. It opened as the

Tacoma smelter in 1890, operating as a lead smelter. Asarco purchased the smelter in 1905 and converted operations to copper smelting. In 1912, arsenic recovery facilities were added. Copper smelting operations stopped in 1985, and the arsenic plant closed in 1986.

Vashon Island is in the footprint of the former Asarco smelter plume, which contributes to higher concentrations of trace elements (Seattle and King County 2000). During operations, emissions were released through a smokestack and escaped through other areas of the smelter plant. Between 1999 and 2001, Ecology and local health departments began to study effects from the smelter emissions. In 2000, the Environmental Health Division of PHSKC released a comprehensive report of surface soil contamination of arsenic, lead, and cadmium on Vashon and Maury Island. The report contained results from a detailed study that showed concentrations of these metals are present at substantially elevated levels and led to multiple studies over many years to characterize the contamination on Vashon Island, Maury Island, and other areas within King, Pierce, Kitsap, and Thurston counties (Ecology, 2012a).

The plant community in the West Hillslope area is a well-developed second-growth successional forest that supports a range of animals. A wetland delineation and habitat assessment of the West Hillslope seep discharge area was conducted on May 9, 2019, by Anchor QEA, LLC, biologists. The wetland delineation, seep locations, existing wells and weirs, and soil sampling locations are shown on Figure 8.1. The U.S. Army Corps of Engineers wetland delineation forms are provided in Appendix J.1.

8.2 Exclusion Evaluation

The criteria for whether a site qualifies for an exclusion of a TEE is specified in WAC 173-340-7491. Per Subsection (1)(c)(i), sites where more than 1.5 acres of contiguous undeveloped land is present on the site or within 500 feet of any area of the site do not qualify for a TEE exclusion. The West Hillslope is 15.3 acres of undeveloped land within the VLF site and therefore does not qualify for a TEE exclusion.

8.3 Evaluation Method Selection

Two methods are available for performing TEEs: a simplified TEE and a site-specific TEE. WAC 173-340-7491(2) provides criteria for selecting the appropriate TEE method.

The West Hillslope area is larger than 10 acres of native vegetation that was observed to be high-quality habitat, including wetlands, and ecological receptors were observed to be attracted to the area. Therefore, the West Hillslope does not qualify for a simplified TEE, and a site-specific TEE was performed.

8.4 Problem Formulation

The TEE problem formulation step includes screening the data to identify chemicals of potential ecological concern (COPECs), determining exposure pathways, identifying terrestrial ecological receptors of concern, and conducting a toxicological assessment that summarizes toxicological properties for the identified COPECs. The following sections detail these problem formulation components.

8.4.1 Screening for Chemicals of Potential Ecological Concern

A qualitative evaluation of surface water data presented in the agency draft "VLF RI Report" (Aspect, 2018b) was performed to select analyses for soil samples collected during the TEE process. Four COCs were present in the seep and weir samples collected on the West Hillslope: dissolved arsenic, dissolved iron, vinyl chloride, and benzene. Concentrations of these COCs are detailed as follows:

- Dissolved arsenic concentrations at the seeps and weirs were found to exceed the Washington State background value per MTCA Method A Table 720-1 (WAC 173-340-900). However, the concentrations are below screening levels for the protection of surface water for ecological receptors.
- Dissolved iron concentrations at the seeps and weirs were found to exceed CWA Section 304(a) screening levels for the protection of ecological receptors with chronic exposure, indicating that dissolved iron may pose a risk to ecological receptors.
- Vinyl chloride concentrations were found to exceed CWA Section 304 screening levels (water and organism) for the protection of human health. No Washington State, CWA, or National Toxics Rule (40 Code of Federal Regulations 131.36) standards have been developed for VOCs for protection of aquatic life, but the concentrations in the seeps and weirs are less than EPA Region 4 Ecological Screening Levels for Surface Water (Chronic Exposures).
- Benzene concentrations at the seeps were found to exceed CWA Section 304 screening levels (water and organism) for the protection of human health. The concentrations are less than EPA Region 4 Ecological Screening Levels for Surface Water (Chronic Exposures).

Based on these surface water results, a lack of existing soil data, and the 2019 wetland delineation, a soil investigation was performed to evaluate risk to terrestrial ecological receptors from soil exposure. Surface soil samples from 0 to 6 inches were collected at 13 locations on July 11, 2019. Soil locations within the wetlands adjacent to groundwater seepages or outfalls from weirs were chosen for sampling to characterize the groundwater to soil pathway. Other locations were selected within wetland areas without evidence of surface water inundation. Additionally, locations that were further from surface flows were chosen to provide information on the spatial variability of chemical concentrations on the West Hillslope; this included a location outside of the wetland that was not affected by groundwater discharge (SO-10) and a location between the roadway and wetland area (SO-13). Table 8.1 includes proposed and actual coordinates. Figure 8.2 shows sampling locations, wetland delineation results, seep and weir locations, and estimated seep channels.

Based on the contaminants detected in groundwater and surface water at the VLF and Ecology's TEE guidance (Ecology, 2017), soil testing included analysis for the following analytes:

- Chromium, hexavalent, solid matrix by EPA Method 7196A

- Arsenic, cadmium, chromium, iron, lead, and manganese by EPA Method 6010C
- Mercury by EPA Method 7471B
- VOCs by EPA Method 8260C; samples for VOC analysis were collected using EPA Method 5035A
- Diesel-range hydrocarbons by Northwest Total Petroleum Hydrocarbons (TPH) – Extended Diesel Range Organics (NWTPH-Dx) Method
- Gasoline-range hydrocarbons by Northwest Total Petroleum Hydrocarbons – Gasoline Range Organics (NWTPH-G) Method
- Total solids by Standard Method 2540G
- Total organic carbon (TOC) by EPA Method 9060 Modified

The soil chemistry lab report is provided in Appendix J.2, and the data validation report is provided in Appendix J.3.

The data obtained during the soil investigation was used to identify surface soil COPECs as part of the TEE. Surface soil COPECs were identified based on point-by-point comparison to ecological screening levels presented in Ecology TEE Table 5.1 (Ecology, 2017). For chemicals where an Ecology TEE screening level was not available, soil screening levels presented in Table 3 of the EPA Region 4 Ecological Risk Assessment Supplemental Guidance (EPA, 2018) were used, as summarized in Table 8.2a of this RI Report.

Additionally, sampling stations SO-10 and SO-13, located in the study area but not within the saturated soil near the wetland seep channel, were used to represent the reference area that is unaffected by seep water. Results from these stations were used for comparison to other stations.

8.4.1.1 Chemicals Detected in Soil

Results from the soil investigation are presented in Table 8.2a, and screening level exceedances are summarized in Table 8.2b. Arsenic, lead, manganese, and mercury were detected at concentrations higher than the ecological screening levels for soil, detailed as follows:

- Arsenic soil concentrations within the wetland areas ranged between 5.17 mg/kg (SO-12) to 59.7 mg/kg (SO-05). Nine wetland area locations contained concentrations higher than Ecology TEE screening levels for the protection of wildlife, which is based on natural background (7 mg/kg). Both reference sample concentrations (SO-10 and SO-13) exceeded the Ecology TEE screening level and were 38.2 and 12.5 mg/kg, respectively.
- Lead concentrations within the wetland areas ranged between 9.21 mg/kg (SO-02) and 67.3 mg/kg (SO-03). Three wetland area locations (SO-03, SO-04, and SO-11) contained concentrations higher than Ecology TEE screening levels for the protection of plants (50 mg/kg). The reference sample concentration for SO-10 also exceeded the screening level and is the maximum detected concentration

at 85.5 mg/kg. The other reference sample concentration for SO-13 is 24.5 mg/kg.

- Manganese concentrations within the wetland areas ranged from 155 (SO-12) to 7,010 mg/kg (SO-02). Four locations had concentrations higher than the state-wide Washington State natural background (1,100 mg/kg), which has been established as the Ecology TEE screening level for the protection of plants. Each of the concentrations at these four locations also exceed the Ecology TEE screening level for the protection of wildlife (1,500 mg/kg). The reference sample concentrations (SO-10 and SO-13) are 573 and 341 mg/kg, respectively. The 95% upper confidence limit (UCL) on the mean for soil manganese in the West Hillslope sample set (n=13) is 3,876 mg/kg, based on the recommended statistic from ProUCL, the 95% Adjusted Gamma UCL (Appendix J.5).

- An exposure point concentration (EPC) for manganese was calculated to further evaluate manganese concentrations related to protectiveness of ecological receptors (Section 8.5.1.4)

- Mercury concentrations within the wetland areas ranged from 0.0158 mg/kg (SO-07) to 0.324 mg/kg (SO-03). Four wetland area locations (SO-01, SO-03, SO-04, and SO-11) had concentrations higher than the Ecology TEE screening levels for the protection of soil biota (0.1 mg/kg). Three locations (SO-03, SO-04, and SO-11) also exceeded the Ecology TEE screening level for the protection of plants (0.3 mg/kg). The reference sample concentration for SO-10 also exceeded the soil biota screening level at 0.221 mg/kg. The reference sample concentration for SO-13 of 0.0749 mg/kg is below Ecology TEE screening levels.

Several VOCs, including acetone, acrolein, bromomethane, and carbon disulfide, were detected at concentrations higher than their respective EPA Region 4 ecological screening levels for soil. No VOCs were detected above Ecology TEE screening levels. VOC concentrations for chemicals with ecological screening level exceedances are detailed as follows:

- Acetone concentrations within the wetland areas ranged from 150 µg/kg (SO-01) to 3,110 µg/kg (SO-04). Five wetland area locations had concentrations higher than the EPA Region 4 ecological screening level for the protection of wildlife (1,200 mg/kg). The reference sample concentration for the field duplicate at SO-10 also exceeded the wildlife screening level at 1,710 µg/kg. The reference sample concentration for SO-13 of 686 µg/kg is below the wildlife screening level. Few detections of acetone are present in groundwater and surface water from the West Hillslope area. It is possible that detections in soil may be an artifact of sample preservation. Soil samples were preserved in the field with sodium bisulfate, which can interact with naturally occurring organic matter to produce acetone with production increasing as organic matter content increases (Clausen et al., 2004; Ecology, 2004). Total organic carbon in soil samples ranged from 6.82% to 28.9% in locations with acetone exceedances.

- Acrolein was detected in one wetland area sample (SO-02). The concentration (65.4 µg/kg) was higher than the EPA Region 4 ecological screening level for the protection of soil biota (0.3 µg/kg) and the practicable quantitation limit (50 µg/kg). Acrolein was not detected in soil reference samples. Acrolein has not been detected in groundwater or surface water from the West Hillslope area.
- Bromomethane was detected in two wetland area samples (SO-02 and SO-05). The concentration for SO-02 (2.24 µg/kg) is below the reporting limit, and the concentration for SO-05 is 8.2 µg/kg. Both concentrations exceed the EPA Region 4 ecological screening level for the protection of soil biota (2 µg/kg). Bromomethane was not detected in soil reference samples. Bromomethane has not been detected above the reporting limit in groundwater or surface water from the West Hillslope area.
- Carbon disulfide was detected in five wetland area samples. Four locations had concentrations higher than the EPA Region 4 screening level for the protection of soil biota (5 µg/kg). Carbon disulfide was not detected in reference area samples. Carbon disulfide has only been detected in 1 percent of groundwater and surface water samples and has not been detected in surface water since 2007. Carbon disulfide naturally occurs in marshes (EPA, 2000), so elevated concentrations may be a natural occurrence and not landfill related.

None of the VOCs identified as human health COCs in surface water (benzene and vinyl chloride) and groundwater (benzene, 1,2-dichloropropane, and vinyl chloride) exceeded ecological screening levels. Concentrations for these VOCs are detailed as follows:

- Benzene was detected in one saturated soil sample (SO-05) at 2.6 µg/kg and one reference sample location (SO-10) at 0.97 µg/kg. Detected concentrations were between the method detection limits (MDLs) and the RDLs and were flagged as estimated. Both detected concentrations were below the EPA Region 4 Ecological Screening Levels for Soil (120 µg/kg).
- 1,2-dichloropropane was not detected (at maximum reporting limit of 14 µg/kg) in any saturated or reference soil sample. Laboratory RDLs were orders of magnitude below the Ecology TEE screening level for the protection of soil biota (700,000 µg/kg).
- Vinyl chloride was not detected in any saturated or reference soil sample (maximum RDL of 14 µg/kg).

TPH was screened against Ecology TEE screening levels. Concentrations for TPH are as follows:

- Gasoline-range hydrocarbons were not detected in any saturated or reference area soil sample. The maximum RDL for gasoline range hydrocarbons is 81.9 mg/kg, below the Ecology TEE screening level (100 mg/kg).
- Diesel-range hydrocarbons were not detected in any saturated or reference area soil sample. Three wetland area samples had elevated RDLs for diesel-range TPH due to low total solids measurements. Total solids for these three samples ranged

from 21.5 to 23.77 percent. The elevated RDLs for these three results (maximum RDL is 231 mg/kg) exceeded the diesel-range TPH screening level (200 mg/kg for diesel and motor oil combined), but all MDLs for these non-detect results were below the screening level, with the maximum MDL at 94 mg/kg.

- Motor oil was detected in one wetland sample (SO-04). The concentration at SO-04, 499 mg/kg, exceeded the Ecology TEE screening level for the protection of soil biota (200 mg/kg for diesel and motor oil combined). The reference sample motor oil concentration for SO-10 also exceeded the screening level and is the maximum detected concentration at 484 mg/kg (543 mg/kg in the field duplicate). Motor oil was not detected in reference sample SO-13.

8.4.2 Background Concentrations of Metals in Soil from Former Asarco Smelter Plume Sources

An Ecology Environmental Information Management System (EIM) data query was performed to assess COPEC metals concentrations in surface soil across Vashon and Maury Islands for comparison to the West Hillslope surface soil concentrations. EIM was queried on August 9, 2019, for all surface soil samples within 0 to 6 inches in depth collected from 1999 to 2017 (2017 was the most recent sampling event in the EIM database) on Vashon and Maury Islands. Table 8.3 provides summary statistics of the EIM query, documented metals concentrations from Asarco smelter plume studies, and the maximum detected result from the 2019 West Hillslope soil investigation. The results of the EIM query are provided in Appendix J.4 (electronic) and are summarized as follows:

- Detected arsenic surface soil concentrations from 1999 to 2017 reported in EIM ranged from 1.7 to 460 mg/kg, with an average of 39.8 mg/kg. Documented metals concentrations from the Asarco smelter plume on Vashon Island near the site range from 40.1 to 100 mg/kg (Ecology 2019a). The maximum detected concentration from the 2019 West Hillslope Soil Investigation is 59.2 mg/kg, indicating that concentrations at the West Hillslope area are within the range measured on Vashon Island and likely related to Asarco smelter emissions.

- Detected lead surface soil concentrations from 1999 to 2017 reported in EIM ranged from 1 to 4,600 mg/kg, with an average of 75.7 mg/kg. A 2000 study by PHSKC found that 75 percent of samples collected from Vashon and Maury Island (n=373), and along the mainland shoreline in West Seattle and south King County line (n=44), had lead concentrations exceeding 250 mg/kg (Ecology, 2001).

  The maximum lead concentration from the 2019 West Hillslope Soil Investigation was detected in the reference sample at 85.5 mg/kg, indicating that concentrations at the West Hillslope area are within the range measured and predicted to be present on Vashon Island and is likely related to Asarco smelter emissions.

- Detected manganese surface soil concentrations from 1999 to 2017 reported in EIM ranged from 497 to 1,852 mg/kg, with an average of 1,162 mg/kg. Manganese was not a contaminant of interest in the Asarco smelter plume studies, and the maximum concentration from the 2019 West Hillslope Soil Investigation (7,010 mg/kg) is higher than expected based on Vashon and Maury Islands data or reported as the Puget Sound Regional 90th percentile value of 1,200 mg/kg (Ecology, 1994). Further evaluation of manganese is discussed in Section 8.5.1.

- Detected mercury surface soil concentrations from 1999 to 2017 reported in EIM ranged from 0.063 to 2.6 mg/kg, with an average of 0.66 mg/kg. Although it is not the focus of intensive studies related to the Asarco smelter plume, mercury is also related to smelter emissions, as cited in Seattle and King County's Vashon/Maury Island Soil Study (2000). The maximum mercury concentration from the 2019 West Hillslope soil investigation is 0.324 mg/kg, indicating that soil concentrations are within the range measured on Vashon Island are likely related to Asarco smelter emissions.

8.4.3 Exposure Pathways

The primary source of VLF-related contaminants is the landfill solid waste, with LFG being the primary source to groundwater. In LFG-driven contamination scenarios, the pathway begins as VOC vapors expelled from the refuse that commingle with LFG. VOCs in the migrating gas dissolve into the soil porewater that subsequently migrates to the water table. VOCs can also dissolve directly into groundwater at the gas-groundwater contact. Metals can dissolve in groundwater from leaching and changes in biogeochemical conditions. Contamination transported by groundwater is then released through seepage and potentially sorbed to soil. The exposure media for this TEE are surface water, including seeps, soil, and biotic uptake. The exposure pathways include the following:

- Direct contact and ingestion of surface water – this exposure pathway is potentially complete for aquatic invertebrates, amphibians, birds, and mammals. Surface water data were screened to identify COPECs for soil sampling for use in the TEE. Surface water was not quantitatively evaluated in this TEE, rather, the data was evaluated above in the Section 6.2.

- Direct contact and incidental ingestion of surface soil – this exposure pathway is potentially complete for terrestrial organisms, including plants, soil invertebrates, birds, and mammals.

- Ingestion of biota – this pathway is potentially complete for herbivorous, insectivorous, and carnivorous birds and mammals. Concentrations in biota were modeled using earthworm and plant uptake coefficients.

8.4.4 Receptors of Concern

Avian and mammalian receptors may be exposed to site contaminants via consumption of plants and invertebrate prey, as well as incidental soil ingestion while foraging at the site. For the purposes of this assessment, it was assumed that the default TEE receptors for mammalian herbivore, mammalian predator, and avian predator (vole, shrew, and robin, respectively) are present and representative of the other similar species that may utilize the site.

Chart 8.1. Summary of Exposure Pathways and Receptors – Terrestrial Ecologic Survey

Primary Source	Primary Release Mechanism	Secondary Source	Secondary Release Mechanism	Exposure Medium	Exposure Route	Potential Receptor
Contaminants in Landfill	Landfill Gas Migration	Groundwater	Seepage	Surface water	Direct contact/ ingestion	Aquatic invertebrates, amphibians, and wildlife. This pathway was not evaluated quantitatively.
				Soil	Direct contact/ incidental ingestion	Terrestrial plants, soil invertebrates, and wildlife (birds and mammals)
				Biotic uptake (plants/prey)	Ingestion	Herbivorous, insectivorous, and carnivorous birds and mammals

8.4.5 Toxicological Assessment

Maximum arsenic concentrations in soil were greater than the protective values for plants and wildlife. Arsenic is naturally present in rocks and soils, with concentrations primarily depending on regional geology and anthropogenic inputs. Arsenic usually occurs as inorganic arsenic in a +3 or +5 oxidation state. In plants, arsenic can inhibit growth; in avian and mammalian wildlife, arsenic can reduce reproductivity, cause a decrease in body weight, and cause mortality or reduced survivorship (EPA, 2005a).

Maximum lead concentrations in soil were greater than the protective value for plants. Lead is naturally present in air, soil, sediment, and water. Lead in soil is usually in the form of organic matter complexes and clay minerals, causing it to be immobile and persistent. The uptake of lead by plants is higher in lower pH soils with low organic carbon content. Lead is not an essential element for plants, and elevated levels may inhibit growth; reduce photosynthesis, chlorophyll, and ATP synthesis; interfere with cell division, respiration, transpiration, and water absorption; and accelerate defoliation and abscission (EPA, 2005b).

Maximum manganese concentrations in soil exceeded the protective values for plants, biota, and wildlife. Manganese is an essential nutrient for plants and animals and can be toxic at elevated concentrations (Graham et al. 1988; Sample et al. 1996; Efroymson et al. 1997a,b). Manganese is the 12th most abundant element in Earth's crust and is a relatively abundant metal. Manganese usually occurs in three oxidation states in the environment (+2, +3, +4). The mobility, solubility, and bioavailability of manganese in an aquatic environment are strongly controlled by pH and oxidation-reduction potential (ORP or Eh). In general, manganese solubility is higher in more acidic (lower pH) conditions and less oxidizing (lower Eh) conditions in which dissolved manganese exists primarily in +2 oxidation state. Elevated manganese levels in plants can cause iron chlorosis, leaf puckering and browning, and uneven distribution of chlorophyll in older leaves. Protective levels of manganese for soil biota are not provided by Ecology (2017). Studies with manganese exposures to soil biota measuring survival, growth, and reproduction endpoints were reported by EPA (2007a) and ranged from 120 mg/kg to 1,200 mg/kg. Because the studies were designed for ecological soil screening level derivation, the study conditions were such that manganese was highly bioavailable, and the estimates of toxicity are conservative (EPA, 2007a). Elevated manganese levels in wildlife can cause neurotoxicity (hypoactivity, nervousness, tremors, and ataxia), liver damage, and decreased growth. The TEE exposure models for vole, shrew, and robin are described in Ecology TEE Table 749-4, and the default input parameters are provided in Ecology TEE Table 749-5 (Ecology, 2017). The default protective levels for vole, shrew, and robin are 1,500 mg/kg, 8,900 mg/kg, and 18,900 mg/kg, respectively.

Maximum mercury concentrations in soil were greater than the protective values for plants and soil biota. While mercury occurs naturally in soil to some extent, atmospheric deposition of mercury, primarily through precipitation, is another important source. In densely forested areas, which receive high amounts of precipitation, mercury concentrations in soil are often 2.5 times higher than concentrations from dry semiarid environments (USGS, 2016). Phytotoxicity to plants may occur at low levels and the protective value is 0.3 parts per million (ppm). However, confidence in this benchmark is low as it is based on a secondary reference. Reduced seedling height and germination was observed by Panda et. al (1992) and the no observed effect concentration (NOEC) for this study was an order of magnitude higher at 34.9 ppm (Efroymson et al. 1997b). Elevated levels of mercury in soil biota were shown to cause reduced survival and cocoon production at 0.5 ppm. A safety factor of 5 was applied to the lowest observed effect concentration (LOEC) of 0.5 ppm resulting in a protective value of 0.1 ppm for soil biota. Confidence in this benchmark is low because it is based on a limited amount of data (Efroymson et al. 1997a).

Maximum acetone concentrations in soil were greater than the protective values for soil biota and wildlife. Acetone does not have a conventional screening benchmark for soil biota; 40 µg/kg is based on water quality benchmarks from ECOSAR and equilibrium partitioning modeling. The wildlife ecological benchmark for mammals is 1,200 µg/kg. These wildlife benchmarks take precedence over the benchmark modeled for soil biota (EPA, 2018). Acetone was observed to cause liver and kidney damage to rats with a no observed adverse effect level (NOAEL) of 1,200 µg/kg and a lowest observed adverse effect level (LOAEL) of 6,300 µg/kg (LANL, 2014).

Maximum acrolein concentrations in soil were greater than the protective values for soil biota. Acrolein does not have a conventional screening benchmark for soil biota; 0.3 µg/kg is based on water quality benchmarks from ECOSAR and equilibrium partitioning modeling. Soil biota is less sensitive to acrolein than aquatic species. Acrolein is mutagenic to microorganisms and fruit fly larvae, but sensitivity decreases with development. Adult fruit flies tolerated 500 µg/L culture medium and 25% mortality was observed when culture medium was 3,700,000 µg/L. Acrolein is volatile and degrades quickly in soil (Eisler, 1994).

Maximum bromomethane concentrations in soil were greater than the protective values for soil biota. Bromomethane occurs naturally in the environment and readily volatizes from soil and water (ASTDR, 2020). Bromomethane does not have a conventional screening benchmark for soil biota; 2 µg/kg is based on water quality benchmarks from ECOSAR and equilibrium partitioning modeling. The EPA Office of Pesticide Programs aquatic life benchmark was derived from a *Daphnia magna* study where the 48-hour (immobilization) EC50 was 2,600 µg/L. This acute toxicity value was multiplied by 0.5, resulting in a 1,300 µg/L aquatic life benchmark (EPA, 2013; EPA, 2019). Because of high volatility of bromomethane, inhalation is expected to be the significant exposure pathway for soil invertebrates.

Maximum carbon disulfide concentrations in soil were greater than the protective values for soil biota. Carbon disulfide is the major degradation product of the fungicide and nematicide sodium tetrathiocarbonate. Carbon disulfide easily volatilizes from soil to the atmosphere and, in aerobic environments, is oxidized to sulfates by biological degradation. Carbon disulfide does not have a conventional screening benchmark for soil biota; 5 µg/kg is based on water quality benchmarks for ECOSAR and equilibrium partitioning modeling. The EPA Office of Pesticide Programs aquatic life benchmark was derived from an 860 µg/L EC50 for *Daphnia magna*, which was the most sensitive aquatic species in the available data. This acute toxicity value was multiplied by 0.5, resulting in a 430 µg/L aquatic life benchmark (EPA, 2007b; EPA, 2019). Another study, a 14-day earthworm acute toxicity test, produced a NOAEC and LC50 of 607 and 1,300 mg Enzone/kg dw soil, respectively (EPA, 2007c). Enzone contains 31.8 percent sodium tetrathiocarbonate (EPA, 2009).

Maximum total diesel and motor oil concentrations in soil were greater than the protective values for soil biota. Diesel and motor oil largely consist of petroleum hydrocarbons and because of widespread use, these compounds are often environmental contaminants. The soil biota protective value (200 mg/kg) is based on a study where soil concentrations of 260 mg/kg diesel were found to cause a 75.9 percent reduction in earthworm survival during a 14-day exposure. However, diesel was not detected in any soil samples from the 2019 West Hillslope investigation. Motor oil may be less toxic to soil biota than diesel. The minimum concentration associated with a significant earthworm bioassay result reported in Ecology (2016) is 3,800 mg/kg. There is high uncertainty with motor oil toxicity, as significant earthworm bioassay results were not observed for concentrations between 500 and 150,000 mg/kg (Ecology, 2016). Detections of motor oil in soil in the West Hillslope soil samples are likely the result of stormwater flow from the Westside Highway and are unrelated to landfill operations.

The West Hillslope contains a complex mixture of groundwater seeps and perennial and ephemeral stream channels that have a mixture of saturated and unsaturated soil conditions that could change the bioavailability of contaminants. This uncertainty is addressed in Section 8.6.

8.5 Ecological Evaluation

The following describes the site-specific TEE for chemicals that exceeded ecological screening levels. Ecological screening levels and exceedances are summarized in Table 8.2b. Screening levels that were used for COPEC evaluation are the lowest soil ecological screening level, substituted with background values or practical quantitation limit (PQL) if higher, as discussed in Section 8.4.1.

For three analytes (manganese, acetone, and acrolein), EPA Region 4 screening levels for the protection of soil biota have been substituted for background concentrations (manganese) or screening levels with less uncertainty (acetone and acrolein). However, the soil biota screening levels will be discussed in this section for informational purposes.

8.5.1 Metals

Metals concentrations in West Hillslope soil were found to exceed ecological screening levels for plants, soil biota, and wildlife.

8.5.1.1 Plants

Arsenic, lead, manganese, and mercury concentrations exceeded plant screening levels. In addition to the screening level evaluation, metals concentrations and plant community field observations were compared to evaluate any differences between wetland and reference areas.

Arsenic and lead concentrations in reference sample SO-10 were found to exceed the screening levels for the protection of plants (10 mg/kg and 50 mg/kg, respectively). The highest lead concentration was measured in reference sample SO-10 (86.9 mg/kg). Manganese and mercury concentrations in the reference samples did not exceed the screening levels for the protection of plants.

During the wetland delineation, field staff evaluated the vegetation conditions, including noting any observed distressed or non-normal vegetation. As discussed in Section 8.4.5, signs of plant stress from arsenic, lead, manganese, or mercury include inhibited growth, defoliation, abscission, iron chlorosis, leaf puckering or crinkling, leaf browning, stem streak necrosis, or internal bark necrosis. During the May 2019 wetland delineation and July 2019 sampling, biologists observed no signs of abnormal growth or stressed plants in either the wetland or reference areas. No differences in vegetation community were observed in areas with higher metals concentrations compared to areas with lower metals concentrations.

8.5.1.2 Soil Biota

Manganese and mercury concentrations exceeded soil biota screening levels. In addition to the screening level evaluation, metals concentrations and soil biota field observations were compared to evaluate any differences between wetland and reference areas.

Manganese and mercury concentrations in reference sample SO-10 and several other samples exceeded the screening level for the protection of soil biota. The manganese screening value for soil biota (450 mg/kg) is less than Puget Sound background soil concentrations (1,200 mg/kg). The mercury screening value for soil biota (0.1 mg/kg) is below the average concentration for Vashon Island surface soils, as discussed in Section 8.4.2.

During the wetland delineation and soil sampling, biologists identified the presence of mollusks (banana slugs, brown slugs, forest snails), annelids (earthworms and castings), and coleoptera (lady bugs, darkling beetles, and brown scarab beetles). These species of soil biota were observed in both the wetland and reference areas.

8.5.1.3 Wildlife

Arsenic and manganese concentrations exceeded wildlife screening levels. In addition to the screening level evaluation, metals concentrations and wildlife field observations were compared to evaluate any differences between wetland and reference areas. For manganese, a literature review was performed to assess if toxicity reference values for wildlife uptake are appropriate or significantly overestimating toxicity. This review is discussed in Section 8.5.1.4.

The arsenic concentration in reference sample SO-10 (38.2 mg/kg) exceeded the screening level for the protection of wildlife (7 mg/kg). The manganese concentrations in the reference samples did not exceed the screening level for the protection of wildlife (1,500 mg/kg).

During the wetland delineation and soil sampling, biologists identified 15 species of birds in the West Hillslope area. Mammals such as squirrels, shrews, and mice were observed or heard. The manganese toxicity reference values for small mammals and birds used as TEE defaults (TEE Table 749-5; Ecology, 2017) were derived by Sample et al. (1996) and were based on tests from dietary exposure. The mammalian manganese toxicity data used for the wildlife exposure model was based on rat dietary exposure to manganese oxide (Mn_3O_4) that was allometrically scaled by body weight to obtain the shrew and vole toxicity reference values (Sample et al., 1996). The avian toxicity value applied to the robin model was based on dietary exposures to manganese oxide in quail. The TEE default worm bioaccumulation factor for manganese used in the exposure models for robin and shrew is 0.29. The default soil-to-plant tissue partitioning coefficient for metals used in the vole model is 1.01. The soil concentration for the protection of wildlife assumes 100 percent bioaccessibility for the relative gut absorption factor.

The default protective levels for shrew and robin are higher than the maximum concentration detected in soil. For vole, the default soil-to-plant partitioning coefficient may be too conservative, and a literature review was conducted to consider the most appropriate value.

8.5.1.4 Literature Survey for Plant Partitioning Coefficient for Wildlife Exposure Model

Ecology (2017) provides a default plant partitioning coefficient (Kplant) of 1.01 for all metals (TEE Table 749-5). To identify Kplant values specifically for manganese, we reviewed available literature regarding manganese deficiency and toxicity for many agricultural species. However, studies presenting synoptic soil and plant tissue data that could be used to calculate a Kplant for manganese were limited.

Whitehead (1987) measured plant manganese in exposures to perennial ryegrass and white clover to 10 different soil samples with a range of manganese from 350 mg/kg to 1,320 mg/kg. The TOC in the soil samples ranges from 0.84% to 3.78%. TOC in West Hillslope soil samples ranged from 1.85% to 28.9%, with an average of 11.5%. Using the Whitehead (1987) samples with manganese concentrations greater than 1,000 mg/kg and TOC greater than 1.85% (n=3), ryegrass and clover root, shoot, and stubble Kplant values range from 0.02 to 0.49, and the 95% UCL on the mean (95% Adjusted Gamma UCL) is 0.183.

EPA (2007) applies the following equation to estimate plant tissue concentrations of manganese ingested by voles:

Equation 1

$$\text{Manganese Cp} = 0.079 * \text{Cs}$$

where:
Cp = manganese concentration in plant tissue (mg/kg dw)
Cs = manganese concentration in soil (mg/kg dw)

The EPA (2007) equation equates to a Kplant of 0.079.

Although the EPA (2007) Kplant is reasonable, to ensure protectiveness of mammalian herbivores (e.g. voles), the Kplant estimated from the Whitehead (1987) study and samples of similar TOC and manganese concentrations to the West Hillslope soil samples was applied to the equation. This modification to the Kplant value is consistent with Ecology (2019a) guidance recommending that chemical concentrations be measured in grasses and forbs. Protective concentrations for vole were calculated using the parameters in Table 8.4a. The resulting calculated protective concentration for vole is 7,727 mg/kg (Table 8.4b).

8.5.2 Volatile Organic Compounds

VOC concentrations in West Hillslope soil were found to exceed ecological screening levels for soil biota and wildlife. Ecological screening levels for the protection of plants were not available for any of the VOCs identified in Section 8.4.1.1. VOCs are not expected to pose a risk to plants in the West Hillslope area.

8.5.2.1 Soil Biota

Acetone, acrolein, bromomethane, and carbon disulfide exceeded soil biota screening levels. As discussed in Section 8.5.1.2, observations during the wetland delineation indicated soil biota was thriving in both the wetland and reference areas.

The acetone concentration for reference sample SO-10 (651 mg/kg) and the SO-10 field duplicate (1,710 mg/kg) exceeded the screening level for the protection of soil biota (40 mg/kg). There were no other VOC exceedances in reference samples.

8.5.2.2 Wildlife

Acetone concentrations exceeded the wildlife screening level. As discussed in Section 8.5.1.3, observations during the wetland delineation indicate the West Hillslope area is high-quality habitat for avian and mammal wildlife.

The acetone concentration in reference area sample SO-10 field duplicate (1,710 mg/kg) exceeded the screening level for the protection of wildlife. There were no VOC exceedances in reference samples.

8.5.3 Total Petroleum Hydrocarbons

TPH concentrations in West Hillslope soil were found to exceed ecological screening levels for soil biota (200 mg/kg). TPH concentrations were well below screening levels for the protections of plants and wildlife (1,600 mg/kg and 6,000 mg/kg, respectively).

8.5.3.1 Soil Biota

Motor oil is the only TPH result with concentrations that exceeded soil biota screening levels. The maximum soil concentration was in reference sample SO-10 (543 mg/kg). The soil biota screening level (200 mg/kg) is based on toxicity tests using diesel-range hydrocarbons and, as shown in Table 8 of Ecology (2016), the LOAEL for earthworm survival is an order of magnitude higher for motor oil (3,800 mg/kg motor oil LOAEL).

As discussed in Section 8.5.1.2, observations during the wetland delineation indicated soil biota was thriving in both the wetland and reference areas.

8.6 Risk Characterization and Uncertainty Evaluation

Overall, the West Hillslope area demonstrates no indication of adverse impacts to plant communities from metals, VOCs, or TPH. A healthy and diverse plant community is present outside of the wetted channels across the wetland and upland portions of the study area. Based on two field inspections, the vegetation exhibits no signs of stress, abnormal growth, or non-normal characteristics. The wetted areas have soil conditions that would not support terrestrial plant communities.

Although arsenic, lead, and mercury concentrations were above literature values for the protection of plants, these concentrations are within the range of area background as discussed in Section 8.4.2. Manganese concentrations appear to be elevated in some locations; however, plant stress was not observed.

No adverse impacts to soil biota from metals, VOCs, and TPH were observed in the West Hillslope Area. Soil biota was observed during two field inspections, and observations were similar between the wetland and reference areas.

Soil biota was assumed to be low given the low manganese concentrations observed at the site. However, soil biota screening levels for manganese are based on very limited data and considered highly uncertain. Puget Sound natural background is approximately three times higher than the EPA (2007a) soil biota screening levels for manganese. The four samples with manganese concentrations above background were also in samples with high TOC and moisture content and located in or near flowing water. The soil biota test data are from studies in soil with TOC content below 2 percent, which is much lower than the average TOC at the site. Further, samples with elevated concentrations are limited to locations near flowing water in the central wetland, which is not suitable habitat for earthworms or other terrestrial soil biota.

The soil biota screening level for mercury is based on limited data, and the maximum West Hillslope area concentration is below the literature LOEC value used to derive the Ecology TEE screening level (Section 8.4.5).

The soil biota screening levels for acetone, acrolein, bromomethane, and carbon disulfide are all based on ECOSAR values for aquatic biota using the EPA Region 4 equilibrium partitioning model. Due to the lack of toxicity studies with soil as the exposure media, these Region 4 screening levels also considered uncertain. Additionally, acetone concentrations may be biased high due to the VOC preservative used during field sampling, as discussed in Section 8.4.1.1. Acrolein, bromomethane, and carbon disulfide were detected in some soil samples but have either not been detected or have been rarely detected in surface water and groundwater (Section 8.4.1.1), so they are not expected to be landfill-related COPECs.

The soil biota screening level for total diesel and motor oil is based on a diesel concentration. Only motor oil was detected in West Hillslope area soil samples, and the concentrations were an order of magnitude below motor oil concentrations shown to have an effect on soil biota.

Based on the analysis in Section 8.5, the protective levels of manganese for vole, shrew, and robin are 7,700 mg/kg, 8,900 mg/kg, and 18,900 mg/kg, respectively (Table 8.4b). The maximum soil concentration (SO-02; 7,010 mg/kg) and the 95% UCL on the mean (3,876 mg/kg) are below the lowest protective level for wildlife. Therefore, vole, shrew, and robin are not at risk from exposure to manganese in soil.

As discussed previously, arsenic concentrations are within the background concentration range expected on Vashon Island. Acetone concentrations may be due to acetone generation during preservation, and the maximum concentration is less than the LOAEL that the wildlife screening level is based on (Section 8.4.5). During the field inspections, birds and mammals were observed in the West Hillslope area, so there is no indication of adverse impacts for these receptors.

8.7 Terrestrial Ecological Evaluation Conclusion and Recommendations

The data from the TEE suggest that no adverse terrestrial ecological impacts are posed by groundwater seeps in the West Hillslope.

Arsenic, lead, and mercury concentrations in the West Hillslope soil samples are within the range of concentrations that have been documented on Vashon sand Maury Islands between 1999 and 2017. Based on this evidence, no elevated risk is present in the West Hillslope area due to arsenic, lead, or mercury.

For manganese, the default protective levels for robin and shrew are above the maximum soil concentration at the West Hillslope; therefore, no risk to these wildlife species is indicated. For vole, the default protective level assumes that plants uptake 100 percent of the soil concentration. Based on an alternative literature Kplant value, the protective concentration for vole is above the maximum detected soil concentration of manganese at the West Hillslope; therefore, no unacceptable risk to vole is indicated.

Soil VOC concentrations were not found to exceed the available Ecology TEE screening levels. Of the VOCs that were identified in the RI as surface water COCs (benzene, 1-2-dichloropropane, and vinyl chloride), only benzene was detected. The benzene detections were in one wetland soil sample and one reference sample at concentrations well below the EPA Region 4 Ecological Screening Level for Soil.

EPA Region 4 Ecological Screening Levels are highly uncertain for other VOCs that were found to have concentrations that exceeded those levels (acetone, acrolein, bromomethane, and carbon disulfide), as they are derived using an equilibrium partitioning model. A source for these VOCs also does not seem to be the landfill, due to few or no detections in surface water and groundwater (acrolein, bromomethane, and carbon disulfide). Furthermore, carbon disulfide may also be naturally occurring in wetland areas and acetone is a known laboratory contaminant produced during sample preservation.

TPHs are not expected to pose a risk, as gasoline- and diesel-range hydrocarbons were not detected in West Hillslope soil samples and the soil biota LOAEL for motor oil is an order of magnitude higher than concentrations in West Hillslope soil samples. Likewise, TPH detected in soil is not associated with the landfill, but rather stormwater runoff from the Westside Highway.

Based on the TEE and field observations, upward adjustment of protective concentrations for ecological receptors is appropriate for some chemicals and receptors. Table 8.5 presents soil concentrations considered protective of plant, soil biota, and wildlife. For plants, the metals values have been adjusted to the maximum soil concentrations detected during the West Hillslope soil study. For soil biota, metals (manganese and mercury), VOCs, and TPH values have been adjusted to the maximum detected concentrations in West Hillslope area soil. For wildlife, arsenic and acetone concentrations have been adjusted to the maximum detected concentrations in West Hillslope area soil.

9 Conceptual Site Model

The conceptual site model (CSM) for the VLF is developed from historical land use information, existing environmental data, and the contaminant fate and transport processes that control the migration of COCs in the natural environment. The following sections describe the components of the CSM and evaluate potential exposure pathways and receptors.

9.1 Physical Conceptual Site Model

The physical components of the CSM are summarized here from more detailed information presented in earlier chapters of this RI.

9.1.1 Hydrogeologic Setting

VLF geology is composed of glacially derived sediments, with surficial geology in the southern portion of the property being primarily glacial till and advance outwash. Groundwater in two underlying stratigraphic units (Unit C and Unit D) has been characterized for the nature and extent of COCs at the VLF.

Unit C is glacially derived, consisting of fine-grained Cf soils deposited in a low-energy glaciomarine or glaciolacustrine setting and coarser-grained soils (Cc) deposited in a higher-energy glaciofluvial deposit. Monitoring wells completed in the Unit Cc1 experience seasonally dry conditions. Hydrographs from Cc1 wells indicate that the residence time of groundwater in this unit is short and that the presence of groundwater in Unit Cc1 wells is likely a transient reflection of downward migration of recharge. Subunits Cc2 and Cc3 are considered to be the principal water-bearing layers of Unit C. As noted in Section 6.1, groundwater contamination is limited to Unit Cc2.

As depicted in the cross sections (Figures 3.2 through 3.6), the Cc units are not continuous across the VLF. For example, Unit Cc3 has not been observed in borings completed north of the VLF closure area. Units Cc2 and Cc3 were not observed in borings northwest of the VLF closure area. In the southeast, Unit Cc2 is thinned in boring MW-20 to not present in boring MW-7 at the east property boundary.

Borings completed at the VLF indicate limited hydraulic interconnection between Cc units, consistent with what is known of their glacial depositional environment. The Cc units are separated from one another by fine grained soils (Cf). The Cf between Units Cc1 and Cc2 consists of interbedded layers of silt, sandy silt, and silty sand. The Cf is noted to become finer grained with clay, clayey silt, and silty clay below Unit Cc2.

Groundwater with concentrations of COCs exceeding PCULs is limited to Unit Cc2. Groundwater flow in Unit Cc2 is westerly and discharges from seeps located on the steep hillslope on the western side of the VLF property. There is no evidence Unit Cc3 has been impacted by landfilling processes.

Unit D is a fluvial deposit exhibiting a wide range in texture consistent with varying energy in a fluvial environment, including sandy gravel channel deposits to fine-grained overbank deposits. Groundwater COCs have not been detected above PCULs in Unit D, whether in on-property wells or off-property domestic drinking water wells monitored by KCSWD.

The lack of interconnection between Unit Cc2 and deeper Units Cc3 and D is supported both by the geologic nature of these units and COC nature and extent. In all deeper borings completed onsite, a fine-grained portion of Unit C (Cf) was observed separating the water-bearing portions of Unit C from the Unit D aquifer as well as between Unit Cc2 and Unit Cc3. Furthermore, Cf soils below Unit Cc2 are noted to have clay or clayey silt in multiple borings across the VLF (MW-19, MW-29, MW-36, and MW-8). As presented in Section 3.4.1, there is limited hydraulic interconnection between the three Cc units. Supporting this, groundwater COCs have not been detected above PCULs in Units Cc3 and D.

9.1.2 Extent of Solid Waste

Based on review of historical topographic maps, solid waste was placed in a former valley starting in the early 1900s. As detailed in Section 2.2, the northwest portion of the landfill (Phase I) was closed in 1988, at which time a liner was placed across the central portion of the landfill. Refuse was accepted for placement in the landfill until 1999.

The estimated location of unlined solid waste (waste placed prior to 1988) is shown on Figure 2.4. Site investigations suggest that refuse extends approximately 300 feet south of the Phase 2 landfill closure area and approximately 70 feet west of the Phase 1 closure area. As shown in Figure 2.4, much of this area is covered by geotextile fabric installed in 1988 at a depth of 3.5 to 6.5 feet bgs. In this unlined area to the south, the geotextile was installed and covered with topsoil at a thickness of 7 or more feet with one exception: approximately 100 feet north of the South Siltation Pond fill soil cover over refuse is 4 feet thick at boring TP-6S/D.[8]

West of the Phase I closure area, 6 or more feet of soil has been noted to cover the waste in explorations along the West Perimeter Road, with one exception: fill soil cover over refuse is approximately 4.5 feet thick at boring BH-8 (completed in 1995).

Within the context of underlying geology, solid waste is in contact with till or the advance outwash. As a coarser-grained unit, the advance outwash would permit greater contaminant transport than the till.

9.2 Contaminants and Source Analysis

The COCs detected in groundwater at concentrations exceeding PCULs are dissolved metals (arsenic, iron, and manganese), VOCs (vinyl chloride, TCE, benzene, and 1,2-dichoropropane), and SVOCs. LFG generated from the refuse area is the primary source of groundwater quality impacts at the VLF, as shown in the following summary of the source analyses and contaminant migration assessments.

[8] Shallow and deep temporary probes TP-6S/D were originally called VTP-6S/D.

9.2.1 Landfill Gas

A suite of gases consisting primarily of methane and carbon dioxide, known collectively as LFG, are typically produced within the subsurface at municipal solid waste landfills as the chemical and biological degradation of solid-waste-containing organic matter progresses as the landfill ages. Methane is most notable due to its flammable and potentially explosive nature. Frequently, due to the type of wastes disposed of within landfills, VOCs may be present and may migrate with the movement of LFG.

In LFG-driven contamination scenarios, the pathway begins as VOC vapors expelled from the refuse commingle with LFG. VOCs in the migrating gas dissolve into the soil porewater that subsequently migrates to the water table. VOCs can also dissolve directly into groundwater at the gas-groundwater contact (Walter et al., 2003). The following subsections summarize the results of key source analysis investigations.

9.2.1.1 Landfill Gas Effects on Groundwater Analysis

Time-series plots and trilinear diagrams developed for a 2005 source evaluation (Berryman & Henigar and UES, 2006b) and included as source evaluation (copies of trilinear plots in Appendix K) indicate that groundwater conditions at the VLF changed in response to closure activities. Their analysis of groundwater and LFG quality indicates that leachate was impacting water quality in the past (prior to and just after Phase 2 landfill closure), but since Phase 2 closure, the leachate influences have become minimal and LFG is the primary source of water quality impacts to groundwater and springs. Time-series plots developed by Berryman & Henigar of groundwater data from impacted wells show a decrease in several parameters (chloride, iron, calcium, magnesium, potassium, sodium, total dissolved solids [TDS], and alkalinity). Calcium, magnesium, potassium, and alkalinity were likely due to dissolution of carbonate materials by carbonic acid from LFG carbon dioxide (Kerfoot et al., 2004).

Trilinear plots of cation and anion groundwater data (Appendix K) provide a water composition assessment and indicate that the impacts to the springs are not the result of mixing of background groundwater and leachate. For the trilinear plot of pre-1997 data (Figure 13 in Appendix K), the data from wells MW-2, MW-5D, and leachate (LS-B), plot closely due to similar concentrations of calcium, chloride, and sulfate. The groundwater and leachate data groups diverge in the plot of 2004 and 2005 data due to changes in leachate composition—increase in chloride and decrease in sulfate.

Theoretically, if the groundwater and seep chemistry were the result of mixing of background groundwater (as monitored at MW-20) and leachate (monitored at LS-B), then the water quality at the West Hillslope weirs and monitoring wells would fall on a line between the two points (see red line on trilinear plot, Figure 15 in Appendix K). Rather, the groundwater and weir data (sample points downslope from West Hillslope seeps) plot closely together and not on this line indicating leachate is not a predominant factor in water quality composition.

Further analysis by Berryman & Henigar (2006b) using groundwater, leachate, and LFG VOC data verified the changes in how leachate has impacted groundwater and LFG impacts on groundwater. In a correlation analysis of pre-closure data, calcium, magnesium, and sodium concentrations from Unit Cc2 wells were highly correlated with leachate chloride concentrations. Alkalinity was correlated with VOCs in both leachate and LFG. A similar analysis of post-closure data found that alkalinity, calcium, magnesium, and sodium in groundwater from these wells were correlated with VOCs in LFG. Berryman & Henigar (2006b) conclude that both LFG and leachate influenced these constituents prior to VLF closure, but that LFG appears to be the dominant influence on groundwater conditions post-closure.

9.2.1.2 Geochemical Source Analysis

Anchor QEA performed a geochemical evaluation of groundwater to distinguish leachate from LFG impacts using data from selected Unit Cc2 wells (MW-2, MW-20, MW-21, MW-33, and MW-35), weirs downgradient of West Hillslope seeps (SW-W2[9] and SW-W3), and from a leachate conveyance structure (LS-B; referred to as “Leachate Box” in Anchor QEA report) (Anchor QEA, 2017; included in Appendix C of this report). Well MW-20 was included to represent background groundwater conditions.

The analyses were completed as a line of evidence to evaluate the relative significance of leachate and LFG on groundwater quality. Based on alkalinity, chloride, and sulfate concentrations, the chemistry of groundwater and seep water differs from that of leachate. Groundwater did not have elevated chloride concentrations indicative of influence from leachate, with one exception: weir SW-W2. Slightly higher chloride and sodium concentrations observed at SW-W2 as compared to other groundwater sample locations suggest a minor contribution of leachate at this location.

Elevated alkalinity at wells MW-33 and MW-35, and weirs SW-W2 and SW-W3, are consistent with LFG influences, not leachate influences. A comparison of alkalinity versus TDS indicated that elevated alkalinity at these wells and seeps is not consistent with impacts from leachate because chloride remains low (Figures 2 and 3 of Anchor QEA, 2017). Furthermore, increased alkalinity in leachate typically also corresponds with increased TDS, whereas the results of this analysis showed that TDS remained low in VLF groundwater data. And finally, sulfate and chloride data are low in groundwater compared to higher concentrations in leachate, for a given TDS concentration. This supports the assertion that leachate is not a source of impact to groundwater.

Further evidence of LFG influence on groundwater includes low dissolved oxygen (0.2 to 0.6 mg/L), absence of detectable nitrate, elevated manganese (959 to 2,030 µg/L),) and elevated dissolved iron (710 to 12,200 µg/L) in wells MW-33 and MW-35. These observations in groundwater are consistent with localized and, likely LFG-induced, mildly reducing conditions downgradient of the landfill. Furthermore, elevated dissolved arsenic concentrations detected at MW-33, MW-35, and SW-W2 (the wet-season sample) are associated with elevated dissolved iron concentrations. Dissolved iron and arsenic were not detected in leachate samples, confirming that arsenic and iron are mobilized in the aquifer under the reducing conditions caused by LFG.

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[9] Anchor QEA cited chloride concentrations at weir “SW-2” in their 2017 geochemical analysis, which is inferred to be weir SW-W2 based on location coordinates presented in the report. SW-S2 is a seep location up-gradient of SW-W2 that historically had higher chloride concentrations than SW-W2.

The final step in the geochemical evaluation (Anchor QEA, 2017) was an isotopic analysis to confirm LFG as the primary source. Downgradient wells and surface water, except for SW-W2, had higher carbon-14 concentrations than upgradient well MW-20 but no increase in chloride concentrations, indicating that the carbon-14 enrichment is due to LFG and not leachate. Isotopic analyses of oxygen ($\delta^{18}O$) and hydrogen (δD) also preclude leachate as a source. The leachate sample was isotopically enriched in δD, reflecting isotopic fractionation associated with methanogenesis, which occurs within the landfill. None of the groundwater and weir samples showed δD-enrichment.

Anchor's findings that LFG is the primary source of groundwater contamination are consistent with the broader VLF dataset. Figures 9.1, 9.2, and 9.3 illustrate the differences between chloride and alkalinity data from leachate (LS-B) with data from Unit Cc2 groundwater wells and groundwater seeps in the south and west slope area where groundwater is impacted (wells MW-5D/MW-35 and MW-33 and seeps SW-S1 through SW-S6). Figures 9.1 and 9.2 are time-series plots for chloride and alkalinity data, respectively, from 2001 through 2017, and Figure 9.3 plots chloride versus alkalinity for the same time period. The data illustrate four key points:

- Chloride concentrations in groundwater have decreased since landfill closure while concentrations in leachate have remained relatively constant, indicating a decline in impacts from leachate to groundwater. Alkalinity concentrations remain elevated in wells MW-33 and MW-35 compared to leachate, indicating LFG influences.
- Alkalinity concentrations have decreased in leachate, indicating LFG controls have been effective within the lined cells.
- No correlations are seen between alkalinity concentrations in groundwater compared to chloride, with the exception of SW-S2 (located upgradient of SW-W2). In groundwater, chloride concentrations remain low while alkalinity is elevated.
- Seep SW-S2 has higher chloride concentrations than other groundwater and weir sampling locations, indicating some possible residual influence from leachate at this seep.

9.2.1.3 Effects of Landfill Gas Extraction

In 2016 and 2018, LFG extraction was expanded into unlined solid waste in the South Slope Area with the completion of LFG extraction wells GW-9, GW-10, and GW-11. In 2016, a set of temporary probes were installed across the South Slope Area to observe changes in LFG concentrations during the influence test of extraction well GW-9. Figure 6.14 shows quarterly maximum methane and carbon dioxide concentrations observed in temporary probes from third quarter 2016 through 2019. The GW-9 influence test was conducted from September 14, 2016 through March 1, 2017. Methane and carbon dioxide concentrations decreased substantially in temporary probes during and following the influence test. The effective radius of influence of GW-9 in the South Slope Area during the influence test was estimated at approximately 100 feet (Aspect, 2017a).

In April 2018, an additional set of temporary probes were installed across the South Slope Area to further define the extent of refuse and methane. Figure 6.12 shows the maximum methane observed at TP-7 through TP-10. Based on the radius of influence determined during the influence test for GW-9, confirmed by methane observed at TP7, two additional gas extraction wells (GW-10 and GW-11) were installed by Aspect in June 2018. GW-10 and GW-11 were connected to the LFG collection system in September 2018. It is hypothesized that the expansion of the extraction well network in the South Slope Area will provide improvements in groundwater quality in the impacted aquifer, Unit Cc2. However, intermittent operation of the LFG collection system during blower repairs in 2019 may have affected short-term groundwater concentrations trends.

As shown in Figure 6.14 and 9.4, startup of GW-9 in September 2016 resulted in decreased LFG concentrations in probes below waste in the South Slope Area within the first year of extraction. During the second year GW-9 was in operation, little to no LFG was observed in probes below waste in the South Slope Area. Following startup of GW-10 and GW-11 in September 2018, an increase in LFG concentrations was initially observed in probes below waste as the radius of influence increased across the South Slope Area. In November and December 2018, elevated LFG concentrations were associated with reduced LFG collection performance due to condensate blockage at GW-9, GW-10, and GW-11. Condensate management was initiated in January 2019, and LFG concentrations subsequently decreased during the first half of 2019 at probes below the waste (Figures 6.14 and 9.4). However, the water level in GW-11 submerged the perforated section, and LFG collection from this location remains limited.

The elevated LFG levels during the second half of 2019 are attributed to blower repairs and subsequent LFG collection system rebalancing. The blower was taken off-line in June 2019 for repairs and was brought back into full-time service in September 2019, as illustrated by low vacuums (negative static pressures) at GW-9 shown on Figure 9.4. System rebalancing and recurring blower shutdowns affected the LFG collection performance from September through December 2019, and elevated methane concentrations was observed at TP-3D during the fourth quarter of 2019.

Vinyl chloride concentrations in South Slope Area groundwater monitoring wells MW-21, MW-35, and MW-33 showed minimum concentrations approximately 2 years after startup of GW-9, as shown in Figure 9.4, consistent with effective landfill gas control. During the first year following startup of GW-10 and GW-11 in September 2018, vinyl chloride increased similar to the temporary increase following startup of GW-9. However, subsequent increases in vinyl chloride at MW-35 and MW-21 during the last half of 2019 are attributed to reduced LFG collection performance due to liquid management challenges, blower repairs, and LFG collection system rebalancing (Figure 9.4). Chloride levels remained near background (refer to Appendix G time series plots and statistical trends) during this period indicating that leachate was not a source of impacts.

As illustrated on Figure 9.4, the increase in LFG concentrations in below waste probe TP-3D correlated closely with the increase in vinyl chloride groundwater concentrations in the South Slope Area. This emphasizes LFG as a source of groundwater impacts and demonstrates the need to maintain LFG collection system performance in the South Slope Area by providing effective liquid management and consistent blower operations.

9.2.2 Leachate

Landfill leachate impacts can be inferred when chloride concentrations in groundwater are higher than background values. As discussed in Section 9.2.1, chloride data indicate leachate-influenced contaminant concentrations in groundwater prior to VLF closure (Berryman & Henigar and UES, 2006b; Anchor QEA, 2017). Leachate does not appear to be a primary source to groundwater contamination post-closure, except at seep SW-S2. Slightly higher chloride and sodium concentrations as compared to MW-33 and MW-35 suggest a minor contribution of leachate at that location, in addition to contribution by LFG.

Chloride concentrations observed at SW-W2 are consistent with a residual leachate impact because chloride concentrations have decreased overtime. For example, SW-W2 (located downslope from seep SW-S2) chloride concentrations were near 30 mg/L in 2001 but had decreased to 17.3 mg/L by 2019 (Table F-3). This decreasing trend in chloride concentrations with consistent elevated alkalinity concentrations presents strong evidence that leachate is a residual impact and LFG is the current and primary impact (Figures 9.1 and 9.2).

9.2.3 Groundwater to Surface Water

Surface water impacts are located along the West Hillslope. Groundwater from Unit C discharges as seeps along the West Hillslope on the west side of the VLF property, flows downhill, and is intercepted by weirs near the western property boundary. The water flows as surface water beyond the western property boundary in an unnamed tributary of Robinwood Creek. Elevation and visual reconnaissance of the soil outcrops at the surface indicate that the seeps are expressions of groundwater discharging from Unit C. An analysis of groundwater chemistry from these seeps and impacted VLF monitoring wells indicates that Unit Cc2 is the primary source of contamination at the seeps. Thus, groundwater discharging from the property is a source to downgradient surface water.

9.3 Fate, Transport, and Attenuation Processes

9.3.1 Fate and Transport

The following sections describe the fate and transport of COCs in groundwater within the VLF. As discussed further in the following sections, the primary contaminant fate and transport processes include:

- Migration of LFG from refuse, followed by dissolution of VOCs to groundwater.
- Migration of leachate from refuse.
- Migration of COC-affected groundwater to potential receptors.

9.3.1.1 Migration of Landfill Gas from Refuse

The LFG generated by waste in the landfill closure area is controlled to the maximum extent possible by the existing LFG collection system. A long history of effective control of horizontal LFG migration has been observed during routine monitoring at compliance probes. In the South Slope Area, LFG control measures were implemented with the operation of extraction well GW-9 beginning in September 2016. Control of LFG migration from unlined waste in the South Slope Area was demonstrated within a radius of approximately 100 feet of extraction well GW-9. Additional measures have been implemented to further control LFG in the South Slope Area with the installation and operation of extraction wells GW-10 and GW-11 in 2018, as discussed in Sections 4.4 and 10.1.3.

LFG not intercepted by the collection system migrates through the native unsaturated zone soils, as inferred from VOCs and LFG in gas probes and affects groundwater quality in the South Slope Area. LFG contacts infiltrating precipitation as soil moisture and shallow groundwater, resulting in reducing conditions in groundwater. VOCs in LFG, in particular vinyl chloride and its parent products, partition into soil moisture or groundwater. Furthermore, the commingling of carbon dioxide in LFG and groundwater generates geochemically reducing conditions (i.e., redox conditions) accompanied by dissolution of naturally occurring metals, which is illustrated at the VLF by the elevated dissolved arsenic and iron concentrations in Unit Cc2 groundwater.

9.3.1.2 Migration of Leachate from Refuse

Leaching of constituents from refuse is a normal process at a landfill, at rates that depend upon refuse age and stage of decomposition. VLF closure included installation of infrastructure to collect leachate and prevent it from commingling with groundwater. Leachate not captured by the collection system may migrate from refuse through the native soils or via other preferential pathways, such as landfill infrastructure. Historically, groundwater in the south VLF area was impacted by leachate (Section 9.2.2). As the impact has attenuated over time, little evidence of leachate migration to groundwater is currently observed.

9.3.1.3 Migration of COC-Affected Groundwater to Potential Receptors

Groundwater contamination at the VLF is limited to Unit Cc2 groundwater at the southern and western portions of the property. The COCs in impacted groundwater are VOCs and dissolved metals. The vinyl chloride-impacted groundwater plume is located adjacent to the South Slope Area of unlined solid waste. Groundwater flow through Unit Cc2, and thus COC transport and attenuation, is toward the west, with discharges as seeps along the steep West Hillslope (west of Westside Highway SW). At two surface water sampling weirs downhill from West Hillslope seeps, vinyl chloride exceeded its PCUL. Exceedances of dissolved metals and other VOCs are found within the VLF property and are generally co-located with vinyl chloride exceedances.

Vinyl chloride concentrations in surface water (based on surface water data collected between 2007 and 2010) decrease further downgradient as VOCs volatilize during aeration of surface water before it enters Robinwood Creek, located 800 feet west of the VLF property boundary. Vinyl chloride was not detected at surface water sampling location SW-E on Robinwood Creek, located 1,500 ft downstream from the western property boundary.

9.3.2 Groundwater Attenuation

9.3.2.1 Natural Attenuation of Organic Compounds

The concentrations of VOCs in Unit Cc2 wells and the seeps have decreased consistently over time. Declining concentrations in wells completed in Unit Cc2 and confirmed presence of chlorinated VOC-degrading bacteria (Anchor QEA, 2017) indicate attenuation is due to both physical (dispersion, dilution) and biological (reductive dechlorination) processes.

Natural attenuation is evident temporally and spatially. Time-series data for vinyl chloride (Figures 9.4 and 9.5) illustrate the decreases at wells MW-2, MW-21, and co-located wells MW-5D/MW-35 since VLF closure in 2001. Vinyl chloride concentration in seeps on the West Hillslope have shown a similar decrease. When seeps were sampled between 2007 and 2010, detected concentrations of vinyl chloride ranged between non-detect (an RDL of 0.02 µg/L) and 7.4 µg/L. When resampled during wet- and dry-season events in 2016/2017, concentrations ranged between non-detect and 0.064 µg/L.

As of 2019, concentrations of vinyl chloride detected on the West Hillslope have ranged from non-detect (an RDL of 0.01 µg/L) to 0.042 µg/L. As discussed in Section 9.2.1.3, an increase in vinyl chloride occurred during 2019 in some of the South Slope Area monitoring wells. An increase in alkalinity accompanied the vinyl chloride increase while chloride levels remained near background conditions indicating the increase is related to control of LFG and maintaining effective blower operation.

Spatially, natural attenuation of vinyl chloride can be seen in Figure 9.4. This figure depicts decreasing vinyl chloride concentrations along an approximate flow path within Unit Cc2 from well MW-33, downgradient to weir SW-W3 on the West Hillslope where groundwater from Unit Cc2 is known to discharge at the surface. Vinyl chloride concentrations decrease by an order-of-magnitude across the illustrated flow path. For example, in 2019, average vinyl chloride concentrations are 31.6 µg/L at MW-33. Further down gradient at MW-35 vinyl chloride concentrations decrease to 4.60 µg/L, and then to 0.035 µg/L at SW-W3 in the West Hillslope Area.

Microorganisms capable of degrading chlorinated VOCs (e.g., *Dehalococcoides* spp.) are found in MW-2, MW-21, MW-33, MW-35, SW-W2, and SW-W3 (Anchor QEA, 2017). The reported abundances of these microbes are highest in the wells with the highest detected VOC concentrations (MW-33 and MW-35).

In February 2016, well and seep samples were collected and analyzed for dissolved methane, ethane, and ethene to represent wet-season conditions. Methane is an indicator of strongly reducing conditions and may also be an indicator of LFG; ethane and ethene are products of microbial reductive dechlorination of chlorinated ethenes and ethanes. All constituents were detected in the wells and seeps sampled, with the highest concentrations detected at wells MW-33 and MW-35, and seep SW-S2. No chlorinated VOCs were detected in SW-W2, and vinyl chloride was detected sporadically at only trace concentrations (approximately 0.05 µg/L) in SW-W1 and SW-W3, indicating essentially complete biodegradation of chlorinated VOCs upgradient of the seeps.

Dissolved gases were again sampled during three events in 2019 from select monitoring wells. Elevated methane and concentrations of ethane and ethene were again detected in

MW-33 and MW-35. The elevated methane concentrations in these wells is attributable to their proximity to the South Slope Area and the affect by LFG. Ethane and ethene are produced from biologically mediated reductive dechlorination. The presence of these non-toxic gaseous end products provide further evidence of biodegradation of chlorinated VOCs (EPA, 1998).

9.3.2.2 Natural Attenuation of Metals

The microbial decomposition of organic matter in landfills creates reducing conditions ultimately leading to methanogenic fermentation. Increased arsenic and iron concentrations commonly occur under reducing conditions, as arsenic can be released by the dissolution of naturally occurring arsenic-bearing iron oxyhydroxides in the aquifer matrix (Anchor QEA, 2017).

Arsenic and iron mobilization is associated with reducing conditions. Arsenic and iron attenuate downgradient of the VLF with the infiltration of oxygenated water. The oxygenated water oxidizes iron to iron oxides, which become effective sorbents for dissolved arsenic. Dissolved oxygen concentrations increase downgradient of wells MW-33 and MW-35 to levels similar to background (1 to 2 mg/L) and, in the seeps, even higher (1 to 20 mg/L), indicating a return to aerobic conditions. Under these conditions, iron is oxidized and typically precipitates as iron oxide coatings on the aquifer matrix grains and hillslope soils. This iron oxidation process results in the orange precipitates visible in the West Hillslope area.

The iron oxides strongly adsorb dissolved arsenic from groundwater, resulting in its attenuation. This attenuation of arsenic is illustrated by comparison of data from wells MW-33 and MW-35 and seep samples. Dissolved arsenic ranges between 22.9 and 57.2 µg/L at MW-33 and MW-35. Downgradient seeps SW-24S and SW-S2 have ranged between 9 and 34.1 µg/L while other West Hillslope seeps range from 1 to 6.1 µg/L. At the weirs, arsenic and iron concentrations further attenuate very low dissolved arsenic (<8 µg/L) and iron (<1,000 µg/L) concentrations.

9.3.3 Landfill Gas Attenuation

LFG attenuates with distance from its source due to physical, chemical, and biological processes. The relative influence of these attenuation factors vary over time and space. LFG migration control at the VLF has been dominated by the active LFG collection system, represented by reduction in the extent of methane, as depicted on Figure 6.12. Observed rebound in methane and carbon dioxide concentrations in the South Slope Area during 2019 (Figure 6.14) resulted from intermittent LFG collection.

9.3.4 Leachate Attenuation

Leachate attenuates with distance from its source through both physical (dispersion, dilution) and biological (reductive dechlorination) processes. Leachate attenuation is also attributed to reduced leachate generation as the landfill ages.

9.4 Pathways of Exposure and Receptors

Potential exposure pathways were introduced in Section 5.3. This section evaluates the likelihood for these exposure pathways to be complete under current or potential future uses on and off the VLF property, based on the data presented in the preceding sections and the pathway-specific PCULs identified in Section 5.5.

Exposure pathways identified in Section 5.3 that are applicable to metal COCs in groundwater are limited because they are not volatile and have limited mobility. One of the metal COCs – iron – also exhibits very low toxicity to humans and therefore has very high screening levels for exposure via direct contact. The driver for iron being a COC in this RI is for the protection of aquatic ecological receptors. However, as depicted in Figure 6.3, the only exceedances of the iron PCUL have been in groundwater within the VLF property and thus aquatic ecological receptors are not exposed to adverse concentrations of iron in surface water.

Arsenic is classified as a human carcinogen and thus the arsenic PCUL takes into account human health exposure. As depicted on Figure 6.1, exceedances of the arsenic PCUL for the protection of human receptors have largely been confined to groundwater within the VLF property. Figure 6.1 also summarizes detections of arsenic in surface water sample locations along the western property boundary (as surface expressions of groundwater) and demonstrates that there have been no exceedances of the arsenic PCUL. Maximum detected concentrations of arsenic were below applicable screening levels for the protection of ecological receptors.

The main COCs driving the evaluation of the exposure pathways under current and future uses presented in Table 9.1 are volatile COCs (1,2-dichloropropane, benzene, TCE, and vinyl chloride). There are no screening levels developed for volatile COCs for the protection of ecological receptors.

Some of the potential pathways and receptors presented in Section 5 are not complete, based on evaluation of the data or when factoring in the VLF operational environmental control systems that are in place. An exposure pathway was considered complete if all of the following criteria apply:

1. There is a chemical release from a source.
2. There is an exposure point where contact can occur.
3. There is an exposure route for contact to occur.

On-property, there are no current residential receptors because the property is actively managed as a landfill. King County Board of Health Code, Title 10, Section 10.09.060 provides construction restrictions for any enclosed structures on or within 1,000 feet of an active, closed, or abandoned landfill. Enclosed structures must be constructed to be protective from potential methane migration. Documentation of the methane migration protection must be provided in a report authored by a licensed professional engineer. Given these development restrictions, the likelihood of potential future residential development of the VLF property for residential land-use is low, therefore current and potential future residents are not considered receptors on the VLF property.

Title 12 Section 12.24.010(C)(4) prohibits installation of new public drinking water wells within 1,000 feet of a sanitary or abandoned landfill. Likewise, WAC 173-160-171 prohibits installation of a drinking water well within 1,000 feet of an existing landfill.

These drinking water well restrictions eliminate the residential exposure pathway on or within 1,000 feet of the VLF.

All the exposure pathways and receptors evaluated are listed in Table 9.1, and each is assigned a status as complete/potentially complete, incomplete, or mitigated. Complete/potentially complete exposure pathways for human and ecological receptors that represent an existing or potential future risk on and off the VLF property are summarized below.

9.4.1 Groundwater

Complete and potentially complete exposure pathways for COCs in groundwater to reach human receptors include direct contact, ingestion, and discharge to surface water. To evaluate this pathway, PCULs for the protection of groundwater were used (Table 6.2).

Direct human exposure via dermal contact

Direct contact of current and potential future on-property VLF staff and construction workers is an exposure pathway mitigated by landfill safety procedures. Although currently mitigated, this represents a potential future exposure pathway that would need to be addressed in the FS.

Direct human exposure is a potentially complete pathway for residents off-property; however, there is no exposure because the extent of impacted Unit Cc2 groundwater does not extend off-property. The pathway for above- and below-ground workers off-property is considered incomplete due to the depth to groundwater.

Direct human exposure via ingestion

This is considered a potentially complete pathway for off-property for both current and potential future residents; however, groundwater monitoring has demonstrated that exceedances of federal and state drinking water MCLs for groundwater COCs are constrained to within the property boundary. Existing King County Board of Health regulations prohibit the installation of drinking water wells within 1,000 feet of landfills.

Discharge to surface water

To evaluate this pathway, PCULs for the protection of surface water were used (Table 6.3). Groundwater on the VLF property exceeds these screening levels for arsenic, iron, 1,2-dichloropropane, benzene, TCE, and vinyl chloride. Complete surface water exposure pathways are further summarized below.

9.4.2 Surface Water

Complete and potentially complete exposure pathways for COCs in surface water to reach human and ecological receptors include direct contact with surface water, ingestion of surface water, and ingestion of aquatic organisms.

Direct contact with surface water

This exposure pathway is complete for current and potential future on-property recreational users and ecological receptors. This exposure pathway is potentially complete for current and future off-property residents, and off-property recreational users. Vinyl chloride is the driver of this pathway being complete for exposure to human receptors. Iron and arsenic are the drivers for this pathway being complete for on-property ecological receptors.

These complete on- and off-property exposures would need to be addressed in the FS and additional investigation pertaining to vinyl chloride exceedances at the south property boundary is identified as a data gap in Section 10.2 below. As indicated above, a covenant restricting residential and recreational land-use of the VLF property would make these pathways incomplete for these receptors.

Although there is a potentially complete pathway for off-property ecological receptors, there are no metals exceedances at the property boundary and there are no ecological criteria for VOCs, so there is no off-property ecological exposure risk. This exposure pathway would not need to be addressed in the FS.

Ingestion of surface water

This exposure pathway is potentially complete for current and potential future on-property ecological receptors due to exceedances on-property of metals COCs in surface water. This pathway would need to be addressed in the FS.

Off-property, the RI data indicates that dissolved metals are not present at the property boundary and thus are not migrating off-property at concentrations exceeding PCULs for the protection of ecological receptors. This exposure pathway would not need to be addressed in the FS.

Ingestion of aquatic organisms

There are only off-property complete pathways for this exposure route. Off-property, this exposure pathway is complete for current residents and recreational users and potentially complete for future residents and recreational users. This exposure pathway is driven by the human ingestion of aquatic organisms containing bioaccumulative compounds originating from discharge of groundwater to surface water.

The complete and potentially complete exposure pathways would need to be addressed in the FS.

9.4.3 Landfill Gas

Potential exposure pathways for LFG are inhalation, explosivity, and impact to groundwater. This exposure pathway affects landfill workers. There is no evidence of off-property LFG migration, so this exposure pathway is incomplete for off-property receptors.

Inhalation of fugitive landfill gas

Exposure to current and potential future on-property above- and below-ground VLF staff and construction workers is mitigated by landfill safety procedures. This exposure pathway would need to be addressed in the FS.

Landfill gas explosions

Exposure to current and potential future on-property above- and below-ground VLF staff and construction workers is mitigated by landfill safety procedures and routine monitoring that are in place for staff and worker protection. This exposure pathway would need to be addressed in the FS.

Impact to groundwater

The migration of fugitive LFG to groundwater is a complete pathway. See the groundwater discussion above.

9.4.4 Leachate

Potential exposure pathways for leachate are direct contact and discharge to groundwater. This exposure pathway affects VLF staff and construction workers. There is no evidence of off-property leachate migration, so this exposure pathway is incomplete for off-property receptors.

Direct contact to fugitive leachate

Exposure to current and potential future on-property above- and below-ground VLF staff and construction workers is mitigated by landfill safety procedures. Placement of a covenant restricting future sub-surface work or requiring appropriate safety procedures would make this pathway incomplete for potential future below-ground workers. This pathway would need to be addressed in the FS.

Impact to groundwater

The migration of fugitive leachate to groundwater is a complete pathway; however, as the landfill ages, this pathway is diminishing. See the groundwater discussion above.

9.4.5 Refuse

Complete and potentially complete exposure pathways for COCs in refuse to reach human receptors include direct contact with shallow refuse and direct contact with soil impacted by shallow refuse. This exposure pathway is only relevant in areas where refuse is present at depths shallower than 15 feet, as specified by MTCA. Figure 2.4 depicts the areas where refuse extends beyond the final cover and identifies the depth to which refuse was observed. This exposure pathway affects only below-ground workers. There is no evidence of off-property refuse placement, so this exposure pathway is incomplete for off-property receptors.

Direct contact by below-ground workers

This exposure pathway is complete for current below-ground workers and potentially complete for potential future below-ground workers. As depicted in Figure 2.4, a geotextile liner and cover soil separates most of the refuse from ground surface in the South Slope Area; however, there are three locations outside the geotextile liner boundary that have refuse shallower than 15 feet bgs. Placement of a covenant restricting current and future sub-surface work would make this pathway incomplete. This pathway would need to be addressed in the FS.

Direct contact by burrowing terrestrial organisms

Within the Phase 1 and Phase 2 closure areas, refuse is beneath a geomembrane, providing a physical barrier to prevent exposure of plants and wildlife. In the South Slope Area, refuse containing hazardous substances that may be present near ground surface has an average soil cover thickness of 10 feet, as estimated from borings that have been completed in the unlined portions of the landfill. The South Slope Area soil cover thickness is greater than 6 feet except near TP-6S/D.[10] The depth of biological activity in the South Slope Area is further reduced by a geotextile fabric that is placed across the South Slope Area to stabilize soils. The geotextile fabric is at an approximately depth of 3.5 to 6.5 feet and its lateral extent is illustrated on Figure 2.4. Based on the depth to refuse and the presence of a geomembrane, the exposure pathway of direct contact by burrowing terrestrial receptors is therefore considered incomplete. This exposure pathway would not need to be addressed in the FS.

9.4.6 Soil

Direct contact and ingestion by terrestrial and burrowing organisms

This pathway is complete for terrestrial organisms (e.g., plants, soil invertebrates, birds and mammals) and burrowing terrestrial organisms (e.g., voles) due to arsenic, lead, manganese, and mercury exceedances of MTCA TEE Screening Levels. However, based on further evaluation of available literature and publicly available soil sampling data, arsenic, lead, and mercury concentrations are consistent with area-wide background concentrations and thus there is no elevated risk to these receptors.

Manganese also exceeded Ecology TEE Screening Levels. However, through further risk evaluation it was determined that manganese concentrations are protective for robin and shrew, so no risk to these species is indicated. A site-specific TEE was conducted for manganese impact to voles and results indicate that observed soil concentrations are protective and there is no risk to vole. This exposure pathway would not need to be addressed in the FS.

Direct contact and ingestion by humans

This exposure pathway is mitigated for current above- and below-ground workers and potentially complete for potential future above- and below -ground workers on the West Hillslope. However, these pathways are mitigated by landfill safety procedures that are in place to protect workers. Where property access is not restricted on the west side of Westside Highway, this exposure pathway is also potentially complete for recreational users and potentially complete for potential future recreational users. As discussed in Section 9.4.5, placement of a covenant restricting current and future sub-surface work and access restrictions on the West Hillslope would make this pathway incomplete. This pathway and any applicable soil cleanup levels would need to be addressed in the FS.

9.4.7 Biotic Uptake

Ingestion by terrestrial and burrowing organisms

This pathway is complete for terrestrial organisms (e.g., herbivorous, insectivorous, and carnivorous birds and mammals) and burrowing terrestrial organisms (e.g., shrew and voles). This pathway considers the uptake of contaminants through plants and prey. During the TEE wetland survey and soil sampling events, no plant impacts were observed and through the site-specific TEE, it was identified that soil concentrations were protective of voles consuming plants. Based on these findings, there is no elevated risk to herbivorous receptors. Like the soil pathways discussed above there are no elevated risks

[10] Shallow and deep temporary probes TP-6S/D were originally called VTP-6S/D.

to prey receptors and thus there is no elevated risk to those carnivorous receptors. This exposure pathway would not need to be addressed in the FS.

10 Remedial Investigation Conclusions

10.1 Conclusions

10.1.1 Groundwater

- Groundwater contamination at the VLF is vertically limited to Unit Cc2 groundwater at the southern and western portion of the property. The horizontal extent of contamination is depicted on Figure 10.1. The extent of vinyl chloride in Unit Cc2 groundwater exceeding PCULs remains undefined south of wells MW-2 and MW-21.
- Groundwater COCs include dissolved metals (arsenic, iron, and manganese), VOCs (vinyl chloride, benzene, 1,2-dichloropropane, and TCE), and SVOC (bis(2-chloroethyl) ether.
- None of the volatile COCs evaluated, including vinyl chloride, benzene, 1,2-dichloropropane, and TCE, had statistically significant increasing trends.
  - Statistically significant decreasing trends for vinyl chloride were observed in South Slope Area wells MW-21, MW-33, and MW-35 as well as surface water weir SW-W1.
- Unit Cc2 groundwater flow direction is westerly and discharges as seeps on the West Hillslope on the west side of the VLF property.
- The primary source of impacts to groundwater is LFG. See Section 10.1.3 for conclusions regarding LFG and groundwater. Residual leachate impacts have diminished overtime.
- Groundwater monitoring has demonstrated that exceedances of federal and state drinking water MCLs for groundwater COCs are constrained to within the property boundary. Unit Cc2 is not a primary drinking water source and there are no drinking water standard exceedances in Unit Cc2 outside of the VLF property boundary. Unit D and deeper groundwater is not impacted by VLF COCs. Domestic water supply wells DW-PA and DW-85 continue to be monitored and no evidence of contamination originating from the VLF has been found in any of the domestic wells.
- Potentially active exposure pathways for impacted groundwater are fish consumption and direct contact with surface water on the VLF property.
- No terrestrial ecological impacts are posed by groundwater seeps in the West Hillslope.

MTCA defines “Site” or “Facility” as everywhere that contamination has come to be located. The VLF MTCA Site includes those areas delineated on Figure 10.1 where COCs exceed PCULs. More specifically, the VLF MTCA Site is bounded to the north by the edge of the Phase 2 final cover and by MW-4 and MW-36, and to the east by the estimated extent of unlined refuse and MW-20. To the south, vinyl chloride exceeds

PCULs at the southern property boundary; however, COC concentrations at MW-21 exceed PCULs and are expected to decline with the expansion of the LFG collection system and consistent system operation. COC concentrations at south boundary well MW-21 are below federal and state drinking water MCLs. At the west property boundary, only vinyl chloride exceeds PCULs; however, downgradient of the VLF, concentrations of vinyl chloride do not exceed PCULs at a sampling location 1,600 feet west of the VLF in Robinwood Creek (SW-E).

10.1.2 Surface Water

- Surface water contamination at the VLF is limited to surface water locations downgradient of Unit Cc2 groundwater discharge points along the West Hillslope of the VLF property. COCs exceeding surface water PCULs include dissolved metals (arsenic and iron) and VOCs (vinyl chloride, benzene, and 1,2-dichloropropane).
- Only vinyl chloride exceeds PCULs at the west VLF property boundary but is not detected at a sample point in Robinwood Creek, 1,500 feet downstream of the west property boundary. Attenuation of vinyl chloride is evidenced by the marked decrease in concentration across the flow path.
- Potentially active exposure pathways for impacted surface water are the same as those for groundwater.

10.1.3 Landfill Gas

- LFG is the primary source of groundwater impact.
- LFG contacts infiltrating precipitation as soil moisture and shallow groundwater, resulting in reducing conditions in groundwater.
- The locations where methane is present in temporary gas probes completed directly below refuse coincides with the area where COCs are present in groundwater (i.e., on the south side of the landfill). This, coupled with the results from the geochemical investigation, provide evidence supporting the LFG-to-groundwater pathway.
- Lateral control of LFG is maintained by active LFG collection infrastructure. No off-property migration of LFG has been observed since at least 1998, as exemplified by Figure 6.9 depicting compliance probes with less than 5 percent (and typically 0 percent) methane.
- LFG extraction from GW-9, GW-10, and GW-11 provided measurable control of migration across most of the South Slope Area, reflected in the methane extent mapped on Figure 6.12.
- Vertical control of LFG migration has been pursued through interim actions conducted by KCSWD since landfill closure, including installation of vertical extraction wells GW-1 through GW-8 in the Phase I closure area, and the

expansion of the LFG control system in the South Slope Area with installation of GW-9, GW-10, and GW-11.

- The "Landfill Gas System Evaluation Summary Report" (Aspect and Herrera, 2019; Appendix H) provides additional details on:
  - The extent of refuse in the South Slope Area
  - Extended influence testing activities
  - LFG system performance and optimization analysis
  - Treatment alternatives analysis
  - Recommendations and next steps
- Observed rebound in methane and carbon dioxide concentrations in the South Slope Area gas probes, coupled with an increase in alkalinity and vinyl chloride concentrations in MW-21 and MW-35 during 2019, is likely attributable to diminished LFG control due to intermittent blower operation during reoccurring shutdowns in 2019 in the South Slope Area, exemplifying the connection between LFG as a source to groundwater.
- If current LFG extraction effort do not demonstrate a reasonable restoration timeframe, consideration must be given to further enhance LFG extraction to protect groundwater in the South Slope Area.

10.1.4 Leachate

- Leachate was evaluated only in the context of the leachate-to-groundwater pathway.
- Historically, leachate was found to be a source of impact to groundwater; however, the geochemical evaluation identified that leachate generation at the landfill has decreased significantly such that leachate is no longer a main source of impact to groundwater.
- Concentration trend plots and current groundwater monitoring results indicate that leachate is now a limited, isolated low-level source to groundwater.
- Residual historical leachate impact to groundwater, in addition to the LFG source is observed at SW-S2.

10.2 Data Gaps

Through the course of this RI, data gaps have been identified that are to be addressed during the Feasibility Study. These data gaps are as follows:

- **GW-11 recharge source.** The source of recharge accumulating in GW-11, seasonally blocking the well screen, and affecting LFG extraction is unknown. An investigation should be performed to identify if there is a long-term recharge source, such as focused infiltration of surface water near the well head, or if the water in the well has accumulated over time from a limited recharge source and effectively represents an isolated area of water trapped in the refuse.

- **Extent of vinyl chloride along south property boundary.** The extent of vinyl chloride in Unit Cc2 groundwater exceeding PCULs remains undefined to the south of the property. Investigations to date have not included a survey of potential groundwater discharge points to surface water from Unit Cc2 in the drainage located south of the VLF. Based on review of existing geology information, these potential points of discharge are inferred to be located on private property in the area of Cemetery Road. This investigation will be pending access from individual property owners.

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12 Limitations

Work for this project was performed for the King County Solid Waste Division (Client), and this report was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

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Please refer to Appendix L titled "Report Limitations and Guidelines for Use" for additional information governing the use of this report.

TABLES

Table 3.1. Well Construction Information

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Well ID	Historical Boring Log ID (if different) [a]	Well Diameter (in)	Stick up (ft)	TOC Elevation (ft, NAVD88)	Well Completion Depth [b] (ft bgs)	Screened Interval [b] (ft bgs)	Filter Pack Interval [b] (ft bgs)	Screened Interval Soil Type [c]	Comments/Notes
Unit B									
MW-24	P-4	2	NA	377.5	90	80 - 90	77 - 90	Very dense, silty, fine to medium SAND (SM)	
Unit Cc1									
MW-1	*NA*	*3*	*NA*	*407.2*	*128*	*118 - 128*	*115 - 130*	*Poorly graded, fine to medium SAND (SP)*	*Decommissioned in April 2015.*
MW-3	NA	3	NA	318.0	40	35 - 40	32 - 40	Poorly graded fine to medium SAND (SP)	
MW-4	NA	3	NA	377.2	110	100 - 110	95 - 110	Dense, SILT with trace sand (ML)	
MW-5S	*NA*	*2*	*NA*	*395.59*	*84*	*74 - 84*	*69 - 84*	*Dense fine to coarse SAND (SP)*	*Decommissioned April 2015, originally screened in proglacial sand, sand, and silt.*
MW-6S	*NA*	*2*	*NA*	*NA*	*115*	*105 - 115*	*102.5 - 115*	*Very dense SAND, with trace gravel and silt (SP); and Very stiff, SILT (ML)*	*Damaged by Nisqually Earthquake. Decommissioned in August 2003 by Udaloy.*
MW-10	MW-10A, B	2	NA	409.9	155	143 - 155	140 - 155	Poorly graded SAND with silt (SP-SM)	
MW-13	P-3	2	NA	377.3	113	108 - 113	106 - 113	Very dense, silty SAND (SM)	
Unit Cc2									
MW-2	NA	3	NA	318.00	84	79 - 84	68 - 85	Dense SILT with clay (ML)	
MW-5D	*NA*	*2*	*NA*	*360.8*	*126*	*115 - 126*	*113 - 126*	*Screened across dense SAND and SILT, SAND, and SILT (SM and CH)*	*Decommissioned in April 2015; replaced by MW-35.*
MW-6D	*NA*	*2*	*NA*	*NA*	*160.5*	*150.5 - 160.5*	*148 - 160.5*	*Dense, fine SAND, trace gravel and silt and gravelly SAND (SW-SP)*	*Damaged by Nisqually Earthquake. Decommissioned in August 2003 by Udaloy.*
MW-9	MW-9B	2	NA	405.2	179	167 - 179	164 - 180	Poorly graded GRAVEL, trace sands (SW)	
MW-20	NA	2	NA	370.3	132	127.7 -132	124.4 - 134	Dense, fine SAND (SP)	
MW-21	NA	2	NA	349.0	110	100.6 - 110	95 - 111	Dense, fine SAND (SP)	
MW-30	NA	2	1.2	235.7	9	4 - 9	3 - 9	Silty SAND with silt, trace coarse gravel (SM-SC)	
MW-32	NA	2	1.93	254.7	20	10 - 20	8 - 20	Medium to coarse SAND with silt (SM)	
MW-33	NA	4	2.25	359.2	137.7	127.3 - 137.3	124.2 - 139.3	Fine SAND with trace silt (SP)	
MW-35	NA	4	2.65	361.3	124.8	114.5 - 124.5	111.5 - 125.2	Fine SAND with trace silt (SP)	Replaced MW-5D (decommissioned).
Unit Cc3									
MW-8	MW-8B	2	NA	386.0	180	170 - 180	167 - 180	Medium coarse sitly SAND (SM)	
MW-14	*MW-4B*	*2*	*NA*	*379.28*	*173*	*161 - 171*	*155 - 173*	*Poorly graded SAND with silt and silty SAND (SM); and Dense SILT (ML)*	*Decommissioned in April 2015; replaced by MW-36.*
MW-27	*NA*	*4*	*NA*	*386.34*	*201.3*	*186.5 - 200.7*	*183.5 -237*	*Gravelly SAND (SP); and Silty GRAVEL (GW-GM)*	*Bottom of borehole extended into Unit D. Well completion included pea gravel from 203.5 - 237 ft bgs. Decommissioned in 2016.*
MW-31	NA	2	2.08	209.24	10	5 - 10	4 - 10.5	Silty SAND with silt, trace coarse gravel (SM-SC)	
MW-36	NA	4	2.75	378.2	164.3	154 - 164	152 -165	Fine to medium silty SAND (SP-SM)	Replaced MW-14 (decommissioned).

Table 3.1. Well Construction Information

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Well ID	Historical Boring Log ID (if different) [a]	Well Diameter (in)	Stick up (ft)	TOC Elevation (ft, NAVD88)	Well Completion Depth [b] (ft bgs)	Screened Interval [b] (ft bgs)	Filter Pack Interval [b] (ft bgs)	Screened Interval Soil Type [c]	Comments/Notes
Unit D									
MW-7	MW-7C	2	NA	376.7	232	220 - 232	217 - 233	Poorly graded SAND with silt and gravel (SP-SM)	
MW-11	*MW-1C*	*3*	*NA*	*NA*	*254*	*242 - 254*	*240 - 260*	*Silty SAND with gravel (SM)*	*Damaged by Nisqually earthquake. Decommissioned in July 2003. Well completion included pea gravel from 254-260 ft bgs, beneath silica sand.*
MW-12	MW-2C	2	NA	315.5	182.5	170.5 - 181	167 - 186	Poorly graded SAND (SP)	Well completion includes pea gravel from 184 - 186 ft bgs, beneath silica sand.
MW-19	MW-9C	2	NA	405.4	271.5	260 - 271.5	260 - 273	Poorly graded SAND with silt (SP-SM)	
MW-25	NA	4	NA	402.3	263.3	248.5 - 262.6	245 - 275.4	Very dense, slightly silty gravel (GP-GM)	Well damaged during construction, and cannot be developed properly. Installed with piezometer after MW-6 was decommissioned.
MW-26	NA	4	NA	406.5	260.8	246.1 - 260.2	242.3 - 267	Sandy fine GRAVEL and clayey GRAVEL (GP & GC)	Well completion includes pea gravel from 263.7 - 267 ft bgs, beneath silica sand.
MW-28	NA	4	NA	398.7	234.4	219.6 - 234	216.5 - 235.8	Silty SAND (SP-SM); silty GRAVEL (GW-GM); and SILT (ML)	Groundwater not collected from MW-28 because it is a dry well; requires 2-foot rise in groundwater levels. Installed at contact between Units D and E.
MW-29	NA	4	NA	413.8	253.2	238.4 - 252.6	235.8 - 261.5	Sandy GRAVEL (GW)	Replaced MW-11 (decommissioned). Well completion includes pea gravel from 255.6 - 261.5 ft bgs, beneath silica sand.
MW-34	NA	4	2.63	386.0	245.6	235.3 - 245.3	232 -247.5	Slightly gravelly, fine SAND (SP)	

Notes:

ft = feet

ft bgs = feet below ground surface

ft btoc = feet below top of casing

in = inches

TOC = top of casing

NA = Data not available or unknown

ft, NAVD88 = feet, North America Vertical Datum of 1988. Existing wells were resurveyed in August 2019.

a - Boring logs in Appendix B note both the current and historical boring log identification number.

b - Screened interval, filter pack, and unit designation derived from boring logs (Appendix B). Well completion depth is bottom of casing.

c - Unified Soil Classification System (USCS) two-letter soil texture classification provided in parentheses.

Table 3.2. Hydraulic Conductivity Estimates

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Well	Slug Test Completed by/Reference	Soil Description at Screened Interval [a]	Estimated Hydraulic Conductivity (k)	
			ft/day	cm/sec
Unit B				
MW-24	Aspect[a]	Very dense, silty, fine to medium SAND (SM)	8.61	3.04E-03
Unit Cc1				
MW-13	Aspect [a]	Very dense, silty SAND (SM)	4.40	1.22E-03
MW-1	Golder Associates, 1986	Poorly graded, fine to medium SAND (SP)	0.48	1.70E-04
MW-3	Golder Associates, 1986	Poorly graded fine to medium SAND (SP)	8.79	3.10E-03
MW-4	Golder Associates, 1986	Dense, SILT with trace sand (ML)	0.43	1.50E-04
MW-5S	Golder Associates, 1986	Dense fine to coarse SAND (SP)	8.22	2.90E-03
MW-10	CH2M HILL, 1996	Poorly graded SAND with silt (SP-SM)	5.76	2.00E-03
Geometric mean for Unit Cc1			2.69	9.08E-04
Cf between Cc1 and Cc2				
MW-5 borehole	Golder Associates, 1986	Silt (ML)	0.01	1.90E-06
Unit Cc2				
MW-2	Aspect [b]	Dense SILT with clay (ML)	3.46	1.22E-03
MW-20	Aspect [b]	Dense, fine SAND (SP)	1.61	5.68E-04
MW-21	Aspect [b]	Very dense, silty fine to medium SAND (SM)	9.08	3.20E-03
MW-33	Aspect [b]	Fine SAND with trace silt (SP)	6.79	2.40E-03
MW-35	Aspect [b]	Fine SAND with trace silt (SP)	19.35	6.82E-03
MW-9	CH2M HILL, 1996	Poorly graded GRAVEL, trace sands (SW)	46.08	1.60E-02
MW-2 [c]	Golder Associates, 1986	Dense SILT with clay (ML)	0.45	1.6E-04
Geometric mean for Unit Cc2 [c]			8.21	2.89E-03
Unit Cc3				
MW-36	Aspect [b]	Dense, slightly gravelly fine SAND (SP)	19.21	6.78E-03
MW-8	CH2M HILL, 1996	Medium coarse sitly SAND (SM)	23.04	8.20E-03
MW-14	CH2M HILL, 1996	Silty SAND (SM)	3.53	1.25E-03
Geometric mean for Unit Cc3			11.6	4.1E-03
Unit D				
MW-26	Aspect [b]	Sandy fine GRAVEL and clayey GRAVEL (GP-GC)	46.09	1.63E-02
MW-34	Aspect [b]	Slightly gravelly, fine SAND (SP)	4.37	1.54E-03
MW-7	CH2M HILL, 1996	Poorly graded SAND with silt and gravel (SP-SM)	9.00	3.20E-03
MW-12	CH2M HILL, 1996	Poorly graded SAND (SP)	6.19	2.20E-03
MW-19	CH2M HILL, 1996	Poorly graded SAND with silt (SP-SM)	9.79	3.51E-03
Geometric mean for Unit D			10.19	3.62E-03

Notes:

ft/day = feet per day

cm/sec = centimeters per second

a - Unified Soil Classification System (USCS) two-letter soil texture classification provided in parentheses.

b - Refer to Appendix E for slug test analyses and figures completed by Aspect in 2015.

c - Hydraulic conductivity value obtained by Golder in 1986 from MW-2 has not been included in the calculation of the geometric mean as the value is significantly lower than the remeasurement completed by Aspect in 2015.

Table 3.3. Groundwater Velocity Estimates

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Groundwater Zone	Horizontal Hydraulic Conductivity			Horizontal Hydraulic Gradient	Effective Porosity	Horizontal Groundwater Velocity	General Direction of Groundwater Flow
	Range	(cm/s)	(ft/d)	(ft/ft)		(ft/d)	
Unit Cc2 Aquifer (property wide)	Low	5.7E-04	1.61	0.014	20%	0.11	West
	High	1.6E-02	46.1	0.024	20%	5.5	
	Average	2.9E-03	8.21	0.019	20%	0.78	
Unit Cc2 Aquifer (South Slope area)	Low	5.7E-04	1.61	0.014	20%	0.11	West
	High	6.8E-03	19.4	0.018	20%	1.7	
	Average	2.1E-03	5.81	0.016	20%	0.46	
Unit D Aquifer (northerly flow direction)	Low	1.5E-03	4.4	0.03	20%	0.7	North - away from ridge
	High	1.6E-02	46.1	0.04	20%	9.2	
	Average	3.6E-03	10.2	0.04	20%	1.8	
Unit D Aquifer (southerly flow direction)	Low	1.5E-03	4.4	0.02	20%	0.4	South - away from ridge
	High	1.6E-02	46.1	0.02	20%	4.6	
	Average	3.6E-03	10.2	0.02	20%	1.0	

Notes:

Unit Cc2 potentiometric surface is illustrated on Figures 3.8 and 3.9.

Unit D potentiometric surface is iluustrated on Figures 3.10 and 3.11.

Horizontal hydraulic conductivity values detailed in Table 3.2. Average hydraulic conductivity values are the geometric mean of those listed in that table, by unit.

Horizontal hydraulic gradients based on gradients measured at several points from the potentiometric maps shown in Figure 3.8 through 3.11.

Effective porosity values are adapted from Potentiometric Surface Maps and Ground Water Velocity Estimates (HWA GeoSciences, 2004).

Horizontal hydraulic conductivity values used for the South Slope Area are based on values from wells MW-2, MW-20, MW-21, MW-33, and MW-35.

cm/s = centimeter/second

ft/d = feet/day

ft/ft = feet/feet (unitless)

Table 4.1. Summary of Site Explorations

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Well(s)[a]	Installation Date	Installed By/Reference[b]	Comments
Units B and C Monitoring Wells			
MW-1 through MW-4	Sep-83	R.W. Beck and Sweet. Edwards and Associates, Inc., 1984	Installed for background monitoring and water quality monitoring. MW-1 decommissioned in April 2015.
MW-5	Mar-86	Golder Associates, 1986	Decommissioned in April 2015.
MW-6	Mar-86	Golder Associates,1986	Damaged by Nisqually Earthquake in 2001. Decommissioned in August 2003.
MW-8 through MW-10	Jun-95	CH2M HILL, 1996	Installed for background monitoring and water quality monitoring.
MW-13	Apr-92	Terra Associates, 1992	Installed for water quality monitoring.
MW-14	Jun-95	CH2M HILL, 1996	Decommissioned in April 2015.
MW-20 through MW-21	Oct-98	B&H and UES, 1999	Installed for background monitoring and water quality monitoring.
MW-24	Apr-92	Terra Associates, 1992	Installed for water level monitoring.
MW-27	Aug-03	B&H and UES, 2003a,b	Installed for water quality and level monitoring. MW-27 has since been decommissioned.
MW-30 through MW-32	Dec-09	King County, 2009	Hand auger, monuments above ground.
MW-33, MW-35, MW-36	Mar-15	Aspect, 2015	Installed for water quality monitoring and hydrostratigraphic data collection. MW-35 replaced MW-5D. MW-36 replaced MW-14.
Unit D Monitoring Wells			
MW-7	Apr-95	CH2M HILL, 1996	Installed for water quality monitoring, downgradient well.
MW-11	May-95	CH2M HILL, 1996	Damaged by Nisqually Earthquake in 2001. Decommissioned in August 2003.
MW-12	May-95	CH2M HILL, 1996	Installed for water quality monitoring, downgradient well.
MW-19	Jun-95	CH2M HILL, 1996	Installed for water quality monitoring.
MW-25, MW-26, MW-28 and MW-29	Aug-03	B&H and UES, 2003a,b	Installed for water quality and level monitoring. MW-28 screened in upper contact of till aquitard, currently dry. MW-25 was damaged during construction (2003).
MW-34	Mar-15	Aspect, 2015	Installed for water quality monitoring and hydrostratigraphic data collection.
Gas Probes			
GP001 and GP002	Apr-92	Terra Associates, 1992	Formerly named GP-1 through GP-2 or also Gas Probe 1 and Gas Probe 2
GP-5	Mar-86	Golder Associates, 1986	Installed in boring for MW-5. Has since been decommissioned.
GP-6	Mar-86	Golder Associates, 1986	Installed in boring for MW-6. Has since been decommissioned.
GP-01D/I/S through GP-05D/I/S	May-95	CH2M HILL, 1996	Originally named NP-1 through NP-5. Multiple completion installations, with three probes installed in a single borehole. Completion depths indicated by "D" = Deep; "I" = Intermediate; "S" = Shallow.
GP-06D/I/S and GP-07D/I/S	Jun-95	CH2M HILL, 1996	Originally named NP-6 through NP-7. Multiple completion installations, with three probes installed in a single borehole. Completion depths indicated by "D" = Deep; "I" = Intermediate; "S" = Shallow.
GP-08D/I/S	May-95	CH2M HILL, 1996	Originally named NP-8. Multiple completion installations, with three probes installed in a single borehole. Completion depths indicated by "D" = Deep; "I" = Intermediate; "S" = Shallow.
P-1 (LFG), P-1A, P-1B	Mar-86	Golder Associates, 1986	Multiple completions in each borehole. Decommissioned prior to construction of landfill liner in 1989.
P-2 (LFG), P-2A	Mar-86	Golde Associatesr, 1986	Multiple completions in each borehole. Decommissioned prior to construction of landfill liner in 1989.
Temporary Gas Probes			
TP-1D	Aug-16	Aspect, 2016	Originally named VTP-1D
TP-1S	Apr-13	Herrera, 2015	Originally named VTP-1S. Decommissioned in 2016. Replaced with TP-1D.
TP-2D	Apr-13	Herrera, 2015	Originally named VTP-2D
TP-2S	Apr-13	Herrera, 2015	Originally named VTP-2S
TP-3D	Aug-16	Aspect, 2016	Originally named VTP-3D
TP-3S	Aug-16	Aspect, 2016	Originally named VTP-3S
TP-4D	Aug-16	Aspect, 2016	Originally named VTP-4D
TP-4S	Aug-16	Aspect, 2016	Originally named VTP-4S
TP-5D	Jan-17	Aspect, 2017	Originally named VTP-5D

Table 4.1. Summary of Site Explorations

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Well(s)[a]	Installation Date	Installed By/Reference[b]	Comments
TP-5S	Jan-17	Aspect, 2017	Originally named VTP-5S
TP-6D	Jan-17	Aspect, 2017	Originally named VTP-6D
TP-6S	Jan-17	Aspect, 2017	Originally named VTP-6S
TP-7 through TP-10, TP-11S, TP-11D	Apr-18	Aspect, 2019 (a)	Originally named VTP-7, VTP-8, VTP-10, and VTP-11S/D
LFG Extraction Wells			
GW-1 through GW-8	Mar-97	CH2M HILL, 1997b	
GW-9	Aug-16	Aspect, 2016	
GW-10 and GW-11	Jun-18	Aspect, 2018	
Soil Borings/Explorations			
B-1 through B-5	Jul-17	King County, 2017	Geotechnical explorations for transfer station road.
B-6 through B-12	Apr-18	Aspect, 2019 (a)	
BH-4A	Jun-01	HWA Geosciences, 2002	Borings were backfilled at time of exploration. Conducted for Transfer Station Geotech Assessment.
BH-4B	Jun-01	HWA Geosciences, 2002	Borings were backfilled at time of exploration.
BH-5	Jun-01	HWA Geosciences, 2002	Borings were backfilled at time of exploration.
BH-6	Jun-01	HWA Geosciences, 2002	Borings were backfilled at time of exploration.
BH-7	Jun-01	HWA Geosciences, 2002	Borings were backfilled at time of exploration.
BH-8	Jun-01	HWA Geosciences, 2002	Borings were backfilled at time of exploration.
BH-9	Jun-01	HWA Geosciences, 2002	Borings were backfilled at time of exploration.
BH-10	Jun-01	HWA Geosciences, 2002	Borings were backfilled at time of exploration.
BH-11	Jun-01	HWA Geosciences, 2002	Borings were backfilled at time of exploration.
P-4 through P-9	Jul-88	Golder Associates, 1988	Geotechnical explorations (only P-8 and P-9 were completed as wells).
Refuse Extent Explorations			
TP-1 through TP-8	Mar-86	Golder Associates, 1986	Test pits. Used to identify extent of refuse and to identify geologic units.
HP-1 through HP-10	Mar-86	Golder Associates, 1986	Hand augered.
TP-1 through TP-32	Oct-87	Golder Associates, 1987	Test Pits. Investigation for landfill closure, backfilled at time of exploration.
B-6 through B-12	Apr-18	Aspect, 2019 (a)	
Piezometer Installation			
P-4 through P-9	Mar-88	Golder Associates, 1988	Piezometer locations, installed for investigation during expansion phase. P-6 has been decommissioned.
P-3 through P-4	Jul-92	Terra Associates, 1992	Piezometer locations (gas probes).
P-1/1A/1B, P-2/2A	Aug-86	Golder Associates, 1986	Multiple completions in each borehole. Decommissioned prior to construction of landfill liner in 1989.

Notes:

B&H = Berryman & Henigar

LFG = landfill gas

UES = Udaloy Environmental Services

a - Well list does not include secondary water level locations.

b - Installation references are presumed based on the date of the well installation, if not provided. If reference is blank, then no reference information is known.

Table 4.2. Gas Probe Construction Information

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Current Probe ID	Historical Boring Log ID	Well Diameter (in)	Stick-up (ft)	TOC Elevation (ft, NAVD88)	Ground Surface Elevation [a] (ft, NAVD88)	Boring Depth (ft bgs)	Screened Interval (ft bgs)	Filter Pack Interval (ft bgs)	Screened Geologic Unit [b]	Notes
Gas Probes										
GP001	GP-1	2	2.48	NA	361.28	36	20 - 30	20 - 36	Upper Unit B	Also formerly known as Gas Probe 1
GP002	GP-2	2	2.48	NA	363.68	36	25 - 30	25 - 35	Upper Unit B	Also formerly known as Gas Probe 2
GP-5	GP-5	0.75	NA	NA	359.46	151	3 - 5	3 - 84.5	NA	In MW-5 boring, decommissioned
GP-6	GP-6	0.75	NA	NA	396.02	166.5	2.5 - 5	3 - 116	NA	In MW-6 boring, decommissioned
GP-01D	NP-1D	0.75	NA	NA	406.72	104.5	90 - 104	58 - 104.5	Unit B	Three probes in singular borehole
GP-01I	NP-1M	0.75	NA	NA	406.72	104.5	38 - 48	36 - 52	Lower Unit A and Upper Unit B	
GP-01S	NP-1S	0.75	NA	NA	406.72	104.5	12 - 22	10 - 25	Unit A	
GP-02D	NP-2 D	0.75	NA	NA	394.81	104.7	79.5 - 94.5	63 - 95	Lower Unit B	
GP-02I	NP-2 M	0.75	NA	NA	394.81	104.7	47 - 57	44 - 58	Upper Unit B	Three probes in singular borehole
GP-02S	NP-2 S	0.75	NA	NA	394.81	104.7	12 - 22	10 - 24	Unit A	
GP-03D	NP-3D	0.75	NA	NA	376.49	100	77 - 92	50 - 97	Unit B and Upper C Unit	Three probes in singular borehole
GP-03I	NP-3M	0.75	NA	NA	376.49	100	33 - 44	31 - 45	Unit A and Upper Unit B	
GP-03S	NP-3S	0.75	NA	NA	376.49	100	12 - 22	10 - 23	Unit A	
GP-04D	NP-4D	0.75	NA	NA	360.48	120	75 - 90	73 - 91	Lower Unit B and Upper Cc1 Unit	
GP-04I	NP-4M	0.75	NA	NA	360.48	120	32 - 42	30 - 43	Upper Unit B	Three probes in singular borehole
GP-04S	NP-4S	0.75	NA	NA	360.48	120	12 - 22	10 - 23	Unit A	
GP-05D	NP-5D	0.75	NA	NA	358.09	90	65 - 80	63 - 85	Unit Cc1	
GP-05I	NP-5M	0.75	NA	NA	358.09	90	30 - 40	28 - 42	Lower Unit B	Three probes in singular borehole
GP-05S	NP-5S	0.75	NA	NA	358.09	90	10 - 20	8 - 21	Lower Unit A and Upper Unit B	
GP-06D	NP-6D	0.75	NA	NA	384.52	115	90 - 105	88 - 108	Unit Cc1	Three probes in singular borehole
GP-06I	P-6M	0.75	NA	NA	384.52	115	35 - 45	33 - 46	Unit B	
GP-06S	NP-6S	0.75	NA	NA	384.52	115	12 - 22	10 - 23	Unit A	
GP-07D	NP-7D	0.75	NA	NA	376.49	110	86 - 99	84 - 104	Lower Unit B and Upper Cc1 Unit	Three probes in singular borehole
GP-07I	NP-7M	0.75	NA	NA	376.49	110	39 - 49	37 - 50	Upper Unit B	
GP-07S	NP-7S	0.75	NA	NA	376.49	110	12 - 22	10 - 24	Unit A	
GP-08D	NP-8D	0.75	NA	NA	403.24	125	95 - 110	93 - 112	Lower Unit B and Unit Cf	
GP-08I	NP-8M	0.75	NA	NA	403.24	125	49 - 59	47 - 60	Mid Unit B	Three probes in singular borehole
GP-08S	NP-8S	0.75	NA	NA	403.24	125	12 - 22	10 - 24	Unit A	
P-1	P-1	0.75	NA	NA	396.6	5	3 - 5	NA	NA	Decommissioned
P-1	P-1	1	NA	NA	396.6	99.5	89.5 - 90.5	NA	NA	Decommissioned
P-1	P-1	1	NA	NA	396.6	140	114 - 124	NA	Unit Cc1 and Unit Cf	Decommissioned
P-1A	P-1A	1	NA	NA	394.02	128.5	114 - 124	NA	NA	Decommissioned
P-1B	P-1B	1	NA	NA	396.68	106	94 - 104	NA	Lower Unit B	Decommissioned.
P-1D	P-1D	NA	NA	NA	398.6	140 est	NA	NA	Unit Cc1 and Unit Cf	Decommissioned.
P-2	P-2	1.25	NA	NA	377.35	126	100 - 115	NA	Unit Cf	Decommissioned.
P-2A	P-2A	2	NA	NA	377.2	94	80 - 92	NA	Unit Cc1	Decommissioned.
P-3	P-3	2	NA	377.37	377.67	115.5	108 - 113	106 - 113	Unit Cc1	Renamed MW-13
P-4	P-4	2	NA	377.93	377.53	90.5	80 - 90	77 - 90	Unit B	Renamed MW-24

Table 4.2. Gas Probe Construction Information

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Current Probe ID	Historical Boring Log ID	Well Diameter (in)	Stick-up (ft)	TOC Elevation (ft, NAVD88)	Ground Surface Elevation [a] (ft, NAVD88)	Boring Depth (ft bgs)	Screened Interval (ft bgs)	Filter Pack Interval (ft bgs)	Screened Geologic Unit [b]	Notes
Temporary Gas Probes										
TP-1D	VTP-1D	0.75	3	NA	NA	34	31 - 33.5	30 - 34	Unit B (SP)	Boring log notes overdrilling VTP-1S to 10 ft bgs and installing VTP-1D in the same location.
TP-1S	VTP-1S	NA	NA	NA	NA	NA	NA	NA	NA	Decommissioned.
TP-2D	VTP-2D	0.75	3.5	NA	NA	25	21.5 - 24	15 - 25	Refuse	
TP-2S	VTP-2S	0.75	3	NA	NA	7	4.5 - 7	4 - 7	Soil cover (GW/ML)	
TP-3D	VTP-3D	0.75	3	365.08	361.58	43.5	36 - 38.5	34 - 40	Unit B (SP)	
TP-3S	VTP-3S	0.75	3	365.90	362.15	40	25 - 27.5	23 - 29	Refuse	Nested with VTP-3D.
TP-4D	VTP-4D	0.75	3	361.86	358.08	60	51.5 - 54	50 - 56	Unit B (SP)	
TP-4S	VTP-4S	0.75	3	362.58	358.58	45	22.5 - 25	21 - 27	Refuse	Not nested with VTP-4D.
TP-5D	VTP-5D	0.75	3.4	363.09	359.69	30	24 - 26.5	22 - 28	Unit B (SP)	
TP-5S	VTP-5S	0.75	3.37	363.38	360.01	30	15 - 17.5	13 - 19	Refuse	Nested with VTP-5D.
TP-6D	VTP-6D	0.75	3.47	328.31	324.84	40	18.5 - 21	17 - 23	Unit B (SP)	Alternating layers of poorly graded sand and silty sands (SP-SM) below 25 ft bgs.
TP-6S	VTP-6S	0.75	3.74	328.25	324.51	20	6.5 - 9	4 - 10	Refuse	
TP-7	VTP-7	2	0.58	359.2	359.78	20	9 - 14	4 - 15	Refuse	
TP-8	VTP-8	2	0.43	358.89	359.32	25	15 - 20	14 - 21	Refuse	
TP-9	VTP-9	2	0.43	373.22	373.65	10	7.5 - 10	7 - 10	Unit A (SM)	
TP-10	VTP-10	2	0.83	375.31	376.14	10	7.5 - 10	6.75 - 10	Unit A (SM)	
TP-11D	VTP-11S	2	0.65	400.83	401.48	15	6 - 11	5 - 12	Unit A (SM)	
TP-11S	VTP-11D	2	0.67	401.48	402.15	45	31 - 41	30 - 42	Unit B (SP)	
Landfill Gas Extraction Wells										
GW-1 to -8	GW-1 to -8	NA	NA	NA	NA	NA	NA	NA	NA	
GW-9	GW-9	4	3	362.28	358.19	40	17 - 35	17 - 35	Refuse	
GW-10	GW-10	4	3.5	361.81	359.95	35	15.5 - 28.5	14.5 - 29.5	Refuse	
GW-11	GW-11	4	3.6	361.58	360.16	25	10.5 - 17	9.5 - 18	Refuse	

Notes:
ft = feet
ft, NAVD88 = feet, North America Vertical Datum of 1988.
ft bgs = feet below ground surface
ft btoc = feet below top of casing
in = inches
NA = data not available
a Ground elevation for probes listed as "Gas Probes" have been adjusted to NAVD88 by adding 3.6 feet. Original elevations were provided on borings logs in NGVD29.
b - Unified Soil Classification System (USCS) two-letter soil texture classification provided in parentheses. Refer to the Figure B-1 Exploration Log in Appendix B for details.

Table 5.1. Applicable Groundwater and Surface Water Criteria

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

			Compiled Applicable Screening Values																			
			Protection of Groundwater for Human Health (Drinking Water)							Protection of Surface Water for Human Health							Protection of Surface Water for Ecological Receptors					
			MTCA Method A	Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs)			ARARs			Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs)			Human Health via Freshwater				Ecological: Freshwater Toxicity					
CAS from 2015 CLARC table	Analytes	units	Table 720-1 WAC 173-340-900	MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	Federal Groundwater Maximum Contaminant Level	Groundwater WA Maximum Contaminant Level (WAC 246-290-310	Lowest Value, Human Health via Drinking Water	MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	Human Health Fresh Water 173-201A WAC [b]	Human Health Fresh Water CWA §304(a) (NRWQC) [c]	Human Health Fresh Water 40 CFR 131.45 [d]	Lowest Value, Human Health via Surface Water	Surface Water Aquatic Life Fresh/Acute 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Chronic 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Acute CWA §304(a) (NRWQC) [c]	Surface Water Aquatic Life Fresh/ChronicCWA §304(a) (NRWQC) [c]	Lowest Value, Ecological, Fresh Water	Preliminary Cleanup Level (PCUL)
Metals																						
7429-90-5	Aluminum [e]	µg/L		16000		--			16000			--				--			1300	420	420	420
7440-36-0	Antimony	µg/L		6.4		--	6	6	6	1000		--	12	5.6	6	5.6					--	5.6
7440-38-2	Arsenic [f]	µg/L	5	4.8	0.058	0.58	10	10	0.58	18	0.098	0.98	10	0.018	0.018	0.018	360	190	340	150	150	8
7440-39-3	Barium	µg/L		3200		--	2000	2000	2000			--		1000		1000					--	1000
7440-41-7	Beryllium	µg/L		32		--	4	4	4	270		--				270					--	4
7440-43-9	Cadmium [g]	µg/L	5	8		--	5	5	5	40		--				40	8.87	2	1.8	0.72	0.72	0.72
7440-47-3	Chromium [g]	µg/L	100			--	100	100	100			--				--	1062	345	--	--	--	100
7440-48-4	Cobalt	µg/L	--	4.8	--	--	--	--	4.8	--	--	--	--	--	--	--	--	--	--	--	--	4.8
7440-50-8	Copper [g]	µg/L		640		--	1300	1300	640	2900		--	1300	1300	--	1300	36	22.6	36	22.6	22.6	22.6
7439-89-6	Iron	µg/L		11000		--			11000			--				--				1000	1000	1000
7439-92-1	Lead [g]	µg/L	15			--	15	15	15			--				--	65	--	65	2.5	2.5	2.5
7439-95-4	Magnesium	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7439-96-5a	Manganese	µg/L	--	750	--	--	--	--	750	--	--	--	--	50	--	50	--	--	--	--	--	750
7439-97-6	Mercury	µg/L	2			--	2	2	2			--				--	2.1	0.012	1.4	0.77	0.012	0.012
7440-02-0	Nickel [g]	µg/L		320		--		100	100	1100		--	150	610	80	80	1400	311	470	--	311	80
7440-09-7	Potassium	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7782-49-2	Selenium	µg/L		80		--	50	50	50	2700		--	120	170	60	60	20	5			5	5
7440-22-4	Silver [g]	µg/L		80		--			80	26000		--				26000	13.81	--	--	--	13.81	13.81
7440-23-5	Sodium	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7440-28-0	Thallium	µg/L		0.16		--	2	2	0.16	0.22		--	0.24	0.24	1.7	0.22	--	--	--	--	--	0.16
7440-31-5	Tin	µg/L		9600		--			9600			--				--	--	--	--	--	--	9600
7440-62-2	Vanadium	µg/L		80		--			80			--				--					--	80
7440-66-6	Zinc [g]	µg/L		4800		--			4800	17000		--	2300	7400	1000	1000	227	207	--	120	120	120
Conventional Parameters																						
DO	Dissolved Oxygen	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7664-41-7	Ammonia as N	µg/L				--			--			--				--					--	--
124-38-9	Carbon Dioxide	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
COD	Chemical Oxygen Demand	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16887-00-6	Chloride	µg/L				--			--			--				--	860000	230000	860000	230000	230000	230000
57-12-5	Cyanide	µg/L		10		--	200	200	10	1600		--	19	4	9	4	22	5.2	22	5.2	5.2	4
DOC	Dissolved Organic Carbon	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16984-48-8	Fluoride	µg/L		960		--	4000	4000	960			--				--					--	960
N+N	Nitrate + Nitrite as N	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14797-55-8	Nitrate as N	µg/L		26000		--	10000	10000	10000			--		10000		10000					--	10000
14797-65-0	Nitrite as N	µg/L		1600		--	1000	1000	1000			--				--					--	1000
7727-37-9	Nitrogen	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7782-44-7	Oxygen	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PO4	Phosphate, Total	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7723-14-0	Phosphorus	µg/L		0.16		--			0.16			--				--					--	0.16
P(SOL)	Phosphorus, Soluble Reactive	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7631-86-9	Silica	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14808-79-8	Sulfate	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
18496-25-8	Sulfide	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TDS	Total Dissolved Solids	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TOC	Total Organic Carbon	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BOD	Biological Oxygen Demand	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7440-42-8	Boron	µg/L		3200		--			3200			--				--					--	3200
Polychlorinated Biphenyls																						
12674-11-2	Aroclor 1016	µg/L		1.1	1.3	13			1.1	0.006	0.003	0.03				0.003					--	0.003
11104-28-2	Aroclor 1221	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11141-16-5	Aroclor 1232	µg/L			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
53469-21-9	Aroclor 1242	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12672-29-6	Aroclor 1248	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11097-69-1	Aroclor 1254	µg/L	--	0.32	0.044	0.44			0.044	0.002	0.0001	0.001				0.0001					--	0.0001
11096-82-5	Aroclor 1260	µg/L	--		0.044	0.44			0.044			--				--					--	0.044
T_AROCLOR	Total Aroclors	µg/L	--	--	0.044	0.44	0.5	0.5	0.44	--	--	--	--	--	--	--	--	--	--	--	--	4.4E-01
Radionuclide Parameters																						
12587-46-1	Gross Alpha Activity	pci/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12587-47-2	Gross Beta Activity	pci/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
R226+228	Radium 226 AND 228	pci/L	5	--	--	--	--	--	5	--	--	--	--	--	--	--	--	--	--	--	--	5
13982-63-3	Radium-226	pci/L	3	--	--	--			3			--				--					--	3
15262-20-1	Radium-228	pci/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10028-17-8	Tritium	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 5.1. Applicable Groundwater and Surface Water Criteria

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

CAS from 2015 CLARC table	Analytes	units	Compiled Applicable Screening Values – Protection of Groundwater for Human Health (Drinking Water): MTCA Method A – Table 720-1 WAC 173-340-900	Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs): MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	ARARs: Federal Groundwater Maximum Contaminant Level	Groundwater WA Maximum Contaminant Level (WAC 246-290-310	Lowest Value, Human Health via Drinking Water	Protection of Surface Water for Human Health – Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs): MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	Human Health via Freshwater: Human Health Fresh Water 173-201A WAC [b]	Human Health Fresh Water CWA §304(a) (NRWQC) [c]	Human Health Fresh Water 40 CFR 131.45 [d]	Lowest Value, Human Health via Surface Water	Protection of Surface Water for Ecological Receptors – Ecological: Freshwater Toxicity: Surface Water Aquatic Life Fresh/Acute 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Chronic 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Acute CWA §304(a) (NRWQC) [c]	Surface Water Aquatic Life Fresh/ChronicC WA §304(a) (NRWQC) [c]	Lowest Value, Ecological, Fresh Water	Preliminary Cleanup Level (PCUL)
Pesticides																						
12789-03-6	Chlordane	µg/L		8	0.25	2.5	2	2	2	0.092	0.0013	0.013	9.3E-05	3.1E-04	2.2E-05	2.2E-05	2.4	0.0043	2.4	0.0043	0.0043	2.2E-05
93-76-5	2,4,5-T	µg/L		160		--			160			--				--					--	160
93-72-1	2,4,5-TP Silvex	µg/L		130		--	50	50	50			--		100		100					--	50
94-75-7	2,4-D	µg/L		160		--	70	70	70			--		1300		1300					--	70
72-54-8	4,4'DDD	µg/L		0.48	0.36	3.6			0.36	0.002	5.0E-04	0.005	3.6E-05	1.2E-04	7.9E-06	7.9E-06					--	7.9E-06
72-55-9	4,4'DDE	µg/L		4.8	0.26	2.6			0.26	0.015	3.6E-04	0.0036	5.1E-05	1.8E-05	8.8E-07	8.8E-07					--	8.8E-07
50-29-3	4,4'DDT	µg/L	0.3	8	0.26	2.6			0.26	0.024	3.6E-04	0.0036	2.5E-05	3.0E-05	1.2E-06	1.2E-06	1.1	0.001	1.1	0.001	0.001	1.2E-06
309-00-2	Aldrin	µg/L		0.24	0.0026	0.026			0.0026	0.017	8.2E-05	8.0E-04	5.7E-06	7.7E-07	0.000000041	4.1E-08	2.5	0.0019	3		0.0019	4.1E-08
319-84-6	Alpha BHC	µg/L		130	0.014	0.14			0.014	160	0.0079	0.079	5.0E-04	3.6E-04	4.8E-05	4.8E-05					--	4.8E-05
5103-71-9	Alpha Chlordane	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
319-85-7	Beta BHC	µg/L			0.049	0.49			0.05		0.0280	0.28	0.0018	0.008	0.0013	0.0013					--	0.0013
319-86-8	Delta BHC	µg/L				--			--			--				--					--	--
60-57-1	Dieldrin	µg/L		0.8	0.0055	0.06			0.0055	0.028	0.0001	8.7E-04	6.1E-06	1.2E-06	7.0E-08	7.0E-08	2.5	0.0019	0.24	0.056	0.056	7.0E-08
88-85-7	Dinoseb	µg/L		16		--	7	7	7			--				--					--	7
959-98-8	Endosulfan I	µg/L				--			--			--	9.7	20	6	6			0.22	0.056	0.056	0.056
33213-65-9	Endosulfan II	µg/L				--			--			--	9.7	20	--	9.7			0.22	0.056	0.056	0.056
1031-07-8	Endosulfan Sulfate	µg/L		96		--			96			--	9.7	20	9	9					--	9
72-20-8	Endrin	µg/L		4.8		--	2	2	2	0.2		--	0.034	0.03	0.002	0.002	0.18	0.0023	0.086	0.036	0.0023	0.002
7421-93-4	Endrin Aldehyde	µg/L				--			--			--	0.034	1	--	0.034					--	0.034
5566-34-7	Gamma-Chlordane	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
76-44-8	Heptachlor	µg/L		8	0.019	0.19	0.4	0.4	0.19	0.12	0.00013	0.001	9.9E-06	5.9E-06	3.4E-07	3.4E-07	0.52	0.0038	0.52	0.0038	0.0038	3.4E-07
1024-57-3	Heptachlor Epoxide	µg/L		0.1	0.0048	0.05	0.2	0.2	0.05	0.003	6.4E-05	6.5E-04	7.4E-06	3.2E-05	2.4E-06	2.4E-06			0.52	0.0038	0.0038	2.4E-06
465-73-6	Isodrin	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
58-89-9	Lindane (Gamma BHC)	µg/L	0.2	4.8	0.08	0.80	0.2	0.2	0.2	6	0.045	0.45	15	4.2	0.43	0.43	2	0.08	0.95		0.08	0.08
72-43-5	Methoxychlor	µg/L		80		--	40	40	40	8.4		--		0.02		0.02				0.03	0.03	0.02
8001-35-2	Toxaphene	µg/L		1.4	0.08	0.80	3	3	0.8	0.018	0.0005	0.005	3.2E-05	0.0007	--	3.2E-05	0.73	0.0002	0.73	0.0002	0.0002	3.2E-05
Dissolved Gases																						
74-84-0	Ethane	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
74-85-1	Ethene	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
74-82-8	Methane	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Volatile Organic Compounds																						
630-20-6	1,1,1,2-Tetrachloroethane	µg/L		240	1.7	17			1.7			--				--					--	1.7
71-55-6	1,1,1-Trichloroethane	µg/L	200	16000		--	200	200	200	930000		--	47000	10000	20000	10000					--	200
79-34-5	1,1,2,2-Tetrachloroethane	µg/L		160	0.22	2.2			0.22	10000	6.5	65	0.12	0.2	0.1	0.1					--	0.1
79-00-5	1,1,2-Trichloroethane	µg/L		32	0.77	7.7	5	5	5	2300	25	250	0.44	0.55	0.35	0.35					--	0.35
75-34-3	1,1-Dichloroethane	µg/L		1600	7.7	77			7.7			--				--					--	7.70
75-35-4	1,1-Dichloroethene	µg/L		400		--	7	7	7	23000		--	1200	300	700	300					--	7
563-58-6	1,1-Dichloropropene	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
96-18-4	1,2,3-Trichloropropane	µg/L	--	32	0.0015	0.015	--	--	0.0015			--				--					--	0.0015
96-12-8	1,2-Dibromo-3-chloropropane	µg/L		1.6	0.0550	0.60	0.2	0.2	0.2			--				--					--	0.2
106-93-4	1,2-Dibromoethane (EDB)	µg/L	0.01	72	0.0220	0.20	0.05	0.05	0.05			--				--					--	0.05
95-50-1	1,2-Dichlorobenzene	µg/L		720		--	600	600	600	4200		--	2000	1000	700	700					--	600
107-06-2	1,2-Dichloroethane (EDC)	µg/L	5	48	0.48	4.8	5	5	4.8	13000	59	590	9.3	9.9	8.9	8.9					--	4.8
78-87-5	1,2-Dichloropropane	µg/L		320	1.20	12	5	5	5	25000	43	430	0.71	0.9	--	0.71					--	0.71
541-73-1	1,3-Dichlorobenzene	µg/L				--			--			--	13	7	2	2					--	2
142-28-9	1,3-Dichloropropane	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
542-75-6	1,3-Dichloropropene	µg/L		240	0.4	4.4			0.44	41000	34	340	0.24	0.27	0.22	0.22					--	0.22
110-57-6	1,4-Dichloro-2-Butene	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
106-46-7	1,4-Dichlorobenzene	µg/L		560	8.1	81	75	75	75	3300	22	220	460	300	200	200					--	75
594-20-7	2,2-Dichloropropane	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
78-93-3	2-Butanone	µg/L		4800		--			4800			--				--					--	4800
110-75-8	2-Chloroethyl Vinyl Ether	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
591-78-6	2-Hexanone	µg/L		40		--			40			--				--					--	40
78-83-1	2-Methyl-1-Propanol	µg/L		2400		--			2400			--				--					--	2400
107-05-1	3-Chloropropene	µg/L			2.1	21			2.1			--				--					--	2.10
460-00-4	4-Bromofluorobenzene	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
60-11-7	4-Dimethylaminoazobenzene	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
108-10-1	4-Methyl-2-pentanone	µg/L		640		--			640			--				--					--	640
67-64-1	Acetone	µg/L		7200		--			7200			--				--					--	7200
75-05-8	Acetonitrile	µg/L				--			--			--				--					--	--
107-02-8	Acrolein	µg/L		4		--			4			--	1	3	--	1			3	3	3	1
107-13-1	Acrylonitrile	µg/L		320	0.08	0.8			0.08	3500	0.4	4.0	0.019	0.061	--	0.019					--	0.019
71-43-2	Benzene	µg/L	5	32	0.8	8.0	5	5	5	2000	23	230	0.44	0.58	--	0.44					--	0.44
74-97-5	Bromochloromethane	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
75-27-4	Bromodichloromethane	µg/L		160	0.7	7.1	80	80	7.1	14000	28	280	0.77	0.95	0.73	0.73					--	0.73
74-96-4	Bromoethane	µg/L	--		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
75-25-2	Bromoform	µg/L		160	5.5	55	80	80	5	14000	220	2200	5.8	7	4.6	4.6					--	4.6
74-83-9	Bromomethane	µg/L		11		--			11	970		--	520	100	300	100					--	11
75-15-0	Carbon Disulfide	µg/L		800		--			800			--				--					--	800
56-23-5	Carbon Tetrachloride	µg/L		32	0.6	6.3	5	5	5	550	4.9	49	0.2	0.4	--	0.2					--	0.2
108-90-7	Chlorobenzene	µg/L		160		--	100	100	100	5000		--	380	100	100	100					--	100
75-45-6	Chlorodifluoromethane	µg/L				--						--				--					--	--
75-00-3	Chloroethane	µg/L				--						--				--					--	--
593-70-4	Chlorofluoromethane	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 5.1. Applicable Groundwater and Surface Water Criteria

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

			Compiled Applicable Screening Values																			
			Protection of Groundwater for Human Health (Drinking Water)							Protection of Surface Water for Human Health							Protection of Surface Water for Ecological Receptors					
			MTCA Method A	Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs)			ARARs			Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs)			Human Health via Freshwater				Ecological: Freshwater Toxicity					
CAS from 2015 CLARC table	Analytes	units	Table 720-1 WAC 173-340-900	MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	Federal Groundwater Maximum Contaminant Level	Groundwater WA Maximum Contaminant Level (WAC 246-290-310	Lowest Value, Human Health via Drinking Water	MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	Human Health Fresh Water 173-201A WAC [b]	Human Health Fresh Water CWA §304(a) (NRWQC) [c]	Human Health Fresh Water 40 CFR 131.45 [d]	Lowest Value, Human Health via Surface Water	Surface Water Aquatic Life Fresh/Acute 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Chronic 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Acute CWA §304(a) (NRWQC) [c]	Surface Water Aquatic Life Fresh/ChronicC WA §304(a) (NRWQC) [c]	Lowest Value, Ecological, Fresh Water	Preliminary Cleanup Level (PCUL)
67-66-3	Chloroform	µg/L		80	1.4	14	80	80	14	6900	56	560	260	60	100	60					--	14
74-87-3	Chloromethane	µg/L				--						--				--					--	--
126-99-8	Chloroprene	µg/L		160		--			160			--				--					--	160
156-59-2	cis-1,2-Dichloroethene (DCE)	µg/L		16		--	70	70	16			--				--					--	16
10061-01-5	cis-1,3-Dichloropropene	µg/L	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
124-48-1	Dibromochloromethane	µg/L		160	0.5	5.2	80	80	5.2	14000	21	200	0.65	0.8	0.6	0.6					--	0.6
74-95-3	Dibromomethane	µg/L		80		--			80			--				--					--	80
75-71-8	Dichlorodifluoromethane	µg/L		1600		--			1600			--				--					--	1600
75-43-4	Dichloromonofluoromethane	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
97-63-2	Ethyl Methacrylate	µg/L		720		--			720			--				--					--	720
100-41-4	Ethylbenzene	µg/L	700	800		--	700	700	700	6900		--	200	68	29	29					--	29
76-13-1	Freon 113	µg/L		240000		--			240000			--				--					--	240000
MPX	m,p-Xylene	µg/L	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
126-98-7	Methacrylonitrile	µg/L		0.8		--			0.8			--				--					--	0.8
80-62-6	Methyl Methacrylate	µg/L		11000		--			11000			--				--					--	11000
75-09-2	Methylene Chloride	µg/L	5	48	22.0	220	5	5	5	17000	3600	36000	16	20	10	10					--	5
74-88-4	Methyliodide	µg/L	--		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
124-18-5	n-Decane	µg/L	--		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
593-45-3	n-Octadecane	µg/L	--		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
95-47-6	o-Xylene	µg/L		1600		--			1600			--				--					--	1600
74-98-6	Propane	µg/L	--		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
107-12-0	Propionitrile	µg/L	--		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
100-42-5	Styrene	µg/L		1600		--	100	100	100			--				--					--	100
2551-62-4	Sulfur Hexafluoride	µg/L	--		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
127-18-4	Tetrachloroethene (PCE)	µg/L	5	48	21.0	210	5	5	5	500	100	1000	4.9	10	2.4	2.4					--	2.4
108-88-3	Toluene	µg/L	1000	640		--	1000	1000	640	19000		--	180	57	72	57					--	57
1330-20-7	Total Xylenes	µg/L	1000	1600		--	10000	10000	1000			--				--					--	1000
156-60-5	trans-1,2-Dichloroethene	µg/L		160		--	100	100	100	33000		--	600	100	200	100					--	100
10061-02-6	trans-1,3-Dichloropropene	µg/L	--		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--
79-01-6	Trichloroethene (TCE)	µg/L	5	4	0.5	5.4	5	5	5	120	13	130	0.38	0.6	0.3	0.3					--	0.3
75-69-4	Trichlorofluoromethane	µg/L		2400		--			2400			--				--					--	2400
108-05-4	Vinyl Acetate	µg/L		8000		--			8000			--				--					--	8000
75-01-4	Vinyl Chloride	µg/L	0.2	24	0.029	0.29	2	2	0.29	6600	3.7	37	0.02	0.02	--	0.02					--	0.02
Semi-Volatile Organic Compounds																						
95-94-3	1,2,4,5-Tetrachlorobenzene	µg/L		4.8		--			4.8			--		0.03		0.03					--	0.03
120-82-1	1,2,4-Trichlorobenzene	µg/L		80	1.5	15	70	70	15	230	2	20	0.12	0.071	0.036	0.036					--	0.036
122-66-7	1,2-Diphenylhydrazine	µg/L			0.11	1.1			0.11		0.33	3.3	0.015	0.03	0.01	0.01					--	0.01
99-35-4	1,3,5-Trinitrobenzene	µg/L		480		--			480			--				--					--	480
130-15-4	1,4-Naphthoquinone	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
134-32-7	1-Naphthylamine	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
108-60-1	2,2-Oxybis (1-Chloropropane)	µg/L		320	0.63	6.3			0.63	42000	37	370		200	400	200					--	0.63
608-27-5	2,3-Dichloroaniline	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
95-95-4	2,4,5-Trichlorophenol	µg/L		800		--			800			--		300		300					--	300
88-06-2	2,4,6-Trichlorophenol	µg/L		8	4	40			4	17	3.9	39	0.25	1.5	--	0.25					--	0.25
120-83-2	2,4-Dichlorophenol	µg/L		24		--			24	190		--	25	10	10	10					--	10
105-67-9	2,4-Dimethylphenol	µg/L		160		--			160	550		--	85	100	--	85					--	85
51-28-5	2,4-Dinitrophenol	µg/L		32		--			32	3500		--	60	10	30	10					--	10
121-14-2	2,4-Dinitrotoluene	µg/L		32	0.28	2.8			0.28	1400	5.5	55	0.039	0.049	--	0.039					--	0.039
87-65-0	2,6-Dichlorophenol	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
606-20-2	2,6-Dinitrotoluene	µg/L		4.8	0.058	0.6			0.058			--				--					--	0.058
53-96-3	2-Acetylaminofluorene	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
91-58-7	2-Chloronaphthalene	µg/L		640		--			640	1000		--	170	800	100	100					--	100
95-57-8	2-Chlorophenol	µg/L		40		--			40	97		--	15	30	--	15					--	15
91-57-6	2-Methylnaphthalene	µg/L		32		--			32			--				--					--	32
95-48-7	2-Methylphenol	µg/L		400		--			400			--				--					--	400
91-59-8	2-Naphthylamine	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
88-74-4	2-Nitroaniline	µg/L		160		--			160			--				--					--	160
88-75-5	2-Nitrophenol	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
91-94-1	3,3'-Dichlorobenzidine	µg/L			0.19	1.9			0.19		0.046	0.46	0.0031	0.049	--	0.0031					--	0.0031
15831-10-4	3-,4-Methylphenol mixture	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
56-49-5	3-Methylcholanthrene	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
108-39-4	3-Methylphenol	µg/L		400		--			400			--				--					--	400
99-09-2	3-Nitroaniline	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
534-52-1	4,6-Dinitro-2-methylphenol	µg/L		1.3		--			1.3			--	7.1	2	3	2					--	1.3
92-67-1	4-Aminobiphenyl	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
101-55-3	4-Bromophenyl phenyl ether	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
59-50-7	4-Chloro-3-methylphenol	µg/L		1600		--			1600			--		500	--	500					--	500
7005-72-3	4-Chlorophenyl phenyl ether	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
106-44-5	4-Methylphenol	µg/L		800		--			800			--				--					--	800
100-01-6	4-Nitroaniline	µg/L	--	64	--	--	--	--	64	--	--	--	--	--	--	--	--	--	--	--	--	64
100-02-7	4-Nitrophenol	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
99-55-8	5-Nitro-o-toluidine	µg/L		320	9.7	97.0			9.7			--				--					--	9.7
57-97-6	7,12-Dimethylbenz(a)anthracene	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
208-96-8	Acenaphthylene	µg/L				--			--			--				--					--	--
83-32-9	Acenaphthene	µg/L		960		--			960	640		--	110	70	30	30					--	30

Table 5.1. Applicable Groundwater and Surface Water Criteria

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

			Compiled Applicable Screening Values																			
			Protection of Groundwater for Human Health (Drinking Water)							Protection of Surface Water for Human Health							Protection of Surface Water for Ecological Receptors					
			MTCA Method A	Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs)			ARARs			Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs)			Human Health via Freshwater				Ecological: Freshwater Toxicity					
CAS from 2015 CLARC table	Analytes	units	Table 720-1 WAC 173-340-900	MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	Federal Groundwater Maximum Contaminant Level	Groundwater WA Maximum Contaminant Level (WAC 246-290-310	Lowest Value, Human Health via Drinking Water	MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	Human Health Fresh Water 173-201A WAC [b]	Human Health Fresh Water CWA §304(a) (NRWQC) [c]	Human Health Fresh Water 40 CFR 131.45 [d]	Lowest Value, Human Health via Surface Water	Surface Water Aquatic Life Fresh/Acute 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Chronic 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Acute CWA §304(a) (NRWQC) [c]	Surface Water Aquatic Life Fresh/ChronicC WA §304(a) (NRWQC) [c]	Lowest Value, Ecological, Fresh Water	Preliminary Cleanup Level (PCUL)
98-86-2	Acetophenone	µg/L		800		--			800			--				--					--	800
62-53-3	Aniline	µg/L		56	7.7	77			7.7			--				--					--	7.7
120-12-7	Anthracene	µg/L		4800		--			4800	26000		--	3100	300	100	100					--	100
92-87-5	Benzidine	µg/L		48	0.00038	0.0038			0.00038	89	0.00032	0.0032	2.0E-05	0.00014	--	2.0E-05					--	2.0E-05
56-55-3	Benz(a)anthracene	µg/L				--			--			--	0.014	0.0012	0.00016	1.6E-04					--	1.6E-04
50-32-8	Benzo(a)pyrene	µg/L	0.1	4.8	0.02	0.2	0.2	0.2	0.2	26	0.035	0.30	0.0014	0.00012	0.000016	1.6E-05					--	1.6E-05
205-99-2	Benzo(b)fluoranthene	µg/L				--			--			--	0.014	0.0012	0.00016	1.6E-04					--	1.6E-04
BJK	Benzo(b,j,k)fluoranthene	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
191-24-2	Benzo(g,h,i)perylene	µg/L				--			--			--				--					--	--
207-08-9	Benzo(k)fluoranthene	µg/L		--		--			--			--	0.014	0.012	0.0016	0.0016					--	0.0016
65-85-0	Benzoic acid	µg/L		64000		--			64000			--				--					--	64000
100-51-6	Benzyl alcohol	µg/L		800		--			800			--				--					--	800
111-91-1	Bis(2-chloroethoxy)methane	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
111-44-4	Bis(2-chloroethyl) ether	µg/L			0.04	0.40			0.04		0.85	8.5	0.02	0.03	--	0.02					--	0.02
117-81-7	Bis(2-ethylhexyl) phthalate	µg/L		320	6.3	63	6	6	6	400	3.6	36.0	0.23	0.32	0.045	0.045					--	0.045
85-68-7	Butylbenzylphthalate	µg/L		3200	46	460			46	1300	8.2	82.0	0.56	0.1	0.013	0.013					--	0.013
86-74-8	Carbazole	µg/L				--			--			--				--					--	--
143-50-0	Chlordecone (Kepone)	µg/L		4.8	0.0088	--			0.0088			--				--					--	0.0088
510-15-6	Chlorobenzilate	µg/L		320	0.8	8.0			0.8			--				--					--	0.8
58-90-2	2,3,4,6-Tetrachlorophenol	µg/L		480		--			480			--				--					--	480
218-01-9	Chrysene	µg/L				--			--			--	1.4	0.12	0.016	0.016					--	0.016
17708-57-5	Cis-Diallate	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17627-76-8	cis-Isosafrol	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1319-77-3	Cresol (mixed isomers)	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
60-51-5	Cygon	µg/L		3.2		--			3.2			--				--					--	3.2
2303-16-4	Di-allate	µg/L			1.4	14.0			1.4			--				--					--	1.4
53-70-3	Dibenzo(a,h)anthracene	µg/L				--			--			--	0.0014	0.00012	1.6E-05	1.6E-05					--	1.6E-05
132-64-9	Dibenzofuran	µg/L		16		--			16			--				--					--	16
84-66-2	Diethyl phthalate	µg/L		13000		--			13000	28000		--	4200	600	200	200					--	200
131-11-3	Dimethyl phthalate	µg/L				--			--			--	92000	2000	600	600					--	600
84-74-2	Di-n-butyl phthalate	µg/L		1600		--			1600	2900		--	450	20	8	8					--	8
117-84-0	Di-n-octyl phthalate	µg/L		160		--			160			--				--					--	160
122-39-4	Diphenylamine	µg/L		400		--			400	2200		--				2200					--	400
298-04-4	Disulfoton	µg/L		0.64		--			0.64			--				--					--	0.64
62-50-0	Ethyl methanesulfonate	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
52-85-7	Famphur	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
206-44-0	Fluoranthene	µg/L		640		--			640	90		--	16	20	6	6					--	6
86-73-7	Fluorene	µg/L		640		--			640	3500		--	420	50	10	10					--	10
118-74-1	Hexachlorobenzene	µg/L		13	0.055	0.55	1	1	0.55	0.24	4.7E-04	0.0047	5.1E-05	7.9E-05	5.0E-06	5.0E-06					--	5.0E-06
87-68-3	Hexachlorobutadiene	µg/L		8	0.56	5.6			0.56	930	30	300	0.69	0.01	0.01	0.01					--	0.01
77-47-4	Hexachlorocyclopentadiene	µg/L		48		--	50	50	48	3600		--	150	4	1	1					--	1
67-72-1	Hexachloroethane	µg/L		5.6	1.1	11.0			1.1	21	1.9	19.0	0.11	0.1	0.02	0.02					--	0.02
1888-71-7	Hexachloropropene	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
193-39-5	Indeno(1,2,3-cd)pyrene	µg/L				--			--			--	0.014	0.0012	1.6E-04	1.6E-04					--	1.6E-04
78-59-1	Isophorone	µg/L		1600	46	460			46	120000	1600	16000	27	34	--	27					--	27
120-58-1	Isosafrole	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
99-65-0	m-Dinitrobenzene	µg/L		1.6		--			1.6			--				--					--	1.6
91-80-5	Methapyrilene	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
66-27-3	Methyl methanesulfonate	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
298-00-0	Methyl Parathion	µg/L		4		--			4			--				--					--	4
924-16-3	N,N-Dibutylnitrosoamine	µg/L			0.0081	0.081			0.0081			--		0.0063		0.0063					--	0.0063
91-20-3	Naphthalene	µg/L	160	160		--			160	4900		--				4900					--	160
98-95-3	Nitrobenzene	µg/L		16		--			16	1800		--	55	10	30	10					--	10
55-18-5	N-Nitrosodiethylamine	µg/L			0.00029	2.9E-03			0.00029			--		8.E-04		8.E-04					--	2.9E-04
62-75-9	N-Nitrosodimethylamine	µg/L		0.064	0.00086	0.0086			0.00086	800	4.9	49	7.E-04	7.E-04	--	7.E-04					--	6.5E-04
621-64-7	N-Nitroso-di-n-propylamine	µg/L			0.013	0.13			0.013		0.82	8.2	0.0044	0.005	--	0.0044					--	0.0044
86-30-6	N-Nitrosodiphenylamine	µg/L			18	179			18		9.7	97	0.62	3.3	--	0.62					--	0.62
10595-95-6	N-Nitrosomethylethylamine	µg/L			0.004	0.04			0.004			--				--					--	0.004
100-75-4	N-Nitrosopiperidine	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
930-55-2	N-Nitrosopyrrolidine	µg/L			0.021	0.21			0.021			--		0.016		0.016					--	0.016
126-68-1	o,o,o-Triethyl Phorphorothioate	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
297-97-2	o,o-Diethyl o-Pyrazinyl Phosphorothioate	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
119-93-7	Orthotolidine	µg/L			0.008	0.08			0.008			--				--					--	0.008
95-53-4	o-Toluidine	µg/L			2.7	--			2.7			--				--					--	2.7
56-38-2	Parathion	µg/L		96	--	--			96			--				--	0.065	0.013	0.065	0.013	0.013	0.013
106-47-8	p-Chloroaniline	µg/L		32	0.22	2.2			0.22			--				--					--	0.22
608-71-9	Pentabromonophenol	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
608-93-5	Pentachlorobenzene	µg/L		13	--	--			13			--		0.1		0.1					--	0.10
82-68-8	Pentachloronitrobenzene	µg/L		48	0.34	3.4			0.34			--				--					--	0.34
87-86-5	Pentachlorophenol	µg/L		80	0.22	2.2	1	1	1	1200	1.5	15.0	0.046	0.03	0.002	0.002	20	13	19	15	13	0.002
62-44-2	Phenacetin	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
85-01-8	Phenanthrene	µg/L				--			--			--				--					--	--
108-95-2	Phenol	µg/L		2400		--			2400	560000		--	18000	4000	9000	4000					--	2400
FG-PHE	Phenol Hydroxylase (PHE)	µg/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
298-02-2	Phorate	µg/L		3.2		--			3.2			--				--					--	3.2

Table 5.1. Applicable Groundwater and Surface Water Criteria

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

			Compiled Applicable Screening Values																			
			Protection of Groundwater for Human Health (Drinking Water)							Protection of Surface Water for Human Health							Protection of Surface Water for Ecological Receptors					
			MTCA Method A	Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs)			ARARs			Calculated MTCA Cleanup Levels (applicable if no sufficiently protective criterion in ARARs)			Human Health via Freshwater				Ecological: Freshwater Toxicity					
CAS from 2015 CLARC table	Analytes	units	Table 720-1 WAC 173-340-900	MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	Federal Groundwater Maximum Contaminant Level	Groundwater WA Maximum Contaminant Level (WAC 246-290-310	Lowest Value, Human Health via Drinking Water	MTCA Method B (non carcinogen)	MTCA Method B (carcinogen)	Modified MTCA Method B [a] (carcinogen)	Human Health Fresh Water 173-201A WAC [b]	Human Health Fresh Water CWA §304(a) (NRWQC) [c]	Human Health Fresh Water 40 CFR 131.45 [d]	Lowest Value, Human Health via Surface Water	Surface Water Aquatic Life Fresh/Acute 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Chronic 173-201A WAC [b]	Surface Water Aquatic Life Fresh/Acute CWA §304(a) (NRWQC) [c]	Surface Water Aquatic Life Fresh/ChronicC WA §304(a) (NRWQC) [c]	Lowest Value, Ecological, Fresh Water	Preliminary Cleanup Level (PCUL)
106-50-3	P-Phenylenediamine	µg/L		3000		--			3000			--				--					--	3000
23950-58-5	Propyzamide	µg/L		1200		--			1200			--				--					--	1200
129-00-0	Pyrene	µg/L		480		--			480	2600		--	310	20	8	8					--	8
94-59-7	Safrole	µg/L	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes:
Screening levels based on values available from Department of Ecology, Cleanup Levels and Risk Calculation (CLARC) resource website, using Ecology's most recent data tables dated May 2019 (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC).
-- indicates no screening leve is available for the given analyte.
CAS = Chemical Abstracts Services Registry Number
µg/L = micrograms per liter
MTCA = Model Toxics Control Act
a - Method B (carcinogen) has been modfied to a 1x10-5 cancer risk per WAC 173-340-720(7)(b) for groundwater and WAC 173-340-730(5)(b) for surface water
b - Ecology's Water Quality Standards established under WAC 173-201A, human health criteria updated in 2016.
c - Human health and aquatic criteria are recommended water quality criteria published pursuant to Section 304(a) of the Clean Water Act. National Recommended Water Quality Criteria (NRWQC)
d - Human health criteria established under the Clean Water Act (40 CFR 131.45). In May 2019, EPA has proposed to withdraw these standards. At the time of this RI report, the standards remain on the Federal Register and, therefore, remain ARARs.
e - Aquatic criteria listed under CWA §304(a) for aluminum are calculated based on EPA's Aquatic Life Ambient Water Quality Criteria for Aluminum in Freshwater (December 21, 2018), based on an average seep hardness of 224 mg/L and pH of 7.
f - Arsenic screening criteria is based on a natural background concentration of 8.0 µg/L of arsenic for the Puget Sound Basin (Ecology Publication No. 14-09-044; Note that Ecology has not finalized this publication). Adjustment to background is allowable per WAC 173-340-720(7)(c).
g - Ecological criteria for WAC 1730-201A and Clean Water Act are hardness dependent for metals cadmium, chromium, copper, lead, nickel, silver, and zinc. Hardness dependent metals criteria are based on an average seep hardness of 224 mg/L. Acute and chronic criteria were calculated and the lower of the two values has been provided in the table.
Gray shaded values are not applicable under MTCA (WAC 173-340-730-3Ciii), given that other "sufficiently protective" federal standards are available.

Table 6.1. Frequency of Cleanup Level Exceedances – VLF Groundwater

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date[2]	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedance
Conventionals																			
Alkalinity, Total	25	1136	10/30/2001	11/6/2019	1136	100%	11/6/2019	496	18.9	72.7	108			mg/l					0%
Ammonia as N	25	1136	10/30/2001	11/6/2019	458	40%	11/6/2019	0.46	0.0021	0.0462	0.0968	0.002	0.05	mg/l					0%
Chemical Oxygen Demand	17	190	10/30/2001	11/2/2004	4	2%	11/2/2004	8	5.4	6.8	6.7	5	5	mg/l					0%
Chloride	25	1135	10/30/2001	11/6/2019	1134	100%	11/6/2019	37.6	0.941	3.68	3.95	1	1	mg/l	230				0%
Cyanide	20	208	10/30/2001	11/6/2019		0%						0.002	0.02		0.004	11/28/2018		203	0%
Dissolved Organic Carbon	5	10	9/15/2015	2/25/2016	6	60%	2/25/2016	6.17	1.27	2.78	3.22	1	1	mg/l					0%
Fecal Coliform	15	187	10/30/2001	11/2/2004	12	6%	5/4/2004	2	0	0	0.2	1	1	cfu/100ml					0%
Fluoride	17	189	10/30/2001	11/2/2004		0%						1	1		0.96	11/2/2004		189	0%
Nitrate + Nitrite as N	17	234	10/30/2001	8/4/2005	118	50%	8/4/2005	8.1	0.01	0.3	1.1	0.01	0.05	mg/l					0%
Nitrate as N	25	1136	10/30/2001	11/6/2019	705	62%	11/6/2019	10.3	0.01	0.339	1.04	0.01	0.2	mg/l	10	3/25/2015	1	0	0.1%
Nitrite as N	19	244	10/30/2001	2/25/2016	12	5%	2/24/2016	0.03	0.01	0.012	0.015	0.01	0.01	mg/l	1				0%
pH	18	497	10/30/2001	11/17/2009	497	100%	11/17/2009	8.1	4.1	7.2	7.21			pH units					0%
Silica	5	10	9/15/2015	2/25/2016	10	100%	2/25/2016	52.1	30.2	35.7	37.7			mg/l					0%
Specific Conductance	25	1136	10/30/2001	11/6/2019	1136	100%	11/6/2019	880	51	189	243			uS/cm					0%
Sulfate	25	1134	10/30/2001	11/6/2019	1134	100%	11/6/2019	28.5	2.6	12.8	12.9			mg/l					0%
Sulfide	7	28	11/14/2007	11/6/2019	11	39%	11/6/2019	0.032	0.01	0.021	0.02	0.01	0.01	mg/L					0%
Total Coliform	15	187	10/30/2001	11/2/2004	68	36%	11/2/2004	56	0	0	2.2	1	1	cfu/100ml					0%
Total Dissolved Solids	25	1134	10/31/2001	11/6/2019	1134	100%	11/6/2019	539	34	130	156			mg/l					0%
Total Organic Carbon	25	1136	10/30/2001	11/6/2019	319	28%	11/6/2019	18.4	0.5	1.5	1.95	0.5	1	mg/l					0%
Total Organic Halides (TOX)	17	189	10/30/2001	11/2/2004	4	2%	10/28/2002	0.06	0.05	0.06	0.06	0.05	0.05	mg/l					0%
Total Solids	25	1136	10/30/2001	11/6/2019	1134	100%	11/6/2019	785	35	136	166	3	3	mg/l					0%
Total Suspended Solids	24	1132	10/30/2001	11/6/2019	567	50%	11/6/2019	637	0.5	3.3	12.7	0.5	2	mg/l					0%
Dissolved Methane	18	63	9/15/2015	11/6/2019	45	71%	11/6/2019	880	0.046	1.48	131.8	0.5	0.5	ug/l					0%
Dissolved Ethane	18	63	9/15/2015	11/6/2019	26	41%	11/6/2019	0.14	0.0048	0.012	0.038	0.1	0.1	ug/l					0%
Dissolved Ethene	18	63	9/15/2015	11/6/2019	28	44%	11/6/2019	1.2	0.0073	0.016	0.213	0.1	0.1	ug/l					0%
Field Parameters																			
Dissolved Oxygen	19	322	3/31/2015	11/6/2019	322	100%	11/6/2019	10.68	0.14	1.855	3.788			mg/L					0%
Oxidation-Reduction Potential	19	322	3/31/2015	11/6/2019	322	100%	11/6/2019	461	-153	174	152.7			mV					0%
pH	25	1139	10/30/2001	11/6/2019	1139	100%	11/6/2019	9.2	5.44	7.26	7.27			pH units					0%
Specific Conductance	25	1136	10/30/2001	11/6/2019	1136	100%	11/6/2019	921.6	60.6	175	228.5			uS/cm					0%
Temperature	25	1140	10/30/2001	11/6/2019	1140	100%	11/6/2019	17.8	8.5	10.47	10.571			deg C					0%
Turbidity	19	302	3/31/2015	11/6/2019	302	100%	11/6/2019	104.3	-1.77	0.945	4.01			NTU					0%
Metals (dissolved)																			
Aluminum	18	191	10/30/2001	11/14/2007	56	29%	11/2/2004	180	21	38	44	0.02	0.02	ug/l	420				0%
Antimony	25	1136	10/30/2001	11/6/2019	1	0.1%	2/25/2010	1.34	1.34	1.34	1.34	0.0003	0.01	ug/l	5.6	7/28/2005		3	0%
Arsenic	25	1136	10/30/2001	11/6/2019	961	85%	11/6/2019	140	0.313	2.11	9.1	0.00005	0.001	ug/l	8	11/6/2019	105	0	9%
Barium	25	1136	10/30/2001	11/6/2019	1136	100%	11/6/2019	64.3	1.2	7	9.2			ug/l	1000				0%
Beryllium	25	1136	10/30/2001	11/6/2019		0%						0.0001	0.001		4				0%
Cadmium	25	1136	10/30/2001	11/6/2019	12	1%	5/21/2018	3	0.0697	2.1	2.05	0.00005	0.002	ug/l	0.72	2/16/2017	10	935	1%
Calcium	25	1135	10/30/2001	11/6/2019	1135	100%	11/6/2019	77400	4300	13300	17500			ug/l					0%
Chromium	25	1136	10/30/2001	11/6/2019	99	9%	11/6/2019	5.9	0.21	2.81	2.55	0.0002	0.005	ug/l	74				0%
Cobalt	25	1136	10/30/2001	11/6/2019	52	5%	11/6/2019	2.04	0.0505	0.23	0.768	0.00005	0.003	ug/l	4.8				0%
Copper	25	1136	10/30/2001	11/6/2019	47	4%	11/4/2019	29	0.201	0.314	2.57	0.0002	0.002	ug/l	22.6	4/30/2007	1	0	0.1%
Iron	25	1135	10/30/2001	11/6/2019	743	65%	11/6/2019	26000	5.9	89	1780	0.005	0.01	ug/l	1000	11/6/2019	122	0	11%
Lead	25	1136	10/30/2001	11/6/2019	3	0.3%	2/7/2008	2	1.1	1.1	1.4	0.0001	0.001	ug/l	2.5				0%
Magnesium	25	1135	10/30/2001	11/6/2019	1135	100%	11/6/2019	65100	1800	10100	14400			ug/l					0%
Manganese	25	1133	10/30/2001	11/6/2019	762	67%	11/6/2019	2560	0.109	120	317	0.0001	0.001	ug/l	750	11/6/2019	85	0	8%
Mercury	25	1121	10/30/2001	11/6/2019	7	1%	5/6/2005	0.3	0.1	0.1	0.1	0.00005	0.00014	ug/l	0.012	11/6/2019	7	1114	1%
Nickel	25	1136	10/30/2001	11/6/2019	178	16%	11/6/2019	17	0.103	0.612	2.19	0.0001	0.01	ug/l	52				0%
Potassium	25	1136	10/30/2001	11/6/2019	1136	100%	11/6/2019	3870	590	2120	2100			ug/l					0%
Selenium	25	1136	10/30/2001	11/6/2019	32	3%	2/12/2008	12	1	1.4	2.1	0.0005	0.01	ug/l	5	2/12/2008	2	37	0.2%
Silver	25	1136	10/30/2001	11/6/2019	4	0.4%	11/9/2018	11	0.0484	0.0686	2.8	0.00004	0.003	ug/l	3.2	4/23/2003	1	0	0.1%
Sodium	25	1136	10/30/2001	11/6/2019	1136	100%	11/6/2019	21400	2200	6210	7370			ug/l					0%
Thallium	25	1136	10/30/2001	11/6/2019		0%						0.0001	0.002		0.16	2/16/2017		945	0%
Tin	20	208	10/30/2001	11/6/2019		0%						0.0005	0.01		9600				0%
Vanadium	25	1136	10/30/2001	11/6/2019	612	54%	11/6/2019	11	0.077	3.93	3.46	0.000075	0.002	ug/l	80				0%
Zinc	25	1136	10/30/2001	11/6/2019	217	19%	11/6/2019	1700	0.504	4.3	15.9	0.0005	0.004	ug/l	120	8/20/2010	2	0	0.2%
Metals (total)																			
Antimony	20	435	5/6/2013	11/6/2019		0%						0.0003	0.001		5.6				0%
Arsenic	20	435	5/6/2013	11/6/2019	385	89%	11/6/2019	91.9	0.0669	2.11	7.41	0.001	0.001	ug/l	8	11/6/2019	55	0	13%
Barium	20	435	5/6/2013	11/6/2019	435	100%	11/6/2019	63.6	3.03	7.88	10.9			ug/l	1000				0%
Beryllium	20	435	5/6/2013	11/6/2019		0%						0.0001	0.001		4				0%
Cadmium	20	435	5/6/2013	11/6/2019	7	2%	8/30/2019	0.112	0.0516	0.0789	0.0788	0.00005	0.002	ug/l	0.72	2/16/2017		244	0%
Calcium	20	435	5/6/2013	11/6/2019	435	100%	11/6/2019	78700	5910	14200	19300			ug/l					0%
Chromium	20	435	5/6/2013	11/6/2019	131	30%	11/6/2019	12	0.204	1.92	2.29	0.0002	0.005	ug/l	74				0%
Cobalt	20	435	5/6/2013	11/6/2019	84	19%	11/6/2019	3.79	0.0508	0.152	0.672	0.00005	0.003	ug/l	4.8				0%
Copper	20	435	5/6/2013	11/6/2019	77	18%	11/6/2019	20.2	0.2	0.4	1.32	0.0002	0.002	ug/l	22.6				0%
Iron	20	435	5/6/2013	11/6/2019	348	80%	11/6/2019	18000	10	160	1930	0.01	0.01	ug/l	1000	11/6/2019	101	0	23%
Lead	20	435	5/6/2013	11/6/2019	30	7%	11/6/2019	5.13	0.116	0.182	0.603	0.0001	0.001	ug/l	2.5	11/23/2015	2	0	0.5%
Magnesium	20	435	5/6/2013	11/6/2019	435	100%	11/6/2019	61100	2200	11300	15600			ug/l					0%

Table 6.1. Frequency of Cleanup Level Exceedances – VLF Groundwater

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date[2]	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedance
Manganese	20	435	5/6/2013	11/6/2019	368	85%	11/6/2019	2920	0.114	110	345	0.0001	0.001	ug/l	750	11/6/2019	46	0	11%
Mercury	20	442	11/9/2011	11/6/2019		0%						0.00005	0.0001		0.012	11/6/2019		442	0%
Nickel	20	435	5/6/2013	11/6/2019	190	44%	11/6/2019	17.9	0.101	0.573	1.82	0.0001	0.01	ug/l	52				0%
Potassium	20	435	5/6/2013	11/6/2019	435	100%	11/6/2019	3890	901	2210	2230			ug/l					0%
Selenium	20	435	5/6/2013	11/6/2019		0%						0.0005	0.001		5				0%
Silver	20	435	5/6/2013	11/6/2019	12	3%	1/23/2019	0.0982	0.0412	0.0533	0.0603	0.00004	0.003	ug/l	3.2				0%
Sodium	20	435	5/6/2013	11/6/2019	435	100%	11/6/2019	20800	2400	6530	7900			ug/l					0%
Thallium	20	435	5/6/2013	11/6/2019		0%						0.0001	0.001		0.16	2/16/2017		244	0%
Tin	5	10	11/27/2018	11/6/2019		0%						0.0005	0.0005		9600				0%
Vanadium	20	435	5/6/2013	11/6/2019	301	69%	11/6/2019	14.2	0.0768	2.7	2.99	0.000075	0.002	ug/l	80				0%
Zinc	20	435	5/6/2013	11/6/2019	145	33%	11/6/2019	803	0.5	1.31	13.3	0.0005	0.004	ug/l	120	11/23/2015	2	0	0.5%
PCBs																			
Aroclor 1016	18	205	10/30/2001	11/6/2019		0%						0.00625	0.011		0.003	11/6/2019		205	0%
Aroclor 1221	18	205	10/30/2001	11/6/2019		0%						0.00625	0.011						0%
Aroclor 1232	18	205	10/30/2001	11/6/2019		0%						0.00625	0.011						0%
Aroclor 1242	18	205	10/30/2001	11/6/2019		0%						0.00625	0.011						0%
Aroclor 1248	18	205	10/30/2001	11/6/2019		0%						0.00625	0.011						0%
Aroclor 1254	18	205	10/30/2001	11/6/2019		0%						0.00625	0.011		0.0001	11/6/2019		205	0%
Aroclor 1260	18	205	10/30/2001	11/6/2019		0%						0.00625	0.011		0.044				0%
Total Aroclors	18	205	10/30/2001	11/6/2019		0%						0.00625	0.025		0.000007	11/6/2019		205	0%
Pesticides																			
2,4,5-T	18	205	10/30/2001	11/6/2019		0%						0.025	2		160				0%
2,4,5-TP Silvex	18	205	10/30/2001	11/6/2019	4	2%	11/6/2019	0.0423	0.0367	0.0394	0.0395	0.025	1	ug/L	50				0%
2,4-D	18	205	10/30/2001	11/6/2019		0%						0.05	5		70				0%
4,4'DDD	18	205	10/30/2001	11/6/2019		0%						0.005	0.11		0.0000079	11/6/2019		205	0%
4,4'DDE	18	205	10/30/2001	11/6/2019		0%						0.005	0.11		0.00000088	11/6/2019		205	0%
4,4'DDT	18	205	10/30/2001	11/6/2019		0%						0.005	0.11		0.0000012	11/6/2019		205	0%
Aldrin	18	205	10/30/2001	11/6/2019		0%						0.005	0.027		0.000000041	11/6/2019		205	0%
Alpha BHC	18	205	10/30/2001	11/6/2019		0%						0.005	0.027		0.000048	11/6/2019		205	0%
Alpha Chlordane	18	205	10/30/2001	11/6/2019		0%						0.005	0.027		0.000022	11/6/2019		205	0%
Beta BHC	18	205	10/30/2001	11/6/2019		0%						0.005	0.027		0.0013	11/6/2019		205	0%
Delta BHC	18	205	10/30/2001	11/6/2019		0%						0.005	0.11						0%
Dieldrin	18	205	10/30/2001	11/6/2019		0%						0.005	0.11		0.00000007	11/6/2019		205	0%
Dinoseb	18	205	10/30/2001	11/6/2019		0%						0.025	1		7				0%
Endosulfan I	18	205	10/30/2001	11/6/2019		0%						0.005	0.11		0.056	11/9/2012		195	0%
Endosulfan II	18	205	10/30/2001	11/6/2019		0%						0.005	0.11		0.056	11/9/2012		195	0%
Endosulfan Sulfate	18	205	10/30/2001	11/6/2019		0%						0.005	0.53		9				0%
Endrin	18	205	10/30/2001	11/6/2019		0%						0.005	0.11		0.002	11/6/2019		205	0%
Endrin Aldehyde	18	205	10/30/2001	11/6/2019		0%						0.005	0.21		0.034	11/9/2012		195	0%
Heptachlor	18	205	10/30/2001	11/6/2019		0%						0.005	0.027		0.00000034	11/6/2019		205	0%
Heptachlor Epoxide	18	205	10/30/2001	11/6/2019		0%						0.005	0.027		0.0000024	11/6/2019		205	0%
Isodrin	18	205	10/30/2001	11/6/2019		0%						0.005	11						0%
Lindane (Gamma BHC)	18	205	10/30/2001	11/6/2019		0%						0.005	0.027		0.08				0%
Methoxychlor	18	205	10/30/2001	11/6/2019		0%						0.025	2.1		0.02	11/6/2019		205	0%
Toxaphene	18	205	10/30/2001	11/6/2019		0%						0.5	2.7		0.000032	11/6/2019		205	0%
SVOCs																			
1,2,4,5-Tetrachlorobenzene	7	26	5/2/2003	11/6/2019		0%						0.952	10		0.03	11/6/2019		26	0%
1,2,4-Trichlorobenzene	7	26	5/2/2003	11/6/2019		0%						0.476	10		0.036	11/6/2019		26	0%
1,2-Diphenylhydrazine	6	11	11/14/2007	11/6/2019		0%						0.19	9.6		0.01	11/6/2019		11	0%
1,3,5-Trinitrobenzene	7	26	5/2/2003	11/6/2019		0%						0.476	10		480				0%
1,4-Naphthoquinone	7	26	5/2/2003	11/6/2019		0%						0.952	10						0%
1-Naphthylamine	7	26	5/2/2003	11/6/2019		0%						4.76	10						0%
2,2-Oxybis (1-Chloropropane)	7	26	5/2/2003	11/6/2019		0%						0.476	10		0.63	11/28/2018		21	0%
2,3,4,6-Tetrachlorophenol	7	26	5/2/2003	11/6/2019		0%						0.952	10		480				0%
2,4,5-Trichlorophenol	7	26	5/2/2003	11/6/2019		0%						0.952	10		300				0%
2,4,6-Trichlorophenol	7	26	5/2/2003	11/6/2019		0%						0.952	10		0.25	11/6/2019		26	0%
2,4-Dichlorophenol	7	26	5/2/2003	11/6/2019		0%						0.476	10		10	11/9/2012		7	0%
2,4-Dimethylphenol	7	26	5/2/2003	11/6/2019		0%						1.9	11		85				0%
2,4-Dinitrophenol	7	26	5/2/2003	11/6/2019		0%						7.1	50		10	11/6/2019		14	0%
2,4-Dinitrotoluene	7	26	5/2/2003	11/6/2019		0%						0.86	10		0.039	11/6/2019		26	0%
2,6-Dichlorophenol	7	26	5/2/2003	11/6/2019		0%						0.476	10						0%
2,6-Dinitrotoluene	7	26	5/2/2003	11/6/2019		0%						0.952	10		0.058	11/6/2019		26	0%
2-Acetylaminofluorene	7	26	5/2/2003	11/6/2019		0%						0.952	20						0%
2-Chloronaphthalene	7	26	5/2/2003	11/6/2019		0%						0.476	10		100				0%
2-Chlorophenol	7	26	5/2/2003	11/6/2019		0%						0.476	10		15				0%
2-Methylnaphthalene	7	23	5/2/2003	11/6/2019		0%						0.0236	10		32				0%
2-Methylphenol	7	26	5/2/2003	11/6/2019		0%						0.476	10		400				0%
2-Naphthylamine	7	26	5/2/2003	11/6/2019		0%						4.76	10						0%
2-Nitroaniline	7	26	5/2/2003	11/6/2019		0%						0.952	50		160				0%
2-Nitrophenol	7	26	5/2/2003	11/6/2019		0%						0.19	10						0%
3,3'-Dichlorobenzidine	7	26	5/2/2003	11/6/2019		0%						0.19	20		0.0031	11/6/2019		26	0%

Table 6.1. Frequency of Cleanup Level Exceedances – VLF Groundwater

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date[2]	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedance
3-,4-Methylphenol mixture	6	17	11/9/2011	11/6/2019		0%						0.476	10						0%
3-Methylcholanthrene	7	26	5/2/2003	11/6/2019		0%						0.476	10						0%
3-Nitroaniline	7	26	5/2/2003	11/6/2019		0%						0.952	50						0%
4-(Dimethylamino)azobenzene	7	26	5/2/2003	11/6/2019		0%						0.952	10						0%
4,6-Dinitro-2-methylphenol	7	26	5/2/2003	11/6/2019		0%						0.952	50		1.3	11/28/2018		21	0%
4-Aminobiphenyl	7	26	5/2/2003	11/6/2019		0%						1.9	20						0%
4-Bromophenyl phenyl ether	7	26	5/2/2003	11/6/2019		0%						0.476	10						0%
4-Chloro-3-methylphenol	7	26	5/2/2003	11/6/2019		0%						0.476	20		500				0%
4-Chlorophenyl phenyl ether	7	26	5/2/2003	11/6/2019		0%						0.476	10						0%
4-Nitroaniline	7	26	5/2/2003	11/6/2019		0%						4.76	20		64				0%
4-Nitrophenol	7	26	5/2/2003	11/6/2019		0%						3.8	50						0%
5-Nitro-o-toluidine	7	26	5/2/2003	11/6/2019		0%						1.9	10		9.7	11/9/2012		7	0%
7,12-Dimethylbenz(a)anthracene	7	26	5/2/2003	11/6/2019		0%						0.476	10						0%
Acenaphthene	7	26	5/2/2003	11/6/2019		0%						0.0236	2.6		30				0%
Acenaphthylene	7	26	5/2/2003	11/6/2019		0%						0.0236	2.7						0%
Acetophenone	7	26	5/2/2003	11/6/2019		0%						0.476	10		800				0%
alpha-Terpineol	5	10	11/27/2018	11/6/2019		0%						0.476	0.98						0%
Aniline	6	11	11/14/2007	11/6/2019		0%						0.952	13		7.7	11/14/2007		1	0%
Anthracene	7	26	5/2/2003	11/6/2019		0%						0.0472	2.2		100				0%
Benz(a)anthracene	7	26	5/2/2003	11/6/2019		0%						0.0472	2.2		0.00016	11/6/2019		26	0%
Benzo(a)pyrene	7	26	5/2/2003	11/6/2019		0%						0.0472	2.7		0.000016	11/6/2019		26	0%
Benzo(b)fluoranthene	5	9	5/2/2003	11/14/2007		0%						0.096	2.3		0.00016	11/14/2007		9	0%
Benzo(b,j,k)fluoranthene	6	17	11/9/2011	11/6/2019		0%						0.0472	1.5						0%
Benzo(g,h,i)perylene	7	26	5/2/2003	11/6/2019		0%						0.0472	3.5						0%
Benzo(k)fluoranthene	5	9	5/2/2003	11/14/2007		0%						0.096	4.5		0.0016	11/14/2007		9	0%
Benzoic acid	5	10	11/27/2018	11/6/2019		0%						9.52	19.6		64000				0%
Benzyl alcohol	7	26	5/2/2003	11/6/2019		0%						3.6	20		800				0%
Benzyl butyl phthalate	7	26	5/2/2003	11/6/2019		0%						0.943	5		0.013	11/6/2019		26	0%
Bis(2-chloroethoxy)methane	7	26	5/2/2003	11/6/2019		0%						0.476	10						0%
Bis(2-chloroethyl) ether	7	26	5/2/2003	11/6/2019	4	15%	11/6/2019	3.16	1.06	2.22	2.16	0.476	10	ug/L	0.02	11/6/2019	4	22	15%
Bis(2-ethylhexyl) phthalate	7	26	5/2/2003	11/6/2019	2	8%	11/28/2018	10.7	2.19	6.45	6.45	0.943	10	ug/L	0.045	11/6/2019	2	24	8%
Chlordecone (KEPONE)	7	26	5/2/2003	11/6/2019		0%						4.76	40		0.0088	11/6/2019		26	0%
Chlorobenzilate	7	26	5/2/2003	11/6/2019		0%						0.476	20		0.8	11/28/2018		21	0%
Chrysene	7	26	5/2/2003	11/6/2019		0%						0.0472	1.7		0.016	11/6/2019		26	0%
Cis-Diallate	6	17	11/9/2011	11/6/2019		0%						0.0377	10						0%
Cygon	7	26	5/2/2003	11/6/2019		0%						0.0943	20		3.2	11/9/2012		16	0%
Di-allate	7	26	5/2/2003	11/6/2019		0%						0.0377	10		1.4	11/9/2012		16	0%
Dibenzo(a,h)anthracene	7	26	5/2/2003	11/6/2019		0%						0.0472	3.7		0.000016	11/6/2019		26	0%
Dibenzofuran	7	26	5/2/2003	11/6/2019		0%						0.476	10		16				0%
Diethyl phthalate	7	26	5/2/2003	11/6/2019	1	4%	11/6/2019	1.96	1.96	1.96	1.96	0.943	5	ug/L	200				0%
Dimethyl phthalate	7	26	5/2/2003	11/6/2019		0%						0.943	5		600				0%
Di-n-butyl phthalate	7	26	5/2/2003	11/6/2019		0%						0.943	5		8				0%
Di-n-octyl phthalate	7	26	5/2/2003	11/6/2019		0%						0.943	10		160				0%
Diphenylamine	7	26	5/2/2003	11/6/2019		0%						0.476	10		400				0%
Disulfoton	7	26	5/2/2003	11/6/2019		0%						0.0377	4.9		0.64	11/9/2012		16	0%
Ethyl methanesulfonate	7	26	5/2/2003	11/6/2019		0%						0.476	10						0%
Famphur	7	26	5/2/2003	11/6/2019		0%						0.0377	20						0%
Fluoranthene	7	26	5/2/2003	11/6/2019		0%						0.0472	1.4		6				0%
Fluorene	7	26	5/2/2003	11/6/2019		0%						0.0472	2		10				0%
Hexachlorobenzene	7	26	5/2/2003	11/6/2019		0%						0.19	5		0.000005	11/6/2019		26	0%
Hexachlorobutadiene	7	26	5/2/2003	11/6/2019		0%						1.9	5		0.01	11/6/2019		26	0%
Hexachlorocyclopentadiene	7	26	5/2/2003	11/6/2019		0%						4.76	9.8		1	11/6/2019		26	0%
Hexachloroethane	7	26	5/2/2003	11/6/2019		0%						3.9	9.8		0.02	11/6/2019		26	0%
Hexachloropropene	7	26	5/2/2003	11/6/2019		0%						1.9	10						0%
Indeno(1,2,3-cd)pyrene	7	26	5/2/2003	11/6/2019		0%						0.0472	3.1		0.00016	11/6/2019		26	0%
Isophorone	7	26	5/2/2003	11/6/2019		0%						0.476	10		27				0%
Isosafrole	7	26	5/2/2003	11/6/2019		0%						0.476	10						0%
m-Dinitrobenzene	7	26	5/2/2003	11/6/2019		0%						0.952	20		1.6	11/28/2018		21	0%
Methapyrilene	7	26	5/2/2003	11/6/2019		0%						4.8	100						0%
Methyl methanesulfonate	7	26	5/2/2003	11/6/2019		0%						0.476	10						0%
Methyl Parathion	7	26	5/2/2003	11/6/2019		0%						0.0377	4.9		4	11/14/2007		9	0%
N,N-Dibutylnitrosoamine	7	26	5/2/2003	11/6/2019		0%						0.476	10		0.0063	11/6/2019		26	0%
Naphthalene	7	26	5/2/2003	11/6/2019		0%						0.0236	10		160				0%
Nitrobenzene	7	26	5/2/2003	11/6/2019		0%						0.476	10		10	11/9/2012		7	0%
N-Nitrosodiethylamine	7	26	5/2/2003	11/6/2019		0%						0.476	20		0.00029	11/6/2019		26	0%
N-Nitrosodimethylamine	7	26	5/2/2003	11/6/2019		0%						0.476	10		0.00065	11/6/2019		26	0%
N-Nitroso-di-n-propylamine	7	26	5/2/2003	11/6/2019		0%						0.476	10		0.0044	11/6/2019		26	0%
N-Nitrosodiphenylamine	7	26	5/2/2003	11/6/2019		0%						0.476	10		0.62	11/28/2018		21	0%
N-Nitrosomethylethylamine	7	25	5/2/2003	11/6/2019		0%						0.476	10		0.004	11/6/2019		25	0%
N-Nitrosopiperidine	7	26	5/2/2003	11/6/2019		0%						0.952	20						0%
N-Nitrosopyrrolidine	7	26	5/2/2003	11/6/2019		0%						0.952	40		0.016	11/6/2019		26	0%

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Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date[2]	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedance
Orthotolidine	7	26	5/2/2003	11/6/2019		0%						4.76	10		0.008	11/6/2019		26	0%
o-Toluidine	7	26	5/2/2003	11/6/2019		0%						0.0952	10		2.7	11/9/2012		16	0%
Parathion	7	26	5/2/2003	11/6/2019		0%						0.0377	4.9		0.013	11/6/2019		26	0%
p-Chloroaniline	7	26	5/2/2003	11/6/2019		0%						0.952	10		0.22	11/6/2019		26	0%
Pentachlorobenzene	7	26	5/2/2003	11/6/2019		0%						0.476	10		0.1	11/6/2019		26	0%
Pentachloronitrobenzene	7	26	5/2/2003	11/6/2019		0%						0.476	20		0.34	11/6/2019		26	0%
Pentachlorophenol	7	26	5/2/2003	11/6/2019		0%						1.7	50		0.002	11/6/2019		26	0%
Phenacetin	7	26	5/2/2003	11/6/2019		0%						0.476	20						0%
Phenanthrene	7	26	5/2/2003	11/6/2019		0%						0.0472	1.7						0%
Phenol	7	26	5/2/2003	11/6/2019		0%						0.476	19		2400				0%
Phorate	7	26	5/2/2003	11/6/2019		0%						0.0377	10		3.2	11/9/2012		16	0%
P-Phenylenediamine	7	26	5/2/2003	11/6/2019		0%						9.5	49		3000				0%
Propyzamide	7	26	5/2/2003	11/6/2019		0%						0.0377	10		1200				0%
Pyrene	7	26	5/2/2003	11/6/2019		0%						0.0472	3.1		8				0%
Safrole	7	26	5/2/2003	11/6/2019		0%						0.952	10						0%
Thionazin	7	26	5/2/2003	11/6/2019		0%						0.0377	20						0%
Total cPAHs TEQ (ND = 1/2 RDL)	5	16	5/2/2003	11/9/2012		0%						0.07765	2.1485						0%
Trans-Diallate	6	17	11/9/2011	11/6/2019		0%						0.0377	10						0%
Triethyl thiophosphate	7	26	5/2/2003	11/6/2019		0%						0.0377	10						0%
VOCs																			
1,1,1,2-Tetrachloroethane	25	1139	10/30/2001	11/6/2019		0%						0.2	0.5		1.7				0%
1,1,1-Trichloroethane	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		200				0%
1,1,2,2-Tetrachloroethane	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		0.1	11/6/2019		1139	0%
1,1,2-Trichloroethane	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		0.35				0%
1,1-Dichloroethane	25	1139	10/30/2001	11/6/2019	66	6%	11/6/2019	2.32	0.12	0.32	0.684	0.1	0.2	ug/l	7.7				0%
1,1-Dichloroethene	25	1139	10/30/2001	11/6/2019	17	1%	11/6/2019	0.28	0.14	0.174	0.195	0.1	0.2	ug/l	7				0%
1,1-Dichloropropene	20	209	10/30/2001	11/6/2019		0%						0.1	0.2						0%
1,2,3-Trichloropropane	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		0.0015	11/6/2019		1139	0%
1,2-Dibromo-3-chloropropane	25	1139	10/30/2001	11/6/2019		0%						0.2	5		0.2	11/6/2019		1139	0%
1,2-Dibromoethane (EDB)	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		0.05	11/6/2019		1139	0%
1,2-Dichlorobenzene	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		600				0%
1,2-Dichloroethane (EDC)	25	1139	10/30/2001	11/6/2019	8	1%	11/6/2019	0.13	0.104	0.119	0.118	0.1	0.2	ug/l	4.8				0%
1,2-Dichloropropane	25	1139	10/30/2001	11/6/2019	58	5%	11/6/2019	12.5	0.24	1.11	3.16	0.1	0.2	ug/l	0.71	11/6/2019	38	0	3%
1,3-Dichlorobenzene	20	209	10/30/2001	11/6/2019		0%						0.1	0.2		2				0%
1,3-Dichloropropane	20	209	10/30/2001	11/6/2019		0%						0.1	0.2						0%
1,4-Dichloro-2-Butene	25	1139	10/30/2001	11/6/2019		0%						0.5	100						0%
1,4-Dichlorobenzene	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		75				0%
2,2-Dichloropropane	20	209	10/30/2001	11/6/2019		0%						0.1	0.5						0%
2-Butanone	25	1139	10/30/2001	11/6/2019	2	0.2%	5/10/2019	5.21	1.57	3.39	3.39	0.25	5	ug/l	4800				0%
2-Hexanone	25	1139	10/30/2001	11/6/2019		0%						0.5	4		40				0%
2-Methyl-1-Propanol	20	209	10/30/2001	11/6/2019	2	1%	11/28/2018	29.8	9.14	19.5	19.5	10	100	ug/L	2400				0%
3-Chloropropene	20	209	10/30/2001	11/6/2019		0%						0.1	10		2.1	11/9/2012		199	0%
4-Methyl-2-pentanone	25	1139	10/30/2001	11/6/2019		0%						2.5	5		640				0%
Acetone	25	1139	10/30/2001	11/6/2019	43	4%	8/14/2019	31	2.6	5.23	6.51	2.5	40	ug/l	7200				0%
Acetonitrile	20	209	10/30/2001	11/6/2019		0%						5	100						0%
Acrolein	20	209	10/30/2001	11/6/2019		0%						2.5	10		1	11/6/2019		209	0%
Acrylonitrile	25	1139	10/30/2001	11/6/2019		0%						0.035	10		0.019	11/6/2019		1139	0%
Benzene	25	1139	10/30/2001	11/6/2019	93	8%	11/6/2019	1.76	0.25	0.751	0.795	0.1	0.2	ug/l	0.44	11/6/2019	86	0	8%
Bromochloromethane	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2						0%
Bromodichloromethane	25	1139	10/30/2001	11/6/2019		0%						0.2	0.5		0.73				0%
Bromoform	25	1139	10/30/2001	11/6/2019		0%						0.2	1		4.6				0%
Bromomethane	25	1139	10/30/2001	11/6/2019	3	0.3%	10/31/2001	0.36	0.24	0.34	0.31	0.1	0.2	ug/l	11				0%
Carbon Disulfide	25	1139	10/30/2001	11/6/2019	12	1%	5/7/2019	0.23	0.1	0.125	0.143	0.1	0.2	ug/l	800				0%
Carbon Tetrachloride	25	1139	10/30/2001	11/6/2019		0%						0.2	0.5		0.2	11/6/2019		1139	0%
Chlorobenzene	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		100				0%
Chloroethane	25	1139	10/30/2001	11/6/2019	19	2%	11/6/2019	0.947	0.24	0.44	0.463	0.1	0.2	ug/l					0%
Chloroform	25	1139	10/30/2001	11/6/2019	10	1%	11/5/2019	1.7	0.102	0.146	0.302	0.1	0.2	ug/L	14				0%
Chloromethane	25	1131	10/30/2001	11/6/2019	44	4%	11/6/2019	1.72	0.2	0.29	0.372	0.2	1	ug/l					0%
Chloroprene	20	209	10/30/2001	11/6/2019		0%						0.1	20		160				0%
cis-1,2-Dichloroethene (DCE)	25	1139	10/30/2001	11/6/2019	190	17%	11/6/2019	52.7	0.105	4.39	7.7	0.1	0.2	ug/l	16	11/6/2019	20	0	2%
cis-1,3-Dichloropropene	25	1139	10/30/2001	11/6/2019		0%						0.2	0.5						0%
Dibromochloromethane	25	1139	10/30/2001	11/6/2019		0%						0.2	1		0.6	3/20/2019		88	0%
Dibromomethane	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		80				0%
Dichlorodifluoromethane	25	1139	10/30/2001	11/6/2019	263	23%	11/6/2019	27	0.2	3.61	4.92	0.1	0.2	ug/l	1600				0%
Ethyl Methacrylate	7	26	5/2/2003	11/6/2019		0%						0.1	10		720				0%
Ethylbenzene	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		29				0%
m,p-Xylene	24	641	11/14/2007	11/6/2019	4	1%	4/22/2010	0.37	0.21	0.25	0.27	0.1	0.2	ug/l					0%
Methacrylonitrile	20	209	10/30/2001	11/6/2019		0%						0.1	5		0.8	11/9/2012		199	0%
Methyl Methacrylate	20	209	10/30/2001	11/6/2019		0%						0.25	2		11000				0%
Methylene Chloride	25	1139	10/30/2001	11/6/2019	22	2%	2/14/2017	2.18	0.2	0.31	0.834	0.2	5	ug/l	5	3/20/2019		88	0%
Methyliodide	25	1139	10/30/2001	11/6/2019		0%						0.1	5						0%

Table 6.1. Frequency of Cleanup Level Exceedances – VLF Groundwater

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date[2]	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedance
o-Xylene	25	832	10/30/2001	11/6/2019	9	1%	5/10/2019	0.34	0.114	0.13	0.152	0.1	0.2	ug/l	1600				0%
Propionitrile	20	209	10/30/2001	11/6/2019		0%						0.5	60						0%
Styrene	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		100				0%
Tetrachloroethene (PCE)	25	1139	10/30/2001	11/6/2019	4	0.4%	1/24/2019	0.21	0.102	0.13	0.143	0.1	0.2	ug/l	2.4				0%
Toluene	25	1139	10/30/2001	11/6/2019	25	2%	11/27/2018	2.25	0.1	0.27	0.356	0.1	0.2	ug/l	57				0%
trans-1,2-Dichloroethene	25	1139	10/30/2001	11/6/2019	94	8%	11/6/2019	1.15	0.104	0.32	0.402	0.1	0.2	ug/l	100				0%
trans-1,3-Dichloropropene	25	1139	10/30/2001	11/6/2019		0%						0.2	1						0%
Trichloroethene (TCE)	25	1139	10/30/2001	11/6/2019	36	3%	11/6/2019	1.22	0.131	0.861	0.654	0.1	0.2	ug/l	0.3	11/6/2019	23	0	2%
Trichlorofluoromethane	25	1139	10/30/2001	11/6/2019	178	16%	11/6/2019	9	0.11	1.73	2.36	0.1	0.2	ug/l	2400				0%
Vinyl Acetate	25	1139	10/30/2001	11/6/2019		0%						0.1	0.2		8000				0%
Vinyl Chloride	25	1139	10/30/2001	11/6/2019	247	22%	11/6/2019	53.1	0.0101	0.51	5.01	0.01	0.5	ug/l	0.02	11/6/2019	246	816	22%

Notes:

RDL = Reporting Detection Limit

PCUL = Preliminary Cleanup Level

1 - Sampling locations included in this table are all on-property monitoring wells.

2 - This is the first sample date that is included in this analysis.

Table 6.2. Frequency of Cleanup Level Exceedances – Off-Property Drinking Water Wells

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedances
Conventionals																			
Alkalinity, Total	11	84	2/12/2002	8/16/2019	84	100%	8/16/2019	76	52	69.2	68.7			mg/l					0%
Ammonia as N	11	84	2/12/2002	8/16/2019	46	55%	8/16/2019	1.3	0.01	0.24	0.238	0.002	0.03	mg/l					0%
Chemical Oxygen Demand	11	11	2/12/2002	2/14/2002	1	9%	2/13/2002	6	6	6	6	5	5	mg/l					0%
Chloride	11	84	2/12/2002	8/16/2019	84	100%	8/16/2019	8.9	2	5.2	4.36			mg/l					0%
Cyanide	11	11	2/12/2002	2/14/2002		0%						0.02	0.02		0.01	2/14/2002	0	11	0%
Fecal Coliform	11	11	2/12/2002	2/14/2002		0%						1	1						0%
Fluoride	11	11	2/12/2002	2/14/2002		0%						1	1		0.96	2/14/2002	0	11	0%
Nitrate + Nitrite as N	11	11	2/12/2002	2/14/2002	8	73%	2/14/2002	2.5	0.01	0.44	0.65	0.01	0.01	mg/l					0%
Nitrate as N	11	84	2/12/2002	8/16/2019	42	50%	8/16/2019	2.5	0.01	0.98	0.932	0.01	0.05	mg/l	10				0%
Nitrite as N	11	11	2/12/2002	2/14/2002		0%						0.01	0.01		1				0%
pH	11	43	2/12/2002	10/29/2009	43	100%	10/29/2009	7.9	6.25	7.4	7.35			pH units					0%
Specific Conductance	11	84	2/12/2002	8/16/2019	84	100%	8/16/2019	360	130	170	174			uS/cm					0%
Sulfate	11	84	2/12/2002	8/16/2019	84	100%	8/16/2019	17	1	9.4	8.57			mg/l					0%
Total Coliform	11	11	2/12/2002	2/14/2002	2	18%	2/14/2002	4	0	2	2	1	1	cfu/100ml					0%
Total Dissolved Solids	11	84	2/12/2002	8/16/2019	84	100%	8/16/2019	160	60	110	109			mg/l					0%
Total Organic Carbon	11	84	2/12/2002	8/16/2019	13	15%	8/17/2018	7.5	0.36	1.02	1.46	0.5	1	mg/l					0%
Total Organic Halides (TOX)	11	11	2/12/2002	2/14/2002		0%						0.05	0.05						0%
Total Solids	11	84	2/12/2002	8/16/2019	84	100%	8/16/2019	150	64	110	112			mg/l					0%
Total Suspended Solids	11	84	2/12/2002	8/16/2019	16	19%	8/16/2019	14	0.5	2	3.2	0.5	2	mg/l					0%
Field Parameters																			
Dissolved Oxygen	11	47	2/12/2002	8/16/2019	47	100%	8/16/2019	11.64	0.01	4.07	4.318			mg/L					0%
Oxidation-Reduction Potential	2	12	6/2/2017	8/16/2019	12	100%	8/16/2019	394.7	-153	128	84.23			mV					0%
pH	11	83	2/12/2002	8/16/2019	83	100%	8/16/2019	8.41	6.5	7.44	7.46			pH units					0%
Specific Conductance	11	83	2/12/2002	8/16/2019	83	100%	8/16/2019	207	0.202	154.5	152.4			uS/cm					0%
Temperature	11	83	2/12/2002	8/16/2019	83	100%	8/16/2019	16.3	4.9	10.3	10.53			deg C					0%
Turbidity	11	47	2/12/2002	8/16/2019	47	100%	8/16/2019	15.1	0.15	0.55	1.1			NTU					0%
Metals (dissolved)																			
Antimony	3	53	4/24/2008	8/16/2019		0%						0.0003	0.001		6				0%
Arsenic	3	53	4/24/2008	8/16/2019	34	64%	8/16/2019	1.8	0.422	1.47	1.3	0.0009	0.001	ug/l	8				0%
Barium	3	53	4/24/2008	8/16/2019	53	100%	8/16/2019	11	3.49	8.68	6.88			ug/l	2000				0%
Beryllium	3	53	4/24/2008	8/16/2019		0%						0.0001	0.001		4				0%
Cadmium	3	53	4/24/2008	8/16/2019		0%						0.00005	0.002		5				0%
Calcium	3	53	4/24/2008	8/16/2019	53	100%	8/16/2019	14900	11300	13200	13200			ug/l					0%
Chromium	3	53	4/24/2008	8/16/2019	6	11%	8/16/2019	2.09	1.34	1.9	1.83	0.0002	0.005	ug/l	100				0%
Cobalt	3	53	4/24/2008	8/16/2019		0%						0.00005	0.003		4.8				0%
Copper	3	53	4/24/2008	8/16/2019	27	51%	8/16/2019	35	3.04	13.2	14	0.0002	0.002	ug/l	640				0%
Iron	3	53	4/24/2008	8/16/2019	30	57%	8/16/2019	560	54	64.5	98.3	0.01	0.01	ug/l	11000				0%
Lead	3	53	4/24/2008	8/16/2019	12	23%	8/16/2019	4.23	0.224	1.13	1.35	0.0001	0.001	ug/l	15				0%
Magnesium	3	53	4/24/2008	8/16/2019	53	100%	8/16/2019	12700	5430	9400	8620			ug/l					0%
Manganese	3	53	4/24/2008	8/16/2019	37	70%	8/16/2019	120	0.116	48.7	41.1	0.0009	0.001	ug/l	750				0%
Mercury	3	55	2/14/2002	8/16/2019		0%						0.00005	0.0001		2				0%
Nickel	3	53	4/24/2008	8/16/2019	6	11%	8/16/2019	0.571	0.496	0.546	0.538	0.0001	0.01	ug/l	100				0%
Potassium	3	53	4/24/2008	8/16/2019	53	100%	8/16/2019	2890	1400	1800	2040			ug/l					0%
Selenium	3	53	4/24/2008	8/16/2019		0%						0.0005	0.001		50				0%
Silver	3	53	4/24/2008	8/16/2019		0%						0.00004	0.003		80				0%
Sodium	3	53	4/24/2008	8/16/2019	53	100%	8/16/2019	7330	4970	6020	6000			ug/l					0%
Thallium	3	53	4/24/2008	8/16/2019		0%						0.0001	0.001		0.16	12/2/2016	0	41	0%
Vanadium	3	53	4/24/2008	8/16/2019	30	57%	8/16/2019	3.55	0.0763	2.91	2.54	0.000075	0.002	ug/l	80				0%
Zinc	3	53	4/24/2008	8/16/2019	33	62%	8/16/2019	37.4	0.616	6.27	9.25	0.0036	0.004	ug/l	4800				0%
Metals (total)																			
Aluminum	11	11	2/12/2002	2/14/2002	6	55%	2/14/2002	550	35	95	170	0.02	0.02	ug/l	16000				0%
Antimony	11	59	2/12/2002	8/16/2019		0%						0.0003	0.001		6				0%
Arsenic	11	59	2/12/2002	8/16/2019	43	73%	8/16/2019	2.4	0.402	1.5	1.42	0.001	0.001	ug/l	8				0%
Barium	11	59	2/12/2002	8/16/2019	59	100%	8/16/2019	11	3.55	9	7.25			ug/l	2000				0%
Beryllium	11	59	2/12/2002	8/16/2019		0%						0.0001	0.001		4				0%
Cadmium	11	59	2/12/2002	8/16/2019	1	2%	6/2/2017	0.178	0.178	0.178	0.178	0.00005	0.002	ug/l	5				0%
Calcium	11	59	2/12/2002	8/16/2019	59	100%	8/16/2019	14700	7000	12500	12200			ug/l					0%
Chromium	11	59	2/12/2002	8/16/2019	10	17%	8/16/2019	7	0.309	1.91	2.07	0.0002	0.005	ug/l	100				0%
Cobalt	11	59	2/12/2002	8/16/2019	1	2%	10/12/2005	0.0933	0.0933	0.0933	0.0933	0.00005	0.003	ug/l	4.8				0%
Copper	11	59	2/12/2002	8/16/2019	43	73%	8/16/2019	273	0.25	15	33.5	0.0002	0.002	ug/l	640				0%
Iron	11	59	2/12/2002	8/16/2019	53	90%	8/16/2019	1200	12	86.8	196	0.01	0.01	ug/l	11000				0%
Lead	11	59	2/12/2002	8/16/2019	24	41%	8/16/2019	18.5	0.153	1.48	2.52	0.0001	0.001	ug/l	15	6/2/2017	1	0	2%
Magnesium	11	59	2/12/2002	8/16/2019	59	100%	8/16/2019	11800	4600	8300	8320			ug/l					0%
Manganese	11	59	2/12/2002	8/16/2019	45	76%	8/16/2019	120	0.129	52.4	49.1	0.001	0.001	ug/l	750				0%
Mercury	11	57	2/12/2002	8/16/2019		0%						0.00005	0.0001		2				0%
Nickel	11	59	2/12/2002	8/16/2019	9	15%	8/16/2019	3.37	0.512	0.558	0.889	0.0001	0.01	ug/l	100				0%
Potassium	11	59	2/12/2002	8/16/2019	59	100%	8/16/2019	2800	740	1800	1920			ug/l					0%
Selenium	11	59	2/12/2002	8/16/2019	6	10%	10/12/2006	5.4	1	2	2.3	0.0005	0.001	ug/l	50				0%
Silver	11	59	2/12/2002	8/16/2019		0%						0.00004	0.003		80				0%
Sodium	11	59	2/12/2002	8/16/2019	59	100%	8/16/2019	7100	4300	5820	5770			ug/l					0%
Thallium	11	59	2/12/2002	8/16/2019		0%						0.0001	0.001		0.16	12/2/2016	0	47	0%
Tin	11	11	2/12/2002	2/14/2002		0%						0.01	0.01		9600				0%
Vanadium	11	59	2/12/2002	8/16/2019	36	61%	8/16/2019	6	0.0806	3.09	2.67	0.002	0.002	ug/l	80				0%
Zinc	11	59	2/12/2002	8/16/2019	50	85%	8/16/2019	210	0.911	8.16	27.9	0.004	0.004	ug/l	4800				0%

Table 6.2. Frequency of Cleanup Level Exceedances – Off-Property Drinking Water Wells

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedances
VOCs																			
1,1,1,2-Tetrachloroethane	11	84	2/12/2002	8/16/2019		0%						0.2	0.5		1.7				0%
1,1,1-Trichloroethane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		200				0%
1,1,2,2-Tetrachloroethane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		0.22				0%
1,1,2-Trichloroethane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		5				0%
1,1-Dichloroethane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		7.7				0%
1,1-Dichloroethene	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		7				0%
1,1-Dichloropropene	11	11	2/12/2002	2/14/2002		0%						0.2	0.2						0%
1,2,3-Trichloropropane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		0.0015	8/16/2019	0	84	0%
1,2-Dibromo-3-chloropropane	11	84	2/12/2002	8/16/2019		0%						0.2	5		0.2	8/16/2019	0	84	0%
1,2-Dibromoethane (EDB)	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		0.05	8/16/2019	0	84	0%
1,2-Dichlorobenzene	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		600				0%
1,2-Dichloroethane (EDC)	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		4.8				0%
1,2-Dichloropropane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		5				0%
1,3-Dichlorobenzene	11	11	2/12/2002	2/14/2002		0%						0.2	0.2						0%
1,3-Dichloropropane	11	11	2/12/2002	2/14/2002		0%						0.2	0.2						0%
1,4-Dichloro-2-Butene	11	84	2/12/2002	8/16/2019		0%						0.5	100						0%
1,4-Dichlorobenzene	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		75				0%
2,2-Dichloropropane	11	11	2/12/2002	2/14/2002		0%						0.2	0.2						0%
2-Butanone	11	84	2/12/2002	8/16/2019	1	1%	5/14/2007	17	17	17	17	0.25	5	ug/l	4800				0%
2-Hexanone	11	84	2/12/2002	8/16/2019		0%						0.5	4		40				0%
2-Methyl-1-Propanol	11	11	2/12/2002	2/14/2002		0%						100	100		2400				0%
3-Chloropropene	11	11	2/12/2002	2/14/2002		0%						10	10		2.1	2/14/2002	0	11	0%
4-Methyl-2-pentanone	11	84	2/12/2002	8/16/2019		0%						2.5	5		640				0%
Acetone	11	84	2/12/2002	8/16/2019	2	2%	9/7/2017	4.4	4.1	4.3	4.3	2.5	5	ug/l	7200				0%
Acetonitrile	11	11	2/12/2002	2/14/2002		0%						100	100						0%
Acrolein	11	11	2/12/2002	2/14/2002		0%						10	10		4	2/14/2002	0	11	0%
Acrylonitrile	11	84	2/12/2002	8/16/2019		0%						0.035	10		0.08	10/29/2009	0	43	0%
Benzene	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		5				0%
Bromochloromethane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2						0%
Bromodichloromethane	11	84	2/12/2002	8/16/2019		0%						0.2	0.5		7.1				0%
Bromoform	11	84	2/12/2002	8/16/2019		0%						0.2	1		5				0%
Bromomethane	11	84	2/12/2002	8/16/2019	3	4%	2/12/2002	0.39	0.34	0.36	0.36	0.1	0.2	ug/l	11				0%
Carbon Disulfide	11	84	2/12/2002	8/16/2019	1	1%	2/13/2002	0.47	0.47	0.47	0.47	0.1	0.2	ug/l	800				0%
Carbon Tetrachloride	11	84	2/12/2002	8/16/2019		0%						0.2	0.5		5				0%
Chlorobenzene	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		100				0%
Chloroethane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2						0%
Chloroform	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		14				0%
Chloromethane	11	84	2/12/2002	8/16/2019	6	7%	8/20/2010	0.47	0.23	0.37	0.36	0.2	1	ug/l					0%
Chloroprene	11	11	2/12/2002	2/14/2002		0%						20	20		160				0%
cis-1,2-Dichloroethene (DCE)	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		16				0%
cis-1,3-Dichloropropene	11	84	2/12/2002	8/16/2019		0%						0.2	0.5						0%
Dibromochloromethane	11	84	2/12/2002	8/16/2019		0%						0.2	1		5.2				0%
Dibromomethane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		80				0%
Dichlorodifluoromethane	11	84	2/12/2002	8/16/2019	1	1%	7/29/2008	0.43	0.43	0.43	0.43	0.1	0.2	ug/l	1600				0%
Ethylbenzene	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		700				0%
m,p-Xylene	2	41	1/29/2010	8/16/2019		0%						0.1	0.2						0%
Methacrylonitrile	11	11	2/12/2002	2/14/2002		0%						5	5		0.8	2/14/2002	0	11	0%
Methyl Methacrylate	11	11	2/12/2002	2/14/2002		0%						2	2		11000				0%
Methylene Chloride	11	84	2/12/2002	8/16/2019		0%						0.2	5		5	1/29/2019	0	6	0%
Methyliodide	11	84	2/12/2002	8/16/2019		0%						0.1	5						0%
o-Xylene	11	52	2/12/2002	8/16/2019		0%						0.1	0.2		1600				0%
Propionitrile	11	11	2/12/2002	2/14/2002		0%						60	60						0%
Styrene	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		100				0%
Tetrachloroethene (PCE)	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		5				0%
Toluene	11	84	2/12/2002	8/16/2019	1	1%	9/1/2011	0.3	0.3	0.3	0.3	0.1	0.2	ug/l	640				0%
trans-1,2-Dichloroethene	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		100				0%
trans-1,3-Dichloropropene	11	84	2/12/2002	8/16/2019		0%						0.2	1						0%
Trichloroethene (TCE)	11	84	2/12/2002	8/16/2019	2	2%	3/31/2015	0.32	0.23	0.28	0.28	0.1	0.2	ug/l	5				0%
Trichlorofluoromethane	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		2400				0%
Vinyl Acetate	11	84	2/12/2002	8/16/2019		0%						0.1	0.2		8000				0%
Vinyl Chloride	11	84	2/12/2002	8/16/2019		0%						0.01	0.02		0.29				0%

Notes:
RDL = Reporting Detection Limit
PCUL = Preliminary Cleanup Level

Table 6.3. Summary of Groundwater Cleanup Levels for Constituents of Concern

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

			Protection of Groundwater for Human Health (Drinking Water)		Protection of Surface Water for Human Health		Protection of Surface Water for Ecological Protection		
	Units	RDL	Cleanup Level	Source of Cleanup Level	Cleanup Level	Source of Cleanup Level	Cleanup Level	Source of Cleanup Level	PCUL
Metals [a]									
Arsenic	µg/L	1	8 [b]	Background	8 [b]	Background	8 [b]	Background	8 [b]
Iron	µg/L	10	11,000	MTCA Method B			1,000	NRWQC	1,000
Manganese	µg/L		750 [c]	MTCA Method B	50 [c]	NRWQC			750 [c]
Volatile Organic Compounds									
1,2-Dichloropropane	µg/L		5	MCL	0.71	173-201A WAC			0.71
Benzene	µg/L	0.2	5	MCL	0.44	173-201A WAC			0.44
Trichloroethene (TCE)	µg/L		5	MCL	0.3	CWA			0.3
Vinyl chloride	µg/L	0.02	0.29	Modified MTCA Method B	0.02	173-201A WAC			0.02
Semi-Volatile Organic Compounds									
Bis(2-chloroethyl) ether	µg/L		0.04	MTCA Method B	0.02	173-201A WAC			0.02

Notes:

COPC = Constituent of Potential Concern

PCUL = Preliminary cleanup level

Refer to Table 5.1 for a full list of criteria and analytes

µg/L = micrograms per liter

CWA = Clean Water Act

MTCA = Model Toxics Control Act

NRWQC = National Recommended Water Quality Criteria

MCL = Maximum Contaminant Level

RDL = Reporting Detection Limit

a - Metals PCULs for human receptors is based on total and dissolved and dissolved fraction only for ecological receptors, as this fraction is more toxic to ecological receptors compared to the total fraction.

b - Arsenic screening criteria is based on a natural background concentration of 8.0 µg/L of arsenic for the Puget Sound Basin (Ecology Publication No. 14-09-044; Note that Ecology has not finalized this publication). Adjustment to background is allowable per WAC 173-340-720(7)(c).

c - Manganese PCUL based on Ecology letter to KCSWD dated December 17, 2019 regarding Review Comments and additional Corresondence on the Vashon Island Closed Landfill Remedial Investigation Report, Agency Draft.

Exceedances of PCULs are only present in the Unit Cc2 aquifer.

Table 6.4. Frequency of Cleanup Level Exceedances – Surface Water

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedances
Conventionals																			
Alkalinity, Total	17	340	12/27/2001	11/7/2019	340	100%	11/7/2019	640	4.2	154	207								0%
Ammonia as N	17	341	11/28/2001	11/7/2019	148	43%	11/7/2019	45	0.0032	0.0204	0.361	0.01	0.05	mg/l					0%
Chemical Oxygen Demand	6	230	11/28/2001	11/7/2019	217	94%	11/7/2019	100	5	16	21.1	5	10	mg/l					0%
Chloride	17	338	11/28/2001	11/7/2019	330	98%	11/7/2019	170	0.739	6.6	12.3	1	10	mg/l	230				0%
Cyanide	6	230	11/28/2001	11/7/2019		0%						0.002	0.02	mg/l	0.004	3/20/2019		212	0%
Dissolved Organic Carbon	3	5	9/16/2015	2/25/2016	5	100%	2/25/2016	6.35	2.29	3.38	3.76								0%
Dissolved Oxygen	10	115	11/28/2001	3/26/2009	115	100%	3/26/2009	15	6.4	10.6	10.8								0%
Fecal Coliform	6	230	11/28/2001	11/7/2019	180	78%	11/7/2019	4000	0	14	110	1	10	cfu/100ml					0%
Fluoride	6	227	11/28/2001	11/7/2019	12	5%	3/20/2019	0.204	0.021	0.107	0.1	0.02	1	mg/l					0%
Nitrate + Nitrite as N	6	230	11/28/2001	11/7/2019	209	91%	11/7/2019	9	0.01	0.379	0.82	0.01	0.05	mg/l					0%
Nitrate as N	17	341	11/28/2001	11/7/2019	302	89%	11/7/2019	9	0.01	0.39	0.789	0.01	0.05	mg/l	10				0%
Nitrite as N	5	50	11/28/2001	2/25/2016	5	10%	3/28/2005	0.03	0.01	0.02	0.02	0.01	0.01	mg/l					0%
pH	17	186	11/28/2001	12/20/2012	186	100%	12/20/2012	8.4	6.5	7.7	7.55								0%
Phosphate, Total	5	45	11/28/2001	5/17/2005	44	98%	5/17/2005	2.6	0.01	0.11	0.26	0.01	0.01	mg/l					0%
Phosphorus	6	184	9/29/2005	11/7/2019	184	100%	11/7/2019	1.53	0.013	0.1	0.165								0%
Phosphorus, Soluble Reactive	6	230	11/28/2001	11/7/2019	225	98%	11/7/2019	1.6	0.00855	0.04	0.0828	0.01	0.01	mg/l					0%
Silica	3	5	9/16/2015	2/25/2016	5	100%	2/25/2016	41.1	37	40.8	39.8								0%
Specific Conductance	17	359	11/28/2001	11/7/2019	359	100%	11/7/2019	1200	34.9	318	404								0%
Sulfate	17	341	11/28/2001	11/7/2019	340	100%	11/7/2019	45	0.988	11	10.5	1	1	mg/l					0%
Sulfide	3	5	9/16/2015	2/25/2016		0%						0.01	0.01	mg/l					0%
Total Coliform	6	230	11/28/2001	11/7/2019	212	92%	11/7/2019	180000	1	205	2460	1	1000	cfu/100ml					0%
Total Dissolved Solids	17	297	9/29/2005	11/7/2019	296	100%	11/7/2019	720	36	200	252	40	40	mg/l					0%
Total Kjeldahl Nitrogen	6	230	11/28/2001	11/7/2019	180	78%	11/7/2019	6.9	0.13	0.435	0.653	0.1	1.0	mg/l					0%
Total Organic Carbon	13	301	11/28/2001	11/7/2019	294	98%	11/7/2019	58	1	5.16	6.94	1	4	mg/l					0%
Total Organic Halides (TOX)	5	113	11/28/2001	12/28/2010	15	13%	7/15/2008	0.08	0.014	0.04	0.041	0.01	0.05	mg/l					0%
Total Solids	17	342	11/28/2001	11/7/2019	342	100%	11/7/2019	4100	40	250	336								0%
Total Suspended Solids	17	341	11/28/2001	11/7/2019	331	97%	11/7/2019	4100	1	25	72.6	1	2	mg/l					0%
Turbidity	11	288	11/28/2001	11/7/2019	285	99%	11/7/2019	252	0.18	7.57	13.4	0.1	1.0	ntu					0%
Field Parameters																			
Dissolved Oxygen	17	341	11/28/2001	11/7/2019	340	100%	11/7/2019	19.5	0.3	10.07	9.129	0	0	mg/L					0%
Dissolved Sulfide	3	6	6/18/2019	8/29/2019		0%						0.1	0.1	ppm					0%
Oxidation-Reduction Potential	4	70	6/18/2014	11/7/2019	70	100%	11/7/2019	376.7	-86	115.5	122.5								0%
pH	17	358	11/28/2001	11/7/2019	358	100%	11/7/2019	10.71	6	7.64	7.562								0%
Specific Conductance	17	362	11/28/2001	11/7/2019	362	100%	11/7/2019	1034	55	311.9	378.23								0%
Temperature	17	359	11/28/2001	11/7/2019	359	100%	11/7/2019	18.4	2.4	9.8	10.039								0%
Turbidity	17	360	11/28/2001	11/7/2019	360	100%	11/7/2019	381	0	9.535	20.1								0%
Metals (dissolved)																			
Aluminum	14	239	3/28/2007	11/7/2019	55	23%	11/7/2019	200	2.14	23.7	40.3	0.002	0.02	ug/l	420				0%
Antimony	13	254	3/28/2007	11/7/2019		0%						0.0003	0.001	ug/l	5.6				0%
Arsenic	17	294	3/28/2007	11/7/2019	247	84%	11/7/2019	34.1	0.92	1.94	3.63	0.0009	0.001	ug/l	8	2/25/2016	22	0	7%
Barium	17	294	3/28/2007	11/7/2019	264	90%	11/7/2019	60.7	0.71	4.81	9.42	0.0009	0.001	ug/l	1000				0%
Beryllium	13	254	3/28/2007	11/7/2019		0%						0.0001	0.001	ug/l	270				0%
Cadmium	17	294	3/28/2007	11/7/2019		0%						0.00005	0.002	ug/l	0.72	2/1/2017		250	0%
Calcium	17	294	3/28/2007	11/7/2019	294	100%	11/7/2019	98500	5060	22200	30200								0%
Chromium	13	254	3/28/2007	11/7/2019	38	15%	11/7/2019	1.3	0.208	0.352	0.566	0.0002	0.005	ug/l	74				0%
Cobalt	13	254	3/28/2007	11/7/2019	22	9%	11/7/2019	0.107	0.0521	0.0851	0.0805	0.00005	0.003	ug/l					0%
Copper	17	294	3/28/2007	11/7/2019	60	20%	11/7/2019	13.7	0.201	0.371	1.96	0.0002	0.002	ug/l	22.6				0%
Iron	17	294	3/28/2007	11/7/2019	279	95%	11/7/2019	27000	11	92	1430	0.01	0.01	ug/l	1000	2/25/2016	25	0	9%
Lead	13	254	3/28/2007	11/7/2019	2	1%	9/20/2017	0.931	0.165	0.548	0.548	0.0001	0.001	ug/l	2.5				0%
Magnesium	17	294	3/28/2007	11/7/2019	294	100%	11/7/2019	82700	2050	19800	26100								0%
Manganese	17	294	3/28/2007	11/7/2019	293	100%	11/7/2019	6400	1.9	83.5	552	0.001	0.001	ug/l	750	9/22/2016	41	0	14%
Mercury	14	116	3/28/2007	10/27/2009	4	3%	1/6/2009	0.782	0.159	0.505	0.488	0.0001	0.00014	ug/l	0.012	10/27/2009	4	112	3%
Nickel	13	254	3/28/2007	11/7/2019	45	18%	11/7/2019	10	0.496	0.876	1.28	0.009	0.01	ug/l	52				0%
Potassium	17	294	3/28/2007	11/7/2019	292	99%	11/7/2019	7160	804	2160	2280	0.3	0.3	ug/l					0%
Selenium	13	254	3/28/2007	11/7/2019	23	9%	2/4/2010	9.1	1	1.8	2.9	0.0005	0.001	ug/l	5	3/11/2008	4	0	2%
Silver	13	254	3/28/2007	11/7/2019		0%						0.00004	0.003	ug/l	3.2				0%
Sodium	17	294	3/28/2007	11/7/2019	294	100%	11/7/2019	24900	1460	8400	9570								0%
Thallium	13	254	3/28/2007	11/7/2019		0%						0.0001	0.001	ug/l	0.22	2/1/2017		210	0%

Table 6.4. Frequency of Cleanup Level Exceedances – Surface Water

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedances
Tin	10	199	3/28/2007	11/7/2019		0%						0.0005	0.01	ug/l					0%
Vanadium	13	254	3/28/2007	11/7/2019	70	28%	11/7/2019	3.4	0.318	2.04	1.61	0.0018	0.002	ug/l					0%
Zinc	13	254	3/28/2007	11/7/2019	117	46%	11/7/2019	2040	0.508	6.8	29.9	0.0005	0.004	ug/l	120	9/28/2010	3	0	1%
Metals (total)																			
Aluminum	12	272	11/28/2001	11/7/2019	272	100%	11/7/2019	10700	22.6	277	676				420	11/7/2019	97	0	36%
Antimony	10	264	11/28/2001	11/7/2019	1	0%	9/20/2017	0.358	0.358	0.358	0.358	0.0003	0.001	ug/l	5.6				0%
Arsenic	12	272	11/28/2001	11/7/2019	262	96%	11/7/2019	83	1	3.5	5.41	0.001	0.001	ug/l	8	11/7/2019	38	0	14%
Barium	12	272	11/28/2001	11/7/2019	272	100%	11/7/2019	335	1.91	10	17.9				1000				0%
Beryllium	10	264	11/28/2001	11/7/2019	1	0%	9/20/2017	0.18	0.18	0.18	0.18	0.0001	0.001	ug/l	270				0%
Cadmium	12	272	11/28/2001	11/7/2019	5	2%	6/18/2019	8	0.0554	2	3.65	0.00005	0.002	ug/l	0.72	2/1/2017	3	225	1%
Calcium	12	274	11/28/2001	11/7/2019	274	100%	11/7/2019	121000	3800	22900	32400								0%
Chromium	10	264	11/28/2001	11/7/2019	64	24%	11/7/2019	33.4	0.322	1.94	4.73	0.0045	0.005	ug/l	74				0%
Cobalt	10	264	11/28/2001	11/7/2019	61	23%	11/7/2019	24	0.0905	0.437	2.21	0.0027	0.003	ug/l					0%
Copper	12	272	11/28/2001	11/7/2019	125	46%	11/7/2019	22.1	0.27	3.3	4.68	0.0018	0.002	ug/l	22.6				0%
Iron	12	272	11/28/2001	11/7/2019	272	100%	11/7/2019	76000	46	1580	3600				1000	11/7/2019	175	0	64%
Lead	10	264	11/28/2001	11/7/2019	89	34%	11/7/2019	10.6	0.115	1.4	1.89	0.0001	0.001	ug/l	2.5	9/20/2017	20	0	8%
Magnesium	12	275	11/28/2001	11/7/2019	275	100%	11/7/2019	92000	1700	19600	26700								0%
Manganese	12	270	11/28/2001	11/7/2019	270	100%	11/7/2019	18000	3.61	582	1110				750	11/7/2019	109	0	40%
Mercury	12	253	11/28/2001	11/7/2019	2	1%	6/7/2004	0.1	0.1	0.1	0.1	0.00005	0.00014	ug/l	0.012	11/7/2019	2	251	1%
Nickel	10	264	11/28/2001	11/7/2019	71	27%	11/7/2019	59	0.989	2.77	9.39	0.009	0.01	ug/l	52	12/19/2012	1	0	0%
Potassium	12	272	11/28/2001	11/7/2019	272	100%	11/7/2019	9500	820	2290	2450								0%
Selenium	10	264	11/28/2001	11/7/2019	42	16%	9/20/2017	8.16	1	2.95	2.93	0.0005	0.001	ug/l	5	7/27/2006	6	0	2%
Silver	10	264	11/28/2001	11/7/2019	1	0%	9/20/2017	0.06	0.06	0.06	0.06	0.00004	0.003	ug/l	3.2				0%
Sodium	12	271	11/28/2001	11/7/2019	271	100%	11/7/2019	25000	1500	8650	9760								0%
Thallium	10	264	11/28/2001	11/7/2019	2	1%	6/7/2004	1	1	1	1	0.0001	0.001	ug/l	0.22	2/1/2017	2	218	1%
Tin	10	264	11/28/2001	11/7/2019		0%						0.0005	0.01	ug/l					0%
Vanadium	10	264	11/28/2001	11/7/2019	160	61%	11/7/2019	33.6	0.529	3.35	4.41	0.0018	0.002	ug/l					0%
Zinc	10	264	11/28/2001	11/7/2019	137	52%	11/7/2019	412	0.523	6.3	16.3	0.004	0.004	ug/l	120	9/28/2010	5	0	2%
Pesticides																			
2,4,5-T	6	230	11/28/2001	11/7/2019		0%						0.0248	2	ug/l					0%
2,4,5-TP Silvex	6	230	11/28/2001	11/7/2019	5	2%	9/17/2018	0.0279	0.0259	0.0271	0.0269	0.0248	1	ug/l	100				0%
2,4-D	6	230	11/28/2001	11/7/2019		0%						0.0495	5	ug/l	1300				0%
Dinoseb	6	230	11/28/2001	11/7/2019		0%						0.0248	1	ug/l					0%
Endrin	6	230	11/28/2001	11/7/2019		0%						0.0119	0.12	ug/l	0.002	11/7/2019		230	0%
Lindane (Gamma BHC)	6	230	11/28/2001	11/7/2019		0%						0.0119	0.029	ug/l	0.08				0%
Methoxychlor	6	230	11/28/2001	11/7/2019		0%						0.0595	2.3	ug/l	0.03	11/7/2019		230	0%
Toxaphene	6	230	11/28/2001	11/7/2019		0%						1.19	2.9	ug/l	0.000032	11/7/2019		230	0%
VOCs																			
1,1,1,2-Tetrachloroethane	13	302	11/28/2001	11/7/2019		0%						0.2	2.0	ug/l					0%
1,1,1-Trichloroethane	13	302	11/28/2001	11/7/2019	11	4%	11/5/2010	1.1	0.33	0.69	0.664	0.1	2.0	ug/l	10000				0%
1,1,2,2-Tetrachloroethane	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l	0.1	11/7/2019		302	0%
1,1,2-Trichloroethane	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l	0.35	3/26/2004		6	0%
1,1-Dichloroethane	17	342	11/28/2001	11/7/2019	2	1%	3/25/2009	0.31	0.22	0.27	0.27	0.1	2.0	ug/l					0%
1,1-Dichloroethene	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l	300				0%
1,1-Dichloropropene	5	50	11/28/2001	7/27/2006		0%						0.2	2.0	ug/l					0%
1,2,3-Trichloropropane	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l					0%
1,2-Dibromo-3-chloropropane	13	302	11/28/2001	11/7/2019		0%						0.20	5	ug/l					0%
1,2-Dibromoethane (EDB)	17	342	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l					0%
1,2-Dichlorobenzene	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l	700				0%
1,2-Dichloroethane (EDC)	13	302	11/28/2001	11/7/2019	1	0%	3/25/2009	0.2	0.2	0.2	0.2	0.1	2.0	ug/l	8.9				0%
1,2-Dichloropropane	17	342	11/28/2001	11/7/2019	19	6%	11/2/2010	7.6	0.49	0.983	1.75	0.1	2.0	ug/l	0.71	11/2/2010	14	6	4%
1,3-Dichlorobenzene	5	39	11/28/2001	12/23/2004		0%						0.20	2.0	ug/l	2	12/17/2003		4	0%
1,3-Dichloropropane	5	39	11/28/2001	12/23/2004		0%						0.20	2.0	ug/l					0%
1,4-Dichloro-2-Butene	13	302	11/28/2001	11/7/2019		0%						0.5	1000	ug/l					0%
1,4-Dichlorobenzene	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l	200				0%
2,2-Dichloropropane	5	39	11/28/2001	12/23/2004		0%						0.20	2.0	ug/l					0%
2-Butanone	13	290	11/28/2001	11/7/2019		0%						0.25	40	ug/l					0%
2-Hexanone	13	302	11/28/2001	11/7/2019		0%						0.5	40	ug/l					0%
2-Methyl-1-Propanol	5	39	11/28/2001	12/23/2004		0%						100	100	ug/l					0%

Table 6.4. Frequency of Cleanup Level Exceedances – Surface Water

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units	PCUL	Date of Last PCUL Exceedance	Number of Exceedances of PCUL	Number of NonDetects with Reporting Limit Above PCUL	Frequency of Detected Exceedances
3-Chloropropene	5	39	11/28/2001	12/23/2004		0%						10	100	ug/l					0%
4-Methyl-2-pentanone	13	302	11/28/2001	11/7/2019		0%						2.5	40	ug/l					0%
Acetone	13	302	11/28/2001	11/7/2019	18	6%	6/18/2019	26	2.5	6.43	8.39	2.5	40	ug/l					0%
Acetonitrile	5	39	11/28/2001	12/23/2004		0%						100	100	ug/l					0%
Acrolein	5	39	11/28/2001	12/23/2004		0%						10	100	ug/l	1	12/23/2004		39	0%
Acrylonitrile	13	302	11/28/2001	11/7/2019	1	0%	1/21/2010	0.083	0.083	0.083	0.083	0.035	100	ug/l	0.019	11/7/2019	1	301	0%
Benzene	17	342	11/28/2001	11/7/2019	22	6%	11/2/2010	3.2	0.24	0.712	0.907	0.1	2.0	ug/l	0.44	11/2/2010	18	6	5%
Bromochloromethane	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l					0%
Bromodichloromethane	13	302	11/28/2001	11/7/2019		0%						0.2	2.0	ug/l	0.73	3/26/2004		6	0%
Bromoform	13	302	11/28/2001	11/7/2019		0%						0.2	2.0	ug/l	4.6				0%
Bromomethane	13	302	11/28/2001	11/7/2019	3	1%	10/20/2009	2.7	0.21	0.26	1.1	0.1	2.0	ug/l	100				0%
Carbon Disulfide	13	302	11/28/2001	11/7/2019	4	1%	5/10/2007	0.7	0.31	0.52	0.51	0.1	2.0	ug/l					0%
Carbon Tetrachloride	13	302	11/28/2001	11/7/2019		0%						0.2	2.0	ug/l	0.2	11/7/2019		302	0%
Chlorobenzene	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l	100				0%
Chloroethane	13	302	11/28/2001	11/7/2019	18	6%	11/5/2010	1.8	0.29	0.84	0.911	0.1	2.0	ug/l					0%
Chloroform	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l	60				0%
Chloromethane	13	300	11/28/2001	11/7/2019	22	7%	11/7/2019	2.79	0.21	0.29	0.467	0.2	2.0	ug/l					0%
Chloroprene	5	39	11/28/2001	12/23/2004		0%						20	200	ug/l					0%
cis-1,2-Dichloroethene (DCE)	17	342	11/28/2001	11/7/2019	44	13%	11/5/2010	2	0.22	0.68	0.778	0.1	2.0	ug/l					0%
cis-1,3-Dichloropropene	13	302	11/28/2001	11/7/2019		0%						0.2	2.0	ug/l					0%
Dibromochloromethane	13	302	11/28/2001	11/7/2019		0%						0.2	2.0	ug/l	0.6	3/20/2019		21	0%
Dibromomethane	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l					0%
Dichlorodifluoromethane	17	342	11/28/2001	11/7/2019	52	15%	11/5/2010	4.8	0.24	1.48	1.79	0.1	2.0	ug/l					0%
Ethylbenzene	13	302	11/28/2001	11/7/2019	3	1%	7/16/2008	0.32	0.23	0.24	0.26	0.1	2.0	ug/l	29				0%
m,p-Xylene	10	152	1/21/2010	11/7/2019		0%						0.1	0.2	ug/l					0%
Methacrylonitrile	5	39	11/28/2001	12/23/2004		0%						5.0	50	ug/l					0%
Methyl Methacrylate	5	39	11/28/2001	12/23/2004		0%						2.0	20	ug/l					0%
Methylene Chloride	13	302	11/28/2001	11/7/2019	5	2%	5/24/2011	6.7	0.21	1.5	2.22	0.2	5	ug/l	10				0%
Methyliodide	13	302	11/28/2001	11/7/2019	1	0%	10/20/2009	0.21	0.21	0.21	0.21	0.1	5	ug/l					0%
o-Xylene	10	191	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l					0%
Propionitrile	5	39	11/28/2001	12/23/2004		0%						60	60	ug/l					0%
Styrene	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l					0%
Tetrachloroethene (PCE)	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l	2.4				0%
Toluene	13	302	11/28/2001	11/7/2019	30	10%	11/2/2010	4.3	0.2	0.27	0.49	0.1	2.0	ug/l	57				0%
trans-1,2-Dichloroethene	17	342	11/28/2001	11/7/2019	11	3%	11/2/2010	0.61	0.22	0.29	0.32	0.1	2.0	ug/l	100				0%
trans-1,3-Dichloropropene	13	302	11/28/2001	11/7/2019		0%						0.2	2.0	ug/l					0%
Trichloroethene (TCE)	13	302	11/28/2001	11/7/2019	1	0%	5/9/2007	0.22	0.22	0.22	0.22	0.1	2.0	ug/l	0.3	3/26/2004		6	0%
Trichlorofluoromethane	17	342	11/28/2001	11/7/2019	28	8%	11/5/2010	2.41	0.22	0.877	0.929	0.1	2.0	ug/l					0%
Vinyl Acetate	13	302	11/28/2001	11/7/2019		0%						0.1	2.0	ug/l					0%
Vinyl Chloride	17	360	11/28/2001	11/7/2019	125	35%	11/7/2019	7.4	0.0103	0.05	0.519	0.01	0.20	ug/l	0.02	11/7/2019	120	223	33%

Notes:

RDL = Reporting Detection Limit

PCUL = Preliminary Cleanup Level

Table 6.5. Summary of Surface Water Cleanup Levels for Constituents of Concern

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

			Protection of Surface Water for Human Health		Protection of Surface Water for Ecological Protection		
	units	RDL	Cleanup Level	Source of Cleanup Level	Cleanup Level	Source of Cleanup Level	PCUL
Metals [a]							
Arsenic	µg/L	1	8 [b]	Background	8 [b]	Background	8 [b]
Iron	µg/L	10			1,000	NRWQC	1,000
Manganese	µg/L	10	50	NRWQC			750 [c]
Volatile Organic Compounds							
Benzene	µg/L	0.2	0.44	173-201A WAC			0.44
Trichloroethene (TCE)	µg/L		0.3	CWA			0.3
Vinyl chloride	µg/L	0.02	0.02	173-201A WAC			0.02

Notes:

Refer to Table 5.1 for a full list of criteria and analytes

PCUL = Preliminary cleanup level

µg/L = micrograms per liter

CWA = Clean Water Act

NRWQC = National Recommended Water Quality Criteria

MTCA = Model Toxics Control Act

RDL = Reporting Detection Limit

a - Metals PCULs for human receptors is based on total and dissolved and dissolved fraction only for ecological receptors, as this fraction is more toxic to ecological receptors compared to the total fraction.

b - Arsenic screening criteria is based on a natural background concentration of 8.0 µg/L of arsenic for the Puget Sound Basin (Ecology Publication No. 14-09-044; Note that Ecology has not finalized this publication). Adjustment to background is allowable per WAC 173-340-720(7)(c).

c - Manganese PCUL based on Ecology letter to KCSWD dated December 17, 2019 regarding Review Comments and additional Correspondence on the Vashon Island Closed Landfill Remedial Investigation Report, Agency Draft.

Table 6.6. Summary of Volatile Organic Compounds in Landfill Gas

Project No. 090057-310.3, Vashon Island Closed Landfill, King County, Washington

Sample Location:		Blower Inlet			EF-2	
Date:		May 1, 2013		March 14, 2019	May 1, 2013	
Chemical	Units	TB	Summa	Summa and TB	TB	Summa
Major Gases (EPA Method 3C)						
Carbon dioxide	%			13.4		
Carbon monoxide	%			< 0.05		
Methane	%			3.44		
Nitrogen	%			70.0		
Oxygen	%			13.1		
Hydrogen	%			< 0.05		
Sulfur Compounds (EPA Method TO-15)						
Carbon disulfide	µg/m^3	< 6.23	< 4.05	5.74	< 0.623	< 0.623
Carbonyl sulfide	µg/m^3			< 24.6		
Dimethyl sulfide (methyl sulfide)	µg/m^3			< 25.4		
Ethyl mercaptan	µg/m^3			< 25.4		
Hydrogen sulfide	µg/m^3			3870 E		
Methyl mercaptan	µg/m^3			< 19.6		
Volatile Organic Compounds (EPA Method 8260C)						
Acrylonitrile	µg/L			< 0.1		
Ethylene dibromide	µg/L			< 0.025		
Volatile Organic Compounds (EPA Method TO-15)						
1,1,1-Trichloroethane	µg/m^3	27.1	8.95	21.3	< 1.09	< 1.09
1,1,2,2-Tetrachloroethane	µg/m^3	< 2.06	< 2.06	< 2.06	< 2.06	< 2.06
1,1-Dichloroethane	µg/m^3	10	5.67	22.7	6.8	4.05
1,1-Dichloroethene	µg/m^3	10	5.67	4.67	< 0.793	< 0.793
1,2-Dibromoethane	µg/m^3	< 0.793	< 0.793	2.36	< 1.54	< 1.54
1,2-Dichlorobenzene	µg/m^3	< 1.8	< 1.8	19.6	< 1.8	< 7.5
1,2-Dichloroethane	µg/m^3	6.48	0.909	5.03	< 0.809	< 0.809
1,2-Dichloropropane	µg/m^3	< 2.31	< 2.31	63.5	< 2.31	< 2.31
1,2,4-Trichlorobenzene	µg/m^3	< 2.23	< 2.23	2.70	< 2.23	< 2.23
1,2,4-Trimethylbenzene	µg/m^3	14.2	5.21	468	9.04	5.31
1,3,5-Trimethylbenzene	µg/m^3	9.05	1.47	209	< 1.47	< 1.47
1,3-Dichlorobenzene	µg/m^3	< 1.8	< 1.8	6.35	< 1.8	< 2.65
1,4-Dichlorobenzene	µg/m^3	< 1.8	< 1.8	57.2	< 1.8	< 1.8
2-Hexanone	µg/m^3	< 4.1	< 4.1	5.86	< 4.1	< 4.1
4-Ethyltoluene	µg/m^3	< 1.47	< 3.15	124	< 1.47	< 1.47
Acetone	µg/m^3	34	46	28.9	27.9	35.7
Benzene	µg/m^3	56	21.4	93.4	24	11.8
Benzyl chloride	µg/m^3	< 2.59	< 2.59	36.0	< 2.59	< 2.59
Butane	µg/m^3					
Carbon tetrachloride	µg/m^3	< 1.26	< 1.26	< 0.413	< 1.26	< 1.26
Chlorobenzene	µg/m^3	< 0.921	< 0.921	127	< 0.921	< 0.921
Chlorodifluoromethane	µg/m^3					
Chloroethane	µg/m^3	< 1.32	< 49.8	36.6	< 1.32	< 17.6
Chloroform	µg/m^3	< 0.977	< 0.977	4.36	< 0.977	< 0.977
Chloromethane	µg/m^3	< 1.03	< 7.52	< 10.3	< 1.03	< 3.14
cis-1,2-dichloroethene	µg/m^3	23.8	12.8	266	< 0.793	< 3.89
Cyclohexane	µg/m^3	255 B	68.2 B	311	116 B	33.7 B
Dichlorobenzene	µg/m^3					
Dichlorobromomethane (bromodichloromethan	µg/m^3	< 2.01	< 2.01	< 2.01	< 2.01	< 2.01
Dichlorofluoromethane	µg/m^3					
Ethane	µg/m^3					
Ethanol	µg/m^3					
Ethylbenzene	µg/m^3	951	5.21	2760 E	165	4.95
Freon 11 (fluorotrichloromethane; CFC-11)	µg/m^3	< 1.69	< 1.69	1360 E	56.6	48.2
Freon 12 (dichlorodifluoromethane; CFC-12)	µg/m^3	174	135	198	175	125
Freon 113 (CFC-113)	µg/m^3	25.8	20.4	13.4	< 3.83	< 3.83
Freon 114 (dichlorotetrafluoroethane; CFC-114	µg/m^3	67.1	62.4	96.1	134	133
Heptane	µg/m^3	407	36.6	294	195	22.3
n-Hexane	µg/m^3	282 B	114 B	365	240 B	98.8 B
Isopropyl alcohol (2-propanol)	µg/m^3	7.86	9.73	4.00	< 2.46	< 2.46
Mercury	µg/m^3					
Methyl ethyl ketone (2-Butanone)	µg/m^3	15.8	72.8	55.0	< 1.47	< 68
Methyl isobutyl ketone	µg/m^3			62.7		
Methylene chloride (dichloromethane)	µg/m^3	< 1.74	< 28.8	119	9.73	3.82
MTBE	µg/m^3	< 0.721	< 0.721	3.13	< 0.721	< 0.721
Naphthalene	µg/m^3	< 1.57	< 1.57	75.9	< 1.57	< 1.57
Pentane	µg/m^3					
Propane	µg/m^3					
Propylene	µg/m^3	676	621	625 E	295	281
Styrene	µg/m^3	< 1.28	< 1.28	108	< 1.28	< 1.28
Tetrachloroethene (PCE)	µg/m^3	15.7	2.03	116	18.5	2.03
Tetrahydrofuran	µg/m^3	132	31.2	111	7.79	26.6
Toluene	µg/m^3	147	42.6	1380 E	48.5	44.1
trans-1,2-Dichloroethene	µg/m^3	< 0.793	< 0.793	17.5	< 0.793	< 0.793
Trichloroethene (TCE)	µg/m^3	9.03	1.07	56.5	< 1.07	< 1.07
Vinyl acetate	µg/m^3	< 3.52	< 3.52	5.61	57.7	3.52
Vinyl chloride	µg/m^3	64.8	69.9	151	55	60
m,p-Xylenes	µg/m^3	1010	9.47	6310 E	142	9.64
o-Xylene	µg/m^3	299	6.17	1530 E	63.9	6.25
Total Volatile Organics	µg/m^3			151000		

Notes:

Analytes included are those listed on the AP-42 analyte list for landfills with waste in place prior to 1992 (which is the same as the LandGem Model Analyte List) and all analytes detected by the laboratory.

E indicates the laboratory results was reported as an estimated value.

B - Analyte dected in associated Method Blank

TB = Tedlar Bag sample

Summa = Summa cannister sample

Source of 2013 Sample Results: Herrera Environmental Consultants, 2013

µg/m^3 = micrograms per cubic meter

Highlighting indicates analyte was detected but not included on the AP-42 Analyte list or LandGem Analyte list for Landfills with waste in place prior to 1992.

Highlighting indicates analyte was included on the AP-42 Analyte list for Landfills with waste in place prior to 1992, but is not included on the WAC-173-460-150 Table for ASIL, SQER and de minimis emission values.

Table 6.7. Summary of Leachate Detections

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units
Conventionals														
Alkalinity, Total	11	250	10/11/2001	8/29/2019	248	99%	8/29/2019	1300	21	132	234	1	4	mg/l
Ammonia as N	11	247	10/11/2001	8/29/2019	143	58%	8/29/2019	58	0.0022	0.164	6.14	0.002	0.05	mg/l
Chemical Oxygen Demand	11	250	10/11/2001	8/29/2019	246	98%	8/29/2019	450	6.7	42.9	69	5	5	mg/l
Chloride	11	242	10/11/2001	8/29/2019	242	100%	8/29/2019	640	1	230	217			mg/l
Cyanide	11	247	10/11/2001	8/29/2019	3	1%	9/23/2005	0.04	0.011	0.02	0.024	0.002	0.05	mg/l
Dissolved Organic Carbon	1	2	9/16/2015	2/25/2016	2	100%	2/25/2016	19.5	5.53	12.5	12.5			mg/l
Fecal Coliform	10	244	10/11/2001	8/29/2019	61	25%	8/29/2019	120000	1	7	3900	1	100	cfu/100ml
Fluoride	11	244	10/11/2001	8/29/2019	55	23%	8/29/2019	1	0.039	0.14	0.17	0.02	10	mg/l
Nitrate + Nitrite as N	11	245	10/11/2001	8/29/2019	227	93%	8/29/2019	126	0.011	14	31.1	0.01	1.3	mg/l
Nitrate as N	1	2	9/16/2015	2/25/2016	2	100%	2/25/2016	44.8	7.43	26.1	26.1			mg/l
Nitrite as N	1	2	9/16/2015	2/25/2016		0%						0.01	0.01	
pH	4	157	10/11/2001	12/29/2009	157	100%	12/29/2009	8.6	3.7	7.5	7.42			pH units
Phosphate, Total	2	63	10/11/2001	8/5/2005	59	94%	8/5/2005	1.7	0.01	0.08	0.2	0.01	0.04	mg/l
Phosphorus	11	184	9/23/2005	8/29/2019	116	63%	6/18/2019	1.84	0.0123	0.0575	0.119	0.01	1	mg/l
Phosphorus, Soluble Reactive	11	247	10/11/2001	8/29/2019	191	77%	8/29/2019	2	0.00478	0.02	0.0783	0.01	0.01	mg/l
Silica	1	2	9/16/2015	2/25/2016	2	100%	2/25/2016	20	19	20	20			mg/l
Specific Conductance	11	247	10/11/2001	8/29/2019	247	100%	8/29/2019	27000	3	1800	1790			uS/cm
Sulfate	11	242	10/11/2001	8/29/2019	241	100%	8/29/2019	1200	3.25	280	316	5	5	mg/l
Sulfide	12	199	10/24/2001	8/29/2019	44	22%	8/29/2019	3.2	0.01	0.0175	0.222	0.01	1	mg/l
Total Coliform	10	243	10/11/2001	8/29/2019	177	73%	8/29/2019	2500000	0	450	49000	1	10000	cfu/100ml
Total Dissolved Solids	9	19	4/12/2011	4/2/2013	19	100%	4/2/2013	2540	93.5	189	406			mg/l
Total Kjeldahl Nitrogen	11	247	10/11/2001	8/29/2019	220	89%	8/29/2019	64	0.245	1.4	6.18	0.5	1	mg/l
Total Organic Carbon	11	246	10/11/2001	8/29/2019	244	99%	8/29/2019	130	2.5	16.6	23.7	1	10	mg/l
Total Organic Halides (TOX)	3	146	10/11/2001	12/15/2010	108	74%	12/15/2010	170	0.05	0.172	1.79	0.05	0.2	mg/l
Total Suspended Solids	12	266	10/11/2001	8/29/2019	213	80%	8/29/2019	9000	0.9	8	128	0.5	8	mg/l
Total Volatile Solids	11	250	10/11/2001	8/29/2019	250	100%	8/29/2019	2000	6	320	375			mg/l
Field Parameters														
Dissolved Oxygen	2	3	9/16/2015	2/25/2016	3	100%	2/25/2016	9.46	7.12	9.11	8.56			mg/L
Dissolved Sulfide	3	7	6/18/2019	11/22/2019	1	14%	11/22/2019	0.1	0.1	0.1	0.1	0.1	0.1	ppm
Oxidation-Reduction Potential	1	1	9/16/2015	9/16/2015	1	100%	9/16/2015	179	179	179	179			mV
pH	12	312	10/11/2001	11/22/2019	312	100%	11/22/2019	8.88	3.66	7.41	7.38			pH units
Specific Conductance	12	312	10/11/2001	11/22/2019	312	100%	11/22/2019	5100	16.5	645	1153			uS/cm
Temperature	12	312	10/11/2001	11/22/2019	312	100%	11/22/2019	22.9	3.3	13.95	13.69			deg C
Turbidity	2	4	9/16/2015	6/18/2019	4	100%	6/18/2019	16.12	0.98	5.51	7.03			NTU
Fats/Oils/Grease														
Fats/Oils/Grease (Non-Polar)	3	117	10/11/2001	3/12/2009	4	3%	3/1/2006	15	1.2	1.5	4.8	1	5.2	mg/l
Fats/Oils/Grease (Polar)	2	62	10/11/2001	8/5/2005	5	8%	8/23/2004	27	1.5	24	20	1	5	mg/l
Fats/Oils/Grease (Total)	11	235	10/11/2001	11/22/2019	57	24%	6/18/2019	27	1.2	2.7	4.9	1	6.4	mg/l
Metals (dissolved)														
Aluminum	12	198	10/11/2001	2/25/2016	44	22%	3/5/2013	1800	21	47.5	195	0.018	0.1	ug/l
Antimony	12	135	9/23/2005	2/25/2016	5	4%	11/16/2009	2.78	0.171	1.39	1.41	0.0009	0.001	ug/l
Arsenic	12	135	9/23/2005	2/25/2016	61	45%	12/29/2009	26	0.94	3.8	4.71	0.001	0.001	ug/l
Barium	12	198	10/11/2001	2/25/2016	198	100%	2/25/2016	290	1	49	69.2			ug/l
Beryllium	12	198	10/11/2001	2/25/2016		0%						0.0009	0.005	
Cadmium	12	198	10/11/2001	2/25/2016	8	4%	8/13/2008	10	2	4.5	4.9	0.0018	0.002	ug/l
Calcium	12	195	10/11/2001	2/25/2016	195	100%	2/25/2016	290000	11400	130000	122000			ug/l
Chromium	12	198	10/11/2001	2/25/2016	10	5%	7/19/2006	8	5	6.5	6.45	0.0045	0.025	ug/l
Cobalt	12	198	10/11/2001	2/25/2016	112	57%	4/2/2013	32	3	6.79	9.2	0.0027	0.003	ug/l

Table 6.7. Summary of Leachate Detections

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units
Copper	12	198	10/11/2001	2/25/2016	163	82%	2/25/2016	2900	2	6	24.3	0.0018	0.002	ug/l
Iron	12	198	10/11/2001	2/25/2016	132	67%	3/5/2013	5200	11	450	712	0.005	0.01	ug/l
Lead	12	198	10/11/2001	2/25/2016	8	4%	7/19/2006	17	0.212	1.55	3.83	0.0009	0.001	ug/l
Magnesium	12	197	10/11/2001	2/25/2016	197	100%	2/25/2016	155000	2700	62000	60000			ug/l
Manganese	12	196	10/11/2001	2/25/2016	144	73%	4/2/2013	9300	1.2	59.5	1370	0.0009	0.001	ug/l
Mercury	11	134	9/23/2005	2/25/2016	1	0.7%	12/22/2005	3.7	3.7	3.7	3.7	0.0001	0.00014	ug/l
Nickel	12	198	10/11/2001	2/25/2016	146	74%	2/25/2016	209	11	62.9	70.2	0.01	0.01	ug/l
Potassium	12	197	10/11/2001	2/25/2016	197	100%	2/25/2016	110000	1480	22000	22200			ug/l
Selenium	12	135	9/23/2005	2/25/2016	45	33%	8/12/2009	100	1.1	15	16.9	0.0009	0.001	ug/l
Silver	12	198	10/11/2001	2/25/2016	2	1%	9/23/2005	22	0.124	11.1	11.1	0.0027	0.003	ug/l
Sodium	12	193	10/11/2001	2/25/2016	193	100%	2/25/2016	520000	3010	150000	141000			ug/l
Thallium	12	135	9/23/2005	2/25/2016		0%						0.0009	0.001	
Tin	12	198	10/11/2001	2/25/2016	1	0.5%	9/23/2005	0.982	0.982	0.982	0.982	0.009	0.01	ug/l
Vanadium	12	198	10/11/2001	2/25/2016	34	17%	9/29/2009	5	1.91	3	2.94	0.0018	0.002	ug/l
Zinc	12	197	10/11/2001	2/25/2016	179	91%	2/25/2016	420	5	29	53.7	0.004	0.004	ug/l
Metals (total)														
Aluminum	12	263	10/11/2001	8/29/2019	147	56%	6/18/2019	280000	8.37	200	5370	0.02	0.2	ug/l
Antimony	12	251	10/11/2001	8/29/2019	21	8%	6/18/2019	5	0.205	1.16	1.68	0.0003	0.01	ug/l
Arsenic	4	183	10/11/2001	11/22/2019	175	96%	11/22/2019	230	0.747	4.13	11.4	0.001	0.01	ug/l
Barium	12	263	10/11/2001	8/29/2019	263	100%	8/29/2019	2200	7.7	54.4	95.4			ug/l
Beryllium	12	263	10/11/2001	8/29/2019	1	0.4%	10/24/2003	2	2	2	2	0.0001	0.01	ug/l
Cadmium	12	312	10/11/2001	11/22/2019	18	6%	6/18/2019	17	0.0717	2.9	4.31	0.00005	0.02	ug/l
Calcium	12	258	10/11/2001	8/29/2019	258	100%	8/29/2019	630000	8440	130000	125000			ug/l
Chromium	12	312	10/11/2001	11/22/2019	51	16%	11/22/2019	520	0.286	8	35.2	0.002	0.05	ug/l
Cobalt	12	263	10/11/2001	8/29/2019	153	58%	8/29/2019	200	0.204	6	10.8	0.0005	0.03	ug/l
Copper	12	312	10/11/2001	11/22/2019	270	87%	11/22/2019	250	2.09	6.57	11.8	0.0018	0.02	ug/l
Iron	12	262	10/11/2001	8/29/2019	226	86%	8/29/2019	570000	29	683	8410	0.01	0.1	ug/l
Lead	12	312	10/11/2001	11/22/2019	57	18%	11/22/2019	170	0.106	3.66	14.8	0.0001	0.01	ug/l
Magnesium	12	261	10/11/2001	8/29/2019	261	100%	8/29/2019	223000	2800	61000	61900			ug/l
Manganese	12	259	10/11/2001	8/29/2019	238	92%	8/29/2019	64000	1.23	97.8	1660	0.001	0.001	ug/l
Mercury	12	271	10/11/2001	8/29/2019	8	3%	2/11/2009	0.8	0.1	0.2	0.268	0.0001	0.0005	ug/l
Nickel	12	312	10/11/2001	11/22/2019	216	69%	11/22/2019	590	2.4	57.9	65.6	0.01	0.1	ug/l
Potassium	12	261	10/11/2001	8/29/2019	256	98%	8/29/2019	61000	1470	22000	21500	5	60	ug/l
Selenium	12	251	10/11/2001	8/29/2019	96	38%	6/18/2019	65.8	0.629	18	19.8	0.0005	0.01	ug/l
Silver	12	312	10/11/2001	11/22/2019	1	0.3%	9/23/2005	0.142	0.142	0.142	0.142	0.00004	0.03	ug/l
Sodium	12	257	10/11/2001	8/29/2019	257	100%	8/29/2019	1700000	3090	142000	144000			ug/l
Thallium	12	251	10/11/2001	8/29/2019	3	1%	6/21/2007	1.6	1	1	1.2	0.0001	0.01	ug/l
Tin	12	263	10/11/2001	8/29/2019	5	2%	4/27/2010	206	0.843	13	49.8	0.0005	0.1	ug/l
Vanadium	12	263	10/11/2001	8/29/2019	77	29%	8/29/2019	590	0.504	3	22.5	0.00075	0.02	ug/l
Zinc	12	311	10/11/2001	11/22/2019	304	98%	11/22/2019	2700	5	38	97.1	0.004	0.005	ug/l
PCBs														
Aroclor 1016	10	243	10/11/2001	8/29/2019		0%						0.01	1	
Aroclor 1221	10	243	10/11/2001	8/29/2019		0%						0.01	1	
Aroclor 1232	10	243	10/11/2001	8/29/2019		0%						0.01	1	
Aroclor 1242	10	243	10/11/2001	8/29/2019		0%						0.01	1	
Aroclor 1248	10	243	10/11/2001	8/29/2019		0%						0.01	1	
Aroclor 1254	10	243	10/11/2001	8/29/2019		0%						0.01	1	
Aroclor 1260	10	243	10/11/2001	8/29/2019	1	0.4%	2/11/2010	0.0316	0.0316	0.0316	0.0316	0.01	1	ug/l
Total Aroclors	9	78	3/7/2012	8/29/2019		0%						0.025	0.025	

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Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units
Pesticides														
2,4,5-T	10	245	10/11/2001	8/29/2019		0%						0.25	30	
2,4,5-TP Silvex	10	245	10/11/2001	8/29/2019	1	0.4%	9/23/2005	7	7	7	7	0.25	15	ug/l
2,4-D	10	245	10/11/2001	8/29/2019	2	0.8%	12/5/2017	6.54	0.667	3.6	3.6	0.5	75	ug/l
4,4'DDD	10	245	10/11/2001	8/29/2019		0%						0.01	10	
4,4'DDE	10	245	10/11/2001	8/29/2019		0%						0.01	10	
4,4'DDT	10	245	10/11/2001	8/29/2019		0%						0.01	10	
Aldrin	10	245	10/11/2001	8/29/2019		0%						0.01	2.4	
Alpha BHC	10	245	10/11/2001	8/29/2019		0%						0.01	2.4	
Alpha Chlordane	10	245	10/11/2001	8/29/2019		0%						0.01	2.4	
Beta BHC	10	245	10/11/2001	8/29/2019		0%						0.01	2.4	
Delta BHC	10	245	10/11/2001	8/29/2019		0%						0.01	10	
Dieldrin	10	245	10/11/2001	8/29/2019		0%						0.01	10	
Dinoseb	10	245	10/11/2001	8/29/2019	2	0.8%	3/22/2005	2.9	1.4	2.2	2.2	0.25	15	ug/l
Endosulfan I	10	245	10/11/2001	8/29/2019		0%						0.01	10	
Endosulfan II	10	245	10/11/2001	8/29/2019		0%						0.01	10	
Endosulfan Sulfate	10	245	10/11/2001	8/29/2019		0%						0.01	10	
Endrin	10	245	10/11/2001	8/29/2019		0%						0.01	10	
Endrin Aldehyde	10	245	10/11/2001	8/29/2019		0%						0.01	20	
Heptachlor	10	245	10/11/2001	8/29/2019		0%						0.01	2.4	
Heptachlor Epoxide	10	245	10/11/2001	8/29/2019		0%						0.01	2.4	
Isodrin	10	245	10/11/2001	8/29/2019		0%						0.01	1000	
Lindane (Gamma BHC)	10	245	10/11/2001	8/29/2019		0%						0.01	2.4	
Methoxychlor	10	245	10/11/2001	8/29/2019		0%						0.05	200	
Toxaphene	10	245	10/11/2001	8/29/2019		0%						1	240	
SVOCs														
1,2,4-Trichlorobenzene	1	3	4/12/2011	5/10/2011		0%						10	10	
1,2-Diphenylhydrazine	1	3	4/12/2011	5/10/2011		0%						10	10	
2,2-Oxybis (1-Chloropropane)	1	3	4/12/2011	5/10/2011		0%						10	10	
2,4,5-Trichlorophenol	1	3	4/12/2011	5/10/2011		0%						10	10	
2,4,6-Trichlorophenol	1	3	4/12/2011	5/10/2011		0%						10	10	
2,4-Dichlorophenol	1	3	4/12/2011	5/10/2011		0%						10	10	
2,4-Dimethylphenol	1	3	4/12/2011	5/10/2011		0%						10	10	
2,4-Dinitrophenol	1	3	4/12/2011	5/10/2011		0%						50	50	
2,4-Dinitrotoluene	1	3	4/12/2011	5/10/2011		0%						10	10	
2,6-Dinitrotoluene	1	3	4/12/2011	5/10/2011		0%						10	10	
2-Chloronaphthalene	1	3	4/12/2011	5/10/2011		0%						10	10	
2-Chlorophenol	1	3	4/12/2011	5/10/2011		0%						10	10	
2-Methylnaphthalene	1	3	4/12/2011	5/10/2011		0%						10	10	
2-Methylphenol	1	3	4/12/2011	5/10/2011		0%						10	10	
2-Nitroaniline	1	3	4/12/2011	5/10/2011		0%						50	50	
2-Nitrophenol	1	3	4/12/2011	5/10/2011		0%						10	10	
3,3'-Dichlorobenzidine	1	3	4/12/2011	5/10/2011		0%						20	20	
3-,4-Methylphenol mixture	1	3	4/12/2011	5/10/2011		0%						10	10	
3-Nitroaniline	1	3	4/12/2011	5/10/2011		0%						50	50	
4,6-Dinitro-2-methylphenol	1	3	4/12/2011	5/10/2011		0%						50	50	
4-Bromophenyl phenyl ether	1	3	4/12/2011	5/10/2011		0%						10	10	
4-Chloro-3-methylphenol	1	3	4/12/2011	5/10/2011		0%						20	20	
4-Chlorophenyl phenyl ether	1	3	4/12/2011	5/10/2011		0%						10	10	

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4-Nitroaniline	1	3	4/12/2011	5/10/2011		0%						20	20	
4-Nitrophenol	1	3	4/12/2011	5/10/2011		0%						50	50	
Acenaphthene	1	3	4/12/2011	5/10/2011		0%						2	2	
Acenaphthylene	1	3	4/12/2011	5/10/2011		0%						1.5	1.5	
Aniline	1	3	4/12/2011	5/10/2011		0%						14	14	
Anthracene	1	3	4/12/2011	5/10/2011		0%						0.1	0.1	
Benz(a)anthracene	1	3	4/12/2011	5/10/2011		0%						0.2	0.2	
Benzo(a)pyrene	1	3	4/12/2011	5/10/2011		0%						0.1	0.1	
Benzo(b,j,k)fluoranthene	1	3	4/12/2011	5/10/2011		0%						1.5	1.5	
Benzo(g,h,i)perylene	1	3	4/12/2011	5/10/2011		0%						0.1	0.1	
Benzoic acid	1	3	4/12/2011	5/10/2011		0%						50	50	
Benzyl alcohol	1	3	4/12/2011	5/10/2011		0%						20	20	
Benzyl butyl phthalate	1	3	4/12/2011	5/10/2011		0%						5	5	
Bis(2-chloroethoxy)methane	1	3	4/12/2011	5/10/2011		0%						10	10	
Bis(2-chloroethyl) ether	1	3	4/12/2011	5/10/2011		0%						10	10	
Bis(2-ethylhexyl) phthalate	1	3	4/12/2011	5/10/2011		0%						10	10	
Carbazole	1	3	4/12/2011	5/10/2011		0%						1	1	
Chrysene	1	3	4/12/2011	5/10/2011		0%						0.2	0.2	
Dibenzo(a,h)anthracene	1	3	4/12/2011	5/10/2011		0%						0.1	0.1	
Dibenzofuran	1	3	4/12/2011	5/10/2011		0%						10	10	
Diethyl phthalate	1	3	4/12/2011	5/10/2011		0%						5	5	
Dimethyl phthalate	1	3	4/12/2011	5/10/2011		0%						5	5	
Di-n-butyl phthalate	1	3	4/12/2011	5/10/2011		0%						5	5	
Di-n-octyl phthalate	1	3	4/12/2011	5/10/2011		0%						10	10	
Fluoranthene	1	3	4/12/2011	5/10/2011		0%						0.3	0.3	
Fluorene	1	3	4/12/2011	5/10/2011		0%						2	2	
Hexachlorobenzene	1	3	4/12/2011	5/10/2011		0%						5	5	
Hexachlorobutadiene	1	3	4/12/2011	5/10/2011		0%						5	5	
Hexachlorocyclopentadiene	1	3	4/12/2011	5/10/2011		0%						5	5	
Hexachloroethane	1	3	4/12/2011	5/10/2011		0%						5	5	
Indeno(1,2,3-cd)pyrene	1	3	4/12/2011	5/10/2011		0%						0.1	0.1	
Isophorone	1	3	4/12/2011	5/10/2011		0%						10	10	
Naphthalene	1	3	4/12/2011	5/10/2011		0%						10	10	
Nitrobenzene	1	3	4/12/2011	5/10/2011		0%						10	10	
N-Nitrosodimethylamine	1	3	4/12/2011	5/10/2011		0%						10	10	
N-Nitroso-di-n-propylamine	1	3	4/12/2011	5/10/2011		0%						10	10	
N-Nitrosodiphenylamine	1	3	4/12/2011	5/10/2011		0%						10	10	
p-Chloroaniline	1	3	4/12/2011	5/10/2011		0%						10	10	
Pentachlorophenol	1	3	4/12/2011	5/10/2011		0%						50	50	
Phenanthrene	1	3	4/12/2011	5/10/2011		0%						0.1	0.1	
Phenol	1	3	4/12/2011	5/10/2011		0%						4	4	
Pyrene	1	3	4/12/2011	5/10/2011		0%						0.2	0.2	
VOCs														
1,1,1,2-Tetrachloroethane	11	243	10/11/2001	8/29/2019		0%						0.2	5	
1,1,1-Trichloroethane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,1,2,2-Tetrachloroethane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,1,2-Trichloroethane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,1-Dichloroethane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,1-Dichloroethene	11	243	10/11/2001	8/29/2019		0%						0.2	4	

Table 6.7. Summary of Leachate Detections

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units
1,1-Dichloropropene	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,2,3-Trichloropropane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,2-Dibromo-3-chloropropane	11	243	10/11/2001	8/29/2019		0%						0.2	50	
1,2-Dibromoethane (EDB)	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,2-Dichlorobenzene	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,2-Dichloroethane (EDC)	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,2-Dichloropropane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,3-Dichlorobenzene	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,3-Dichloropropane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
1,4-Dichloro-2-Butene	11	243	10/11/2001	8/29/2019		0%						5	2000	
1,4-Dichlorobenzene	11	243	10/11/2001	8/29/2019		0%						0.2	4	
2,2-Dichloropropane	11	243	10/11/2001	8/29/2019		0%						0.2	5	
2-Butanone	11	243	10/11/2001	8/29/2019	7	3%	9/21/2016	43.7	4.15	7.96	16.9	2.5	80	ug/l
2-Hexanone	11	243	10/11/2001	8/29/2019		0%						4	80	
2-Methyl-1-Propanol	11	243	10/11/2001	8/29/2019	1	0.4%	9/28/2007	1500	1500	1500	1500	50	1000	ug/l
3-Chloropropene	11	243	10/11/2001	8/29/2019		0%						1	200	
4-Methyl-2-pentanone	11	243	10/11/2001	8/29/2019		0%						4	80	
Acetone	11	243	10/11/2001	8/29/2019	46	19%	9/21/2016	380	2.5	6.14	18.4	4	80	ug/l
Acetonitrile	11	243	10/11/2001	8/29/2019		0%						25	1000	
Acrolein	11	243	10/11/2001	8/29/2019		0%						10	200	
Acrylonitrile	11	243	10/11/2001	8/29/2019		0%						0.07	200	
Benzene	11	243	10/11/2001	8/29/2019	1	0.4%	6/8/2006	0.27	0.27	0.27	0.27	0.2	4	ug/l
Bromochloromethane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
Bromodichloromethane	11	243	10/11/2001	8/29/2019		0%						0.2	5	
Bromoform	11	243	10/11/2001	8/29/2019		0%						0.2	10	
Bromomethane	11	243	10/11/2001	8/29/2019	2	0.8%	10/19/2009	3.4	0.22	1.8	1.8	0.2	4	ug/l
Carbon Disulfide	11	243	10/11/2001	8/29/2019	2	0.8%	7/19/2006	0.31	0.28	0.3	0.3	0.2	4	ug/l
Carbon Tetrachloride	11	243	10/11/2001	8/29/2019		0%						0.2	5	
Chlorobenzene	11	243	10/11/2001	8/29/2019	1	0.4%	11/27/2001	2.2	2.2	2.2	2.2	0.2	4	ug/l
Chloroethane	11	243	10/11/2001	8/29/2019	5	2%	7/10/2013	4.37	0.21	0.25	1.37	0.2	4	ug/l
Chloroform	11	243	10/11/2001	8/29/2019	1	0.4%	10/19/2009	0.28	0.28	0.28	0.28	0.2	4	ug/l
Chloromethane	11	240	10/11/2001	8/29/2019	16	7%	4/2/2013	1.1	0.21	0.355	0.504	0.2	10	ug/l
Chloroprene	11	243	10/11/2001	8/29/2019		0%						1	400	
cis-1,2-Dichloroethene (DCE)	11	243	10/11/2001	8/29/2019		0%						0.2	4	
cis-1,3-Dichloropropene	11	243	10/11/2001	8/29/2019		0%						0.2	5	
Dibromochloromethane	11	243	10/11/2001	8/29/2019		0%						0.2	10	
Dibromomethane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
Dichlorodifluoromethane	11	243	10/11/2001	8/29/2019		0%						0.2	4	
Ethylbenzene	11	243	10/11/2001	8/29/2019	3	1%	7/28/2009	7.79	0.22	0.25	2.75	0.2	4	ug/l
m,p-Xylene	10	113	1/28/2010	8/29/2019	2	2%	8/29/2019	1.92	0.37	1.15	1.15	0.2	2	ug/l
Methacrylonitrile	11	243	10/11/2001	8/29/2019		0%						1	100	
Methyl Methacrylate	11	243	10/11/2001	8/29/2019		0%						2	40	
Methylene Chloride	11	243	10/11/2001	8/29/2019	27	11%	11/21/2016	24	0.21	6.23	6.4	0.2	50	ug/l
Methyliodide	11	243	10/11/2001	8/29/2019	1	0.4%	10/19/2009	0.24	0.24	0.24	0.24	0.2	50	ug/l
o-Xylene	11	243	10/11/2001	8/29/2019	6	2%	1/8/2014	10.6	0.2	3.66	4.33	0.2	4	ug/l
Propionitrile	11	243	10/11/2001	8/29/2019		0%						5	600	
Styrene	11	243	10/11/2001	8/29/2019		0%						0.2	4	
Tetrachloroethene (PCE)	11	243	10/11/2001	8/29/2019		0%						0.2	4	
Toluene	11	243	10/11/2001	8/29/2019	8	3%	10/5/2011	12	0.23	0.354	1.86	0.2	4	ug/l

Table 6.7. Summary of Leachate Detections

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Analyte	Number of Sampled Locations	Number of Samples (excluding Field Dups)	First Sample Date	Most Recent Available Sample Date	Number of Samples with Detected Concentration	Frequency of Detection	Last Sample Date with Detected Concentration	Maxumim Detected Concentration	Minimum Detected Concentration	Median Detected Concentration	Average Detected Concentration	Min RL	Max RL	Units
trans-1,2-Dichloroethene	11	243	10/11/2001	8/29/2019		0%						0.2	4	
trans-1,3-Dichloropropene	11	243	10/11/2001	8/29/2019		0%						0.2	10	
Trichloroethene (TCE)	11	243	10/11/2001	8/29/2019		0%						0.2	4	
Trichlorofluoromethane	11	243	10/11/2001	8/29/2019	7	3%	3/5/2013	1.4	0.23	0.92	0.897	0.2	4	ug/l
Vinyl Acetate	11	243	10/11/2001	8/29/2019		0%						0.2	4	
Vinyl Chloride	11	243	10/11/2001	8/29/2019	20	8%	9/6/2017	0.92	0.0203	0.116	0.183	0.02	1	ug/l

Notes:

Analysis based on data collected from the leachate sample locations (LS-B, LS-BE, LS-CT, LS-LVPS, LS-PS1, LS-PS2, LS-LVT, LS-PA-D, LS-PA-S, LS-PN-D, LS-PN-S). See Section 6.4 text for a detailed description of these locations.

deg C - degrees Celsius

cfu/100 ml - coliform forming units per 100 milliliters

mg/l - milligrams per liter

ug/l - micrograms per liter

uS/cm - microsiemens per centimeter

mV - millivolts

NTU - Nephelometric Turbidity Units

ppm - parts per million

Table 6.8a. Summary of Statistically Significant Trends

Project No. 090057 Task 310.3, Vashon Island Closed Landfill, King County, Washington

		Upgradient		Downgradient												
Well ID		**MW-20**		**MW-2**		**MW-21**		**MW-33**		**MW-35**		**SW-W1**		**SW-W2**		
Analyte	**Units**	**Statistically Significant Trend**	**Slope**	**Statistically Significant Trend**	**Slope**	**Statistically Significant Trend**	**Slope**	**Statistically Significant Trend**	**Slope**	**Statistically Significant Trend**	**Slope**	**Statistically Significant Trend**	**Slope**	**Statistically Significant Trend**	**Slope**	**Notes**
1,2-Dichloropropane	ug/L	--	--	--	--	--	--	Decreasing	-0.23	NS	-0.0133	--	--	--	--	
Alkalinity	ug/L	NS	-575	Decreasing	-1899.1597	Decreasing	-1000	Decreasing	-5125	Decreasing	-5769.2308	NS	562.5	NS	-2495.098	
Arsenic	ug/L	Increasing	0.0271	Decreasing	-0.0068	NS	-0.0217	Decreasing	-0.675	Increasing	0.35	NS	0.0977	NS	-0.0135	
Benzene	ug/L	--	--	--	--	--	--	Decreasing	-0.0337	NS	-0.0033	--	--	--	--	
Chloride	ug/L	Decreasing	-7.8889	Decreasing*	-53	NS	-0.8333	Decreasing	-107.7778	Decreasing	-101.1111	NS	140.4444	NS	-156.4103	*MW-2 outlier not included.
Iron	ug/L	Increasing	19.9313	--	--	Decreasing	-26.1534	Decreasing	-60	Increasing	286.6667	NS	3.2443	NS	-0.1107	
Manganese	ug/L	Decreasing	-11.697	Increasing	6.525	NS	-6.75	Decreasing	-7.4545	Increasing	26.1538	NS	14.3229	NS	-0.3143	
Trichloroethene (TCE)	ug/L	--	--	--	--	--	--	Decreasing	-0.0044	NS	0.0065	--	--	--	--	
Vinyl Chloride	ug/L	Decreasing*	--	NS	-0.001	Decreasing	-0.003	Decreasing	-0.5571	Decreasing	-0.1983	Decreasing	-0.0005	--	--	*MW-20 outlier not included. Has decreasing trend despite all non-detects due to change in detection limits.

Statistics:

Theil-Sen Slope

Mann-Kendall Trend Analysis

Statistical analyses were performed assuming nonparametric data distributions in accordance to the EPA Unified Guidance Document - Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA, 2009).

Notes:

Decreasing - Indicates statistically significant decreasing trend.

Increasing - Indicates statistically significant increasing trend.

No shading indicates trend not statistically significant.

NS = Insufficient statistical evidence of a significant trend.

-- Indicates parameter not detected above laboratory PQL.

Table 6.8b. Summary of Seasonal Statistical Trends

Project No. 090057 Task 310.3, Vashon Island Closed Landfill, King County, Washington

All Data

Well ID	Analyte	Statistically Significant Seasonality	Statistically Significant Seasonal Trend
MW-2	Iron	NS	
MW-2	Manganese	NS	
MW-20	Arsenic	NS	
MW-20	Iron	NS	
MW-21	Arsenic	NS	
MW-21	Iron	NS	
MW-21	Manganese	NS	
MW-35	Arsenic	NS	
MW-35	Iron	NS	
MW-35	Manganese	NS	
SW-W1	Alkalinity	Significant	NS
SW-W1	Arsenic	Significant	NS
SW-W1	Iron	NS	
SW-W1	Manganese	NS	
SW-W2	Arsenic	Significant	Increasing
SW-W2	Iron	NS	
SW-W2	Manganese	NS	
SW-W2	Trichloroethene	NS	

Statistics:

Seasonality tested with 2-season Kruskal-Wallis.

Seasonal Trend tested with Seasonal Kendall

Statistical analyses were performed assuming nonparametric data distributions in accordance to the EPA Unified Guidance Document - Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA, 2009).

Notes:

Decreasing - Indicates statistically significant decreasing trend.

Increasing - Indicates statistically significant increasing trend.

No shading indicates trend not statistically significant.

NS = Insufficient statistical evidence of a significant trend/seasonality.

N/A = Test indicated insufficient data

Table 7.1. Beneficial Use Survey Results, by Property

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

	King County Tax Assessor Record Data								Water Source Location Information			Water Well Details			2019 KC Beneficial Use Survey Response Data				
Study Reference Number (Well and/or Parcel)	Parcel No.	Current Listed Owner (iMAP)	Site Address	City	State	ZIP Code	Parcel Water Source	Water System Name	Well On Parcel (or Other Reference Number)	Water Source Location Data Source (Figure 7.1)	Map Label sourced from 2002 KC Survey	Owner of Record on Well Log (Ecology) [b]	Well Water Used	Well Log Available	Resident Contacted	Resident Responded	Domestic	Drinking	Irrigation (Lawn and Garden)
1	3623029053	Richard and Pamela Schubert	17711 Thorsen Road SW	Vashon	WA	98070	Group B System	THORSEN ROAD	7	--	--	--	--	--	Note b	--	--	--	--
2	3623029054	Eric and Sharon Horsting	17723 Thorsen Road SW	Vashon	WA	98070	Group B System	THORSEN ROAD	7	--	--	--	--	--	Note b	--	--	--	--
3	3623029055	Shirley Lyon	17815 Thorsen Road SW	Vashon	WA	98070	Group B System	THORSEN ROAD	7	--	--	--	--	--	Note b	--	--	--	--
4	3623029056	Gretchen Woods	--	Vashon	WA	98070	Group B System	THORSEN ROAD	7	--	--	--	--	--	Note b	--	--	--	--
5	3623029068	Philip Cushman	17804 Thorsen Road SW	Vashon	WA	98070	Group B System	THORSEN ROAD	7	--	--	--	--	--	Note b	--	--	--	--
6	3623029069	Bradley Shirk	17920 Thorsen Road SW	Vashon	WA	98070	Group B System	THORSEN ROAD	7	--	--	--	--	--	Note b	--	--	--	--
7	**3623029006**	Moritz Shive	17710 Thorsen Road SW	Vashon	WA	98070	Group B System	THORSEN ROAD	Y	PHSKC	--	--	Y	N	Note b	--	--	--	--
8	3623029050	Michael Drummond	18136 Thorsen Road SW	Vashon	WA	98070	Group B System	THORSEN ROAD	7	--	--	--	--	--	Y	Returned to Sender	--	--	--
9	**3623029051**	Nicolaas Warmnhoven	18130 Thorsen Road SW	Vashon	WA	98070	Group B System	DRIVEN SNOW	Y	PHSKC / OSS		George Mason	Y	Y	Y	N	--	--	--
10	3623029076	Terry Hershey	18132 Thorsen Road SW	Vashon	WA	98070	Group B System	DRIVEN SNOW	9	--	--	--	--	--	Y	N	--	--	--
11	3523029106	Jeff Sayre	--	Vashon	WA	98070	Group B System	SAYRE	12	--	--	--	--	--	Note b	--	--	--	--
12	**3523029016**	Jeff Sayre	13545 SW 186th Street	Vashon	WA	98070	Group B System	SAYRE	Y	PHSKC	--	George Henrikson	Y	Y	Note b	--	--	--	--
13	3523029105	Charles Backus	18719 Robinwood Road SW	Vashon	WA	98070	Group B System	SAYRE	12	--	--	--	--	--	Y	Returned to Sender	--	--	--
14	3523029066	Craig Beles	18823 Robinwood Road SW	Vashon	WA	98070	Group B System	PAQUETTE	15	--	--	--	--	--	Y	N	--	--	--
15	**3523029081**	Rick Paquette	18827 Robinwood Road SW	Vashon	WA	98070	Group B System	PAQUETTE	Y	PHSKC / OSS	DW-PA	Rick Paquetts	Y	Y	Y	Y	X	X	X
16	**3523029012**	Mark McCulley and Wendy SooHoo	18672 Westside Highway	Vashon	WA	98070	Group B System	PATIENCE	Y	PHSKC / OSS	--	Ed Otto	Y	Y	Y	Y	X	X	X
17	3523029013	Joseph Reoux	18650 Westside Highway SW	Vashon	WA	98070	Group B System	PATIENCE	16	--		--	--	--	Y	Y	X	X	X
18	3623029043	Tyler Young	18705 Westside Highway SW	Vashon	WA	98070	Group B System	DUMP ROAD	19	--	--	--	--	--	Y	N	--	--	--
19	**3623029057**	John Dally	18717 Westside Highway SW	Vashon	WA	98070	Group B System	DUMP ROAD	Y	PHSKC / OSS	DW-LO	Linda Lotus	Y	Y	Y	N	--	--	--
20	3623029058	Francis Goodall	18731 Westside Highway SW	Vashon	WA	98070	Group B System	DUMP ROAD	19	--	--	--	--	--	Y	N	--	--	--
21	**0122029089**	David Zapp	12436 SW Cemetery Road	Vashon	WA	98070	Group B System	PICKETT	Y	PHSKC / OSS	--	--	Y	N	Y	N	--	--	--
22	0122029067	Matthew Pickett	12428 SW Cemetery Road	Vashon	WA	98070	Group B System	PICKETT	21	--	--	--	--	--	Y	N	--	--	--
23	0122029088	John Ward Pickett	12316 SW Cemetery Road	Vashon	WA	98070	Group B System	PICKETT	21	--	--	--	--	--	Y	Returned to Sender	--	--	--
24	0122029087	Ted and Theresa Alumbaugh	12320 SW Cemetery Road	Vashon	WA	98070	Group B System	PICKETT	21	--	--	--	--	--	N	N	--	--	--
25	3623029009	KC Property Services	18900 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Landfill Property		--	--	--
26	0122029082	Robert Cryderman	19205 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
27	0122029073	Leanna Spidell	19215 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	Y	X	X	X
28	0122029072	Gregory Love	19227 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
29	0122029071	John and Georgia Galus	19323 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
30	0122029079	Laura Powers	19407 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
31	0122029070	Thomas Rosser	19421 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	Y	X	X	X
32	**0122029069**	Kishore Shrestha	19506 131st Avenue SW	Vashon	WA	98070	Group A System	85 Acres	Y	85 Acres	DW-85	--	Y	N	Y	N	--	--	--
33	0122029063	Kim Martin	19616 131st Avenue SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	Y	X	X	X
34	0122029013	James Rempt	12933 SW Cemetery Road	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	Returned to Sender	--	--	--
35	0122029074	Vaughn Trust	19318 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
36	0222029064	Nina Sullivan	19401 131st Avenue SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
37	0222029065	Zane Clevenger	19417 131st Avenue SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
38	0222029066	Stephen Evans	19425 131st Avenue SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
39	0222029067	Scott Thorpe	19511 131st Avenue SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
40	0222029068	Steven Nourse	13216 SW 196th Street	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
41	0222029076	Marc Lord	13231 SW 196th Street	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
42	0222029070	Marc Lord	13223 SW 196th Street	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Note b	--	--	--	--
43	0222029069	Larry Buxton	13205 SW 196th Street	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
44	0222029079	Puget Sound Energy Inc	13123 SW 196th Street	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	Returned to Sender	--	--	--
45	0222029071	Charlotte Morton	19731 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--
46	0222029073	Claudia Kimball	19915 Westside Highway SW	Vashon	WA	98070	Group A System	85 Acres	32	--	--	--	--	--	Y	N	--	--	--

Table 7.1. Beneficial Use Survey Results, by Property

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Study Reference Number (Well and/or Parcel)	King County Tax Assessor Record Data								Water Source Location Information			Water Well Details			2019 KC Beneficial Use Survey Response Data				
	Parcel No.	Current Listed Owner (iMAP)	Site Address	City	State	ZIP Code	Parcel Water Source	Water System Name	Well On Parcel (or Other Reference Number)	Water Source Location Data Source (Figure 7.1)	Map Label sourced from 2002 KC Survey	Owner of Record on Well Log (Ecology) [b]	Well Water Used	Well Log Available	Resident Contacted	Resident Responded	Domestic	Drinking	Irrigation (Lawn and Garden)
47	5238800010	Ruth Johnson	18227 Thorsen Rd SW	Vashon	WA	98070	Unknown	--	--	--	--	--	--	N	Y	N	--	--	--
48	3523029010	Geoff and Terri Fletcher	18528 Westside Hwy SW	Vashon	WA	98070	Single Family	--	Y	PHSKC / OSS	DW-FL	Kevin Britz	Y	Y	Y	Y	X	X	X
49	3523029009	Robert and Anne Robinson Nelson	18427 Thorsen Road SW	Vashon	WA	98070	Single Family	--	Y	PHSKC / OSS	DW-BA	Richard C. Bain Jr	Y	Y	Y	N	--	--	--
50	3623029041	Michael and Erica Logar	18412 Thorsen Road SW	Vashon	WA	98070	Single Family	--	Y	PHSKC / OSS	DW-SE	*Joy Holahan*	Y	Y	Y	N	--	--	--
51	3623029036	Katie Bladon	18722 Westside Highway SW	Vashon	WA	98070	Single Family	--	Y	PHSKC / 2002 Survey	DW-AV	Lena Canada	Y	Y	Y	Returned to Sender	--	--	--
52	3623029070	Katie Bladon and Simon Paquette	18722 Westside Highway SW	Vashon	WA	98070	Single Family	--	51	OSS	--	See 51	Y	See 51	Y	Returned to Sender	--	--	--
53	3523029088	George Humphreys	18610 Westside Highway SW	Vashon	WA	98070	Single Family	--	Y	PHSKC / OSS	DW-HU	George Humphreys	Y	Y	Y	N	--	--	--
54	3523029086	Donald Harlander	13518 SW 186th Street	Vashon	WA	98070	Single Family	--	Y	OSS	--	Don Hollender (Hardlander)	Y	Y	Y	Returned to Sender	--	--	--
55	3623029066	Vernon Jensen	12620 SW 184th ST	Vashon	WA	98070	Single Family	--	Y	OSS	--	Steve Russel	Y	Y	Y	N	--	--	--
56	3623029067	Cynthia Young	12628 SW 184th ST	Vashon	WA	98070	Single Family	--	Y	OSS	--	Cindy Young	Y	Y	Y	N	--	--	--
57	3623029064	Gerald Connors	18318 125th AVE SW	Vashon	WA	98070	Single Family	--	Y	PHSKC / OSS	--	Jerry Conners	Y	Y	Y	N	--	--	--
58	3523029078	Jill Janow	18708 Robinwood Road SW	Vashon	WA	98070	Single Family	--	Y	OSS	--	Adam Weintraub	Y	Y	Y	Y	X	X	X
59	3523029104	Patricia and Hugh Turner	18826 Robinwood Road SW	Vashon	WA	98070	Single Family	--	Y	OSS	--	Rex Stratton	Y	Y	Y	N	--	--	--
60	3523029062	Gould Gartzmann II	18930 Robinwood Road SW	Vashon	WA	98070	Single Family	--	Y	OSS	--	Connie Whiteside	Y	Y	Y	N	--	--	--
61	3523029067	David Dwinell	18925 Robinwood Road SW	Vashon	WA	98070	Single Family	--	Y	Beneficial Use Survey / ECY	--	David Dwinell	Y	Y	Y	Y	X	X	X
62	3523029100	Jackson Family Trust	18937 Robinwood Road SW	Vashon	WA	98070	Single Family	--	Y	OSS	--	*Cord Harms Zum Spreckle*	Y	Y	Y	N	--	--	--
63	0122029012	F.M. Shiratori/ William Smith	19402 Westside Highway	Vashon	WA	98070	Single Family	--	Y	PHSKC / OSS	DW-SS	--	Y	N	Y	Y	X		X
64	0122029045	Liz Carrie Lewis	12714 SW Cemetery Road	Vashon	WA	98070	Single Family	--	Y	OSS	--	Liz Lewis	Y	Y	Y	N	--	--	--
65	0122029055	One Cherry LLC	12630 SW Cemetery Road	Vashon	WA	98070	Single Family	--	Y	OSS	--	*C/O Midling Const.*	Y	Y	Y	N	--	--	--
66	0122029057	Albert Francisco	12440 SW Cemetery Road	Vashon	WA	98070	Single Family	--	Y	OSS / Beneficial Use Survey	--	Dave Nestor	Y	Y	Y	Y	X	X	--
67	0122029011	Heather Youngs	12717 SW Cemetery Road	Vashon	WA	98070	Single Family	--	Y	OSS	--	--	Unknown	N	Y	N	--	--	--
68	122029044	Karen and William Gerrior	12625 SW Cemetery Road	Vashon	WA	98070	Judd Creek/Spring [d]	--	Unknown	Beneficial Use Survey	DW-GE	--	Unknown	N	Y	N	--	--	--
68	122029044	Karen and William Gerrior	12625 SW Cemetery Road	Vashon	WA	98070	Well	--	Unknown	ECY Water Resources	--	--	Unknown	N	Y	N	--	--	--
69	5238800050	Ruth Johnson	--	Vashon	WA	98070	Unknown	--	Vacant	--	--	--	--	N	Y	N	--	--	--
70	3623029047	Michael and Mary Drummond	--	Vashon	WA	98070	Unknown	--	Vacant	--	--	--	--	N	Y	Returned to Sender	--	--	--
71	3523029103	Khademi Shahab	--	Vashon	WA	98070	Unknown	--	Vacant	--	--	--	--	N	Y	N	--	--	--
72	3523029029	Khademi Shahab	--	Vashon	WA	98070	Unknown	--	Vacant	--	--	--	--	N	N	N	--	--	--
73	3623029042	KC Solid Waste	--	Vashon	WA	98070	Unknown	--	Vacant	--	--				Note b	--	--	--	--
74	3523029094	William and Kim Jackson	--	Vashon	WA	98070	Unknown	--	Vacant	--	--	--	--	N	Y	N	--	--	--
75	3523029017	William and Kim Jackson	--	Vashon	WA	98070	Unknown	--	Vacant	--	--	--	--	N	Y	N	--	--	--
76	0122029078	Michael May	--	Vashon	WA	98070	Unknown	--	Vacant	--	--	--	--	N	Y	N	--	--	--
77	0222029001	Brian Roggenbuck	--	Vashon	WA	98070	Unknown	--	Vacant	--	--	--	--	N	Y	N	--	--	--
78	3623029077	KC Parks	--	Vashon	WA	98070	Unknown	--	Park Land	--	--	Island Center Forest	--	--	Note b	--	--	--	--
79	3623029012	KC Parks	--	Vashon	WA	98070	Unknown	--	Park Land	--	--	Island Center Forest	--	--	Note b	--	--	--	--
80	0122029043	KC Property Services	--	Vashon	WA	98070	Unknown	--	Vacant	--	--	--	--	--	Note b	--	--	--	--
81	0122029076	Frank and Nancy Zellerhoff	12726 SW Cemetery Road	Vashon	WA	98070	Unknown	--	Vacant [c]	--	--	--	Unknown	N	Y	Returned to Sender	--	--	--
82	0122029050	Maryan Zurek	12905 SW Cemetery Road	Vashon	WA	98070	Unknown	--	Unknown	--	--	--	Unknown	N	Y	Returned to Sender	--	--	--
83	3523029080	Kathryn Olsen	18539 Westside Highway SW	Vashon	WA	98070	Single Family	--	Y	OSS	--	John Olsen	Y	Y	Y	Y	X	X	X
84	3623029063	Sarah and Matthew Edwards	18216 125th AVE SW	Vashon	WA	98070	Single Family	--	Y	OSS	--	Tom Hoohah	Y	Y	N	N	--	--	--
85	3623029065	Brian Anderson	18109 125th AVE SW	Vashon	WA	98070	Single Family	--	Y	ECY	--	Robert McCormick	Y	Y	Y	N	--	--	--

Notes:
a Italicized owner names indicate association of well log with parcel based on KC Assessor records accessed on 10/28/19. Association made based on date of well well installation and property owner at corresponding time.
b These parcels are outside of the search radius and/or were not contacted by mailer. They are included in this table, as parcel 8, which is within the search radius and is served by the same water system that serves these parcels.
c Study Reference Number 81 is located adjacent south of the VLF. A King County Hearing Examiner Report dated 9/18/2009 indicates the property remains vacant and the property owners have been able to obtain a leagal source of water. Item 8 of the report indicates a well has not been installed on the property. See Appendix I for a copy of the Hearing Examiner Report.
d Study Reference Number 82 had two surface water claims listed in the Water Resources online database.
Gray shading indicates parcels are adjacent to the search radius.
Bold parcel numbers indicate public water supply well (Group A or B) located on parcel.
-- = Information was not available or no response provided in mailer responses.
PHSKC = Public Health Seattle King County provided GIS location data for certain wells, typically Group B systems.
OSS = On-Site Sewage System Records (PHSKC) provide well locations relative to proposed homes and septic systems. Well placed based on review of aerial photos relative to figures in OSS files.
ECY = Well log obtained from Department of Ecology website. If listed as the only source, note that the exact location cannot be obtained from the well log and is shown to the nearest 1/4, 1/4, section.
ECY Water Resources = GIS locations from online database - not field verified.
Y = Yes
N = No

Table 7.2. Drinking Water Source Information

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Study Reference Number (Well and/or Parcel)	Parcel Number [a]	Owner of Record on Well Log (Ecology) [b]	Water Source (Spring or Well)	Water Source Details (if applicable/available) [c]										King County 2002 Well Sample ID	Inferred Geologic Unit of Groundwater Source [e]
				Date Well Completed	Type	Total Depth (ft)	Water Level Depth (ft bgs)	Diameter (inches)	Casing Depth (ft)	Screened Interval Depth (ft bgs)	Estimated Surface Elevation (derived from GIS)[d]	Data Source	ECY Well Log Number		
7	**3623029006**	--		--	Drilled	175	145	--	--	--	450	PHSKC Records	--	--	--
9	**3623029051**	George Mason	Well	1986	Drilled	180	159	6	176	175 - 180	441	ECY Well Log	91840	--	Unit B or Upper Unit C
12	**3523029016**	George Henrikson	Well	1979	Drilled	314	214	6	299	304 - 309	200	ECY Well Log/ PHSKC Record	91826	--	Below Unit D
15	**3523029081**	Rick Paquette	Well	1979	Drilled	132	104	6	132	No perforation	254	ECY Well Log	96838	DW-PA	Unit D or Below
16	**3523029012**	Ed Otto	Well	1983	Drilled	400	250	6	360	347 - 355	361	ECY Well Log	91008	--	Below Unit D
19	**3623029057**	Linda Lotus	Well	1980	Drilled	109	90	6	104	104 - 109	363	ECY Well Log	94739	DW-LO	Unit B or Upper Unit C
21	**0122029089**	--	Well	--	Drilled	45	--	--	--	--	305	PHSKC Records	--	--	
32	**0122029069**	Dan Spano	Well	1979	Drilled	145	89	6	145	140-145	275	ECY Well Log	--	DW-85	Unit D
48	3523029010	Kevin Britz	Well	1984	Drilled	102	78	6	94	No perforation	305	ECY Well Log	94131	DW-FL	Unit B or Upper Unit C
49	3523029009	Richard C. Bain Jr	Well	1977	Drilled	100	88	6	95	95 - 100	387	ECY Well Log	96619	DW-BA	Unit B or Upper Unit C
50	3623029041	Joy Holahan[b]	Well	1997	Drilled	153	130	6	148	148 - 153	431	ECY Well Log	93872	--	Unit B or Upper Unit C
51	3623029036	Lena Canada	Well	1993	Drilled	169	147	6	164	164 - 169	436	ECY Well Log	94606	DW-AV	Unit B or Upper Unit C
53	3523029088	George Humphreys	Well	1995	Drilled	396	*253*	6	*396.3*	*389.3 - 396.3*	301	ECY Well Log	99435	DW-HU	Below Unit D
54	3523029086	Don Hollender (Hardlander)	Well	1992	Drilled	360	215	6	355	355 - 360	248	ECY Well Log	90613	--	Below Unit D
55	3623029066	Steve Russel	Well	1991	Drilled	140	103	6	135	135 - 140	422	ECY Well Log	97940	--	Unit B or Upper Unit C
56	3623029067	Cindy Young	Well	2005	Drilled	170	155	6	165	165 - 170	440	ECY Well Log	424664	--	Unit B or Upper Unit C
57	3623029064	Jerry Conners	Well	2000	Drilled	103	70	6	98	98 - 103	370	ECY Well Log	247180	--	Unit B or Upper Unit C
58	3523029078	Adam Weintraub	Well	1999	Drilled	401	*295*	6	396	396 - 401	331	ECY Well Log	342176	--	Below Unit D
59	3523029104	Rex Stratton	Well	1999	Drilled	401	225	6	396	396 - 401	312	ECY Well Log	235879	--	Below Unit D
60	3523029062	Connie Whiteside	Well	1997	Drilled	336	230	6	328	328 - 333	232	ECY Well Log	89666	--	Below Unit D
61	3523029067	David Dwinell	Well	2002	Drilled	122	100	6	117	117 - 122	255	BUS Survey / ECY Well Log	336042	--	Unit D
62	3523029100	Cord Harms Zum Spreckle[b]	Well	1987	Drilled	35	10	6	30	No perforation	200	ECY Well Log	89674	--	Unit C or Upper Unit D
63	0122029012	--[f]	Well	1997	Drilled	--	--	--	165	--	301	KC 2002 Survey	--	DW-SS	Unit D
64	0122029045	Liz Lewis	Well	1991	Drilled	80	33	6	80	No perforation	300	ECY Well Log	94749	--	Unit C
65	0122029055	C/O Midling[b]	Well	1992	Drilled	293	195	6	293	No perforation	314	ECY Well Log	89045	--	Below Unit D
66	0122029057	Dave Nestor[b]	Well	1994	Drilled	115	40	6	115	No perforation	225	ECY Well Log	90113	--	Unit D or Below
67	0122029011	--	Well	--	--	--	--	--	--	--	213	--	--	--	no well log to review
68	0122029044	--	Spring	--	--	--	--	--	--	--	206	KC 2002 Survey / Water Right Claim	--	DW-GE	Unit C [g]
68	0122029044	--	Well	1974[h]	--	--	--	--	--	--	208	Water Right Claim	--	--	no well log to review
i	--	Kurt Monier	Well	1992	Drilled	91	45	6	91	No perforation	#N/A	ECY Well Log	94302	--	Unit C
83	3523029080	John Olsen	Well	1995	Drilled	292	*172.5*	6	*281.1*	*281.8 - 292.3*	184	ECY Well Log	99443	--	
84	3623029063	Tom Hoohah	Well	1993	Drilled	103	78	6	99	98 - 103	376	ECY Well Log	98410	--	Unit B or Upper Unit C
85	3623029065	Robert McCormick	Well	2004	Drilled	142	117	6	137	137 - 142	434	ECY Well Log	389920	--	Unit B or Upper Unit C
j	122029062	Bill Thomas	Well	1993	Drilled	200	120	6	200	195 - 200	231	ECY Well Log	112441	--	Unit F

Notes:

BUS Survey - Beneficial Use Survey flyer respondent

a **Bold** Parcel Numbers indicate Group A or B system.

b Owner names associated with well log based on names listed on KC Assessor online records accessed on 10/28/19. Association made based on date of well installation and property owner at corresponding time.

c Italicized well details indicate poor quality of well log scan. Best inference made based on interpretation of scan.

d Surface elevation obtained from the WA DNR Lidar Portal, King County 2016 dataset. The vertical elevation is presented in the NAVD88 vertical datum and based on best available well location data.

e Determination of groundwater source for the geologic unit is based on review of well logs (if available), completion depth, and correlation to Cross Sections A-A' and D-D'. See Section 7 text for details.

f No well log has been located for the well located on this parcel (Reference ID 63/Smith-Shiratori). King County has a database from the 2002 well survey, which includes a lithology summary. This information was incorporated into cross section D-D'.

g The inferred unit for the spring (DW-GE, Study Reference Number 68) is based on the elevation of the spring location from the 2002 survey and the observed elevation on Unit C at VLF>

h Well install date based on water right claim. January 1974 listed as "Date of first putting water to use."

i The exact location of the Kurt Monier well is based on the quarter-quarter township range location on the Ecology Well Report, not a particular parcel. Refer to text in Section 7.1 for further discussion on the location of this well.

j The Thomas well has been included in this table since it is depicted on the D-D' cross section.

-- indicates information was not available.

Gray shading indicates parcels are adjacent to the search radius.

Table 8.1. Soil Sampling Locations – Actual vs. Target

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Station ID	Proposed Coordinates[1]		Actual Coordinates[1]	
	Northing	Easting	Northing	Easting
SO-01	162704	1227123	162716	1227133
SO-02	162651	1227127	162650	1227133
SO-03	162418	1227125	162417	1227132
SO-04	162737	1227194	162741	1227189
SO-05	162683	1227216	162663	1227206
SO-06	162831	1227237	162840	1227247
SO-07	162683	1227257	162682	1227260
SO-08	162596	1227251	162596	1227238
SO-09	162582	1227211	162582	1227234
SO-10	162478	1227195	162470	1227182
SO-11	162400	1227227	162402	1227224
SO-12	162336	1227241	162328	1227237
SO-13	162696	1227366	162688	1227366

Notes:

1. Washington State Plane North, North American Datum of 1983, U.S. feet.

Table 8.2a. Soil Chemistry Summary

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Chemical	Method	Lowest Soil Eco SL	Location ID / SL Source	SO-01_1907	SO-02_1907	SO-03_1907	SO-04_1907	SO-05_1907	SO-06_1907	SO-07_1907
Conventional Parameters (pct)										
Total organic carbon	SW9060A	--	--	**6.09**	**6.32**	**24.8**	**28.9**	**10.9**	**6.65**	**1.85**
Total Solids	SM2540G	--	--	**49.02**	**44.87**	**23.77**	**21.73**	**33.67**	**50.18**	**63.69**
Grain Size (pct)										
Percent retained 1.3 micron sieve	D422	--	--	**3.945426628**	**2.96018661**	**2.491768342**	**5.339865083**	**4.85561483**	**1.456336363**	**0.724260945**
Percent retained 3.2 micron sieve	D422	--	--	**7.890853257**	**3.700233262**	**6.644715579**	**7.119820111**	**6.797860762**	**5.825345454**	**1.44852189**
Percent retained 7 micron sieve	D422	--	--	**3.945426628**	**1.480093305**	**3.32235779**	**2.669932542**	**4.85561483**	**1.456336363**	**0.724260945**
Percent retained 9 micron sieve	D422	--	--	**6.312682605**	**4.440279915**	**2.491768342**	**2.669932542**	**4.85561483**	**2.912672727**	**0.724260945**
Percent retained 13 micron sieve	D422	--	--	**12.62536521**	**5.180326567**	**4.983536685**	**4.44988757**	**9.71122966**	**7.281681817**	**3.621304726**
Percent retained 22 micron sieve	D422	--	--	**9.469023908**	**6.660419872**	**8.305894474**	**12.45968519**	**7.768983728**	**5.825345454**	**0.724260945**
Percent retained 32 micron sieve	D422	--	--	**17.92445555**	**11.21060914**	**7.75044834**	**11.98091621**	**26.73693784**	**10.98202959**	**15.11034067**
Percent retained 75 micron sieve (#200)	D422	--	--	**11.23679378**	**24.12171416**	**14.16684668**	**11.76700498**	**13.11142318**	**17.30643331**	**40.50251695**
Percent retained 150 micron sieve (#100)	D422	--	--	**10.29120104**	**17.6330913**	**19.82363206**	**11.67813032**	**6.22598645**	**22.76014129**	**27.07882562**
Percent retained 250 micron sieve (#60)	D422	--	--	**5.232279855**	**9.17866697**	**12.27572195**	**7.323271983**	**3.258460198**	**12.59442962**	**5.728213111**
Percent retained 425 micron sieve (#40)	D422	--	--	**2.379741741**	**4.729747875**	**9.273146714**	**9.811762462**	**2.540823131**	**5.439164756**	**1.634565862**
Percent retained 850 micron sieve (#20)	D422	--	--	**2.836778235**	**3.872481073**	**4.52874607**	**5.545778783**	**3.820932495**	**1.890618765**	**0.882376262**
Percent retained 2000 micron sieve (#10)	D422	--	--	**1.046159043**	**1.425602523**	**1.626569829**	**2.070348717**	**1.353528387**	**0.666281666**	**0.330693505**
Percent retained 4750 micron sieve (#4)	D422	--	--	**0.129300556**	**1.186407469**	**0.653668249**	**0.663775924**	**0.222497817**	**0.69051009**	0.1 U
Percent retained 0.375 inch (3/8 inch sieve)	D422	--	--	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Percent retained 0.5 inch (1/2 inch sieve)	D422	--	--	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Percent retained 0.75 inch (3/4 inch sieve)	D422	--	--	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Percent passing 1.3 micron sieve	D422	--	--	**4.734511954**	**2.220139957**	**1.661178895**	**4.44988757**	**3.884491864**	**2.912672727**	**0.724260945**
Metals (mg/kg)										
Arsenic	SW6010C	20	a	**17.5**	**25.6**	**13.6 J**	**47.1**	**59.2**	**38.1**	**19.4**
Cadmium	SW6010C	4	b	**0.635**	**0.365 J**	**0.942**	**1.2**	**0.758**	**0.54**	**0.414**
Chromium	SW6010C	42	b	**34.7**	**28.2**	**30.8**	**23.7**	**33.2**	**34.1**	**24.2**
Chromium VI	SW7196A	0.34	e	**-- R**	**-- R**	**-- R**	**-- R**	**-- R**	**-- R**	**-- R**
Iron	SW6010C	--	--	**19400**	**35700**	**7090**	**51300**	**51400**	**27800**	**19100**
Lead	SW6010C	50	b	**17.5**	**9.21**	**67.3**	**56.6**	**19.6**	**17.6**	**8.38**
Manganese	SW6010C	1200	a	**732**	**7010**	**1040**	**1850**	**6840**	**2840**	**187**
Mercury	SW7471B	0.1	c	**0.111**	**0.0457**	**0.324**	**0.318**	**0.0975**	**0.0825**	**0.0158 J**
Volatile Organics (µg/kg)										
1,1,1,2-Tetrachloroethane	SW8260C	70	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,1,1-Trichloroethane	SW8260C	40	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,1,2,2-Tetrachloroethane	SW8260C	127	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	SW8260C	--		8.81 U	6.39 U	17.2 U	28 U	13.4 U	5.75 U	4.12 U
1,1,2-Trichloroethane	SW8260C	320	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,1-Dichloroethane	SW8260C	140	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,1-Dichloroethene	SW8260C	40	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,1-Dichloropropene	SW8260C	--		4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,2,3-Trichlorobenzene	SW8260C	20000	c	**-- R**	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
1,2,3-Trichloropropane	SW8260C	--	--	8.81 U	6.39 U	17.2 U	28 U	13.4 U	5.75 U	4.12 U
1,2,4-Trichlorobenzene	SW8260C	20000	c	**-- R**	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
1,2,4-Trimethylbenzene	SW8260C	--	--	4.4 U	**1.15 J**	8.61 U	14 U	**2.56 J**	**0.82 J**	2.06 U
1,2-Dibromo-3-chloropropane	SW8260C	--	--	22 UJ	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
1,2-Dichlorobenzene	SW8260C	90	e	4.4 UJ	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,2-Dichloroethane	SW8260C	400	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,2-Dichloroethene, cis-	SW8260C	40	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,2-Dichloroethene, trans-	SW8260C	40	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,2-Dichloropropane	SW8260C	700000	c	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,3,5-Trimethylbenzene (Mesitylene)	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,3-Dichlorobenzene	SW8260C	80	e	4.4 UJ	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,3-Dichloropropane	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,3-Dichloropropene, cis-	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
1,3-Dichloropropene, trans-	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U

Table 8.2a. Soil Chemistry Summary

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Chemical	Method	Lowest Soil Eco SL	Location ID SL Source	SO-01_1907	SO-02_1907	SO-03_1907	SO-04_1907	SO-05_1907	SO-06_1907	SO-07_1907
1,4-Dichloro-2-butene, trans-	SW8260C	--	--	22 U	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
1,4-Dichlorobenzene	SW8260C	20000	c	4.4 UJ	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
2-Chloroethylvinyl ether	SW8260C	--	--	**-- R**	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
2-Chlorotoluene	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
2-Hexanone (Methyl butyl ketone)	SW8260C	360	e	22 U	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
2-Pentanone	SW8260C	--	--	22 U	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
4-Chlorotoluene	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
4-Methyl-2-pentanone (Methyl isobutyl ketone)	SW8260C	--	--	22 U	**27.6**	43 U	69.9 U	33.5 U	14.4 U	10.3 U
Acetone	SW8260C	1200	e	**150**	**1230**	**3020**	**3110**	**2940**	**849**	**302**
Acrolein	SW8260C	50	f	22 UJ	**65.4**	43 U	69.9 U	33.5 U	14.4 U	10.3 U
Acrylonitrile	SW8260C	--	--	22 U	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
Benzene	SW8260C	120	e	4.4 U	3.2 U	8.61 U	14 U	**2.6 J**	2.87 U	2.06 U
Bromobenzene	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Bromochloromethane	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Bromodichloromethane	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Bromoform (Tribromomethane)	SW8260C	70	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Bromomethane (Methyl bromide)	SW8260C	2	e	4.4 U	**2.24 J**	8.61 U	14 U	**8.2**	2.87 U	2.06 U
Carbon disulfide	SW8260C	5	e	4.4 U	**78.2**	8.61 U	**25.8**	6.69 U	2.87 U	2.06 U
Carbon tetrachloride (Tetrachloromethane)	SW8260C	50	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Chlorobenzene	SW8260C	40000	c	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Chloroethane	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Chloroform	SW8260C	50	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Chloromethane	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Cymene, p- (4-Isopropyltoluene)	SW8260C	--	--	4.4 U	**10.3**	**76.4**	**30.4**	**8.43**	**4.44**	**1.22 J**
Dibromochloromethane	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Dibromomethane	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Dichlorodifluoromethane	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Dichloromethane (Methylene chloride)	SW8260C	210	e	8.81 U	6.39 U	**5.83 J**	28 U	13.4 U	5.75 U	4.12 U
Ethyl bromide (Bromoethane)	SW8260C	--	--	8.81 U	6.39 U	17.2 U	28 U	13.4 U	5.75 U	4.12 U
Ethylbenzene	SW8260C	270	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Ethylene dibromide (1,2-Dibromoethane)	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Hexachlorobutadiene (Hexachloro-1,3-butadiene)	SW8260C	9	e	22 UJ	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
Isopropylbenzene (Cumene)	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
m,p-Xylene	SW8260C	--	--	8.81 U	6.39 U	17.2 U	28 U	13.4 U	5.75 U	4.12 U
Methyl ethyl ketone (2-Butanone)	SW8260C	1000	e	**13.7 J**	**89.2**	**148**	**141**	**354**	**55.5**	**19.8**
Methyl iodide (Iodomethane)	SW8260C	--	--	4.4 U	**8.33**	8.61 U	**7.04 J**	**53.4**	2.87 U	**0.65 J**
Methyl tert-butyl ether (MTBE)	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Naphthalene	SW8260C	--	--	**-- R**	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
n-Butylbenzene	SW8260C	--	--	4.4 UJ	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
n-Propylbenzene	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
o-Xylene	SW8260C	--	--	4.4 U	3.2 U	8.61 U	6.39 U	6.69 U	2.87 U	2.06 U
sec-Butylbenzene	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Styrene	SW8260C	300000	b	4.4 UJ	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
tert-Butylbenzene	SW8260C	--	--	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Tetrachloroethene (PCE)	SW8260C	60	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Toluene	SW8260C	200000	b	**2.53 J**	**2.94 J**	**8.24 J**	**11.9 J**	**6.88**	**3.13**	**1.45 J**
Trichloroethene (TCE)	SW8260C	60	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Trichlorofluoromethane (Fluorotrichloromethane)	SW8260C	16400	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Vinyl acetate	SW8260C	--	--	22 UJ	16 U	43 U	69.9 U	33.5 U	14.4 U	10.3 U
Vinyl chloride	SW8260C	30	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Total 1,3-Dichloropropene (U = 1/2)	--	1	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Total Xylene (U = 1/2)	--	100	e	8.81 U	6.39 U	17.2 U	28 U	13.4 U	5.75 U	4.12 U
Total 1,3-Dichloropropene (U = 0)	--	1	e	4.4 U	3.2 U	8.61 U	14 U	6.69 U	2.87 U	2.06 U
Total Xylene (U = 0)	--	100	e	8.81 U	6.39 U	17.2 U	28 U	13.4 U	5.75 U	4.12 U

Table 8.2a. Soil Chemistry Summary

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Chemical	Method	Lowest Soil Eco SL	Location ID / SL Source	SO-01_1907	SO-02_1907	SO-03_1907	SO-04_1907	SO-05_1907	SO-06_1907	SO-07_1907
Total Petroleum Hydrocarbons (mg/kg)										
Diesel range hydrocarbons	NWTPHDx	200	c	101 U	111 U	210 U	228 U	147 U	99.5 U	78.3 U
Gasoline range hydrocarbons	NWTPHG	100	c	20.7 U	20 U	65.8 U	64 U	46.2 U	26.5 U	11.5 U
Motor oil range hydrocarbons	NWTPHDx	--	--	203 U	221 U	419 U	**499**	295 U	199 U	157 U
Total Diesel and Motor Oil (U = 1/2)	--	200	c	203 U	221 U	419 U	**727**	295 U	199 U	157 U
Total Diesel and Motor Oil (U = 0)	--	200	c	203 U	221 U	419 U	**499**	295 U	199 U	157 U

Notes:

Detected concentration is greater than the ecological screening level for soil

Non-detected concentration is greater than the ecological screening level for soil

Bold : Detected result

EPA Stage 2A validation performed

J: Estimated value

U: Compound analyzed, but not detected above detection limit

UJ: Compound analyzed, but not detected above estimated detection limit

R: Rejected

a. Natural background. For arsenic, WAC 176-340-900 Table 740-1 Method A Soil Cleanup Levels for Unrestricted Land Use. For manganese, Natural Background Soil Metals Concentrations in Washington State (Ecology 1994).

b. Ecology Terrestrial Ecological Evaluations under MTCA – Plants

c. Ecology Terrestrial Ecological Evaluations under MTCA – Soil Biota

d. Ecology Terrestrial Ecological Evaluations under MTCA – Wildlife

e. US EPA Region 4 ERA Guidance - Plants, Biota, or Wildlife

f. Analytic Resources Inc. Practical Quantitation Limit

--: not applicable

µg/kg: micrograms per kilogram

Eco SL: ecological screening level

Ecology: Washington State Department of Ecology

EPA: U.S. Environmental Protection Agency

mg/kg: milligrams per kilogram

MTCA: Model Toxics Control Act

pct: percent

SL: screening level

Table 8.2a. Soil Chemistry Summary

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Chemical	Method	Lowest Soil Eco SL	Location ID / SL Source	SO-08_1907	SO-09_1907	SO-10_1907	SO-10_FieldQC	SO-11_1907	SO-12_1907	SO-13_1907
Conventional Parameters (pct)										
Total organic carbon	SW9060A	--	--	**8.45**	**2.65**	**10.6**	**11.1**	**28.7**	**7.48**	**6.13**
Total Solids	SM2540G	--	--	**47.73**	**66.02**	**71.7**	**72.28**	**21.5**	**42.67**	**87.59**
Grain Size (pct)										
Percent retained 1.3 micron sieve	D422	--	--	**0.692616757**	**2.734331141**	**4.203708908**	**3.50915424**	**2.68012027**	**2.185605194**	**1.832515378**
Percent retained 3.2 micron sieve	D422	--	--	**3.463083784**	0.1 U	**7.006181514**	**8.421970176**	**4.466867117**	**3.642675324**	**2.443353838**
Percent retained 7 micron sieve	D422	--	--	**1.385233514**	**2.050748356**	**4.203708908**	**4.912815936**	**3.573493694**	**2.914140259**	**1.832515378**
Percent retained 9 micron sieve	D422	--	--	**1.385233514**	**2.050748356**	**4.90432706**	**4.210985088**	**3.573493694**	**1.45707013**	**1.221676919**
Percent retained 13 micron sieve	D422	--	--	**2.770467027**	**2.734331141**	**9.108035968**	**8.421970176**	**7.146987387**	**4.371210389**	**1.832515378**
Percent retained 22 micron sieve	D422	--	--	**4.155700541**	**2.734331141**	**11.20989042**	**12.63295526**	**7.146987387**	**4.371210389**	**1.832515378**
Percent retained 32 micron sieve	D422	--	--	**3.972700947**	**5.651704855**	**20.61597706**	**17.61262176**	**11.47897936**	**8.429858348**	**4.728853527**
Percent retained 75 micron sieve (#200)	D422	--	--	**20.69443157**	**20.04223209**	**8.3538107**	**8.578528317**	**13.1322686**	**16.07835641**	**9.515900444**
Percent retained 150 micron sieve (#100)	D422	--	--	**27.62485284**	**30.43197229**	**8.451761579**	**8.424339083**	**14.38126154**	**26.03093178**	**20.20298864**
Percent retained 250 micron sieve (#60)	D422	--	--	**15.67298862**	**19.05923433**	**6.730624701**	**6.728257504**	**9.581560107**	**17.72256842**	**21.88657102**
Percent retained 425 micron sieve (#40)	D422	--	--	**5.284273303**	**6.266610714**	**3.988000083**	**4.233195346**	**8.582365757**	**5.383703051**	**10.60168908**
Percent retained 850 micron sieve (#20)	D422	--	--	**3.126297818**	**2.006953758**	**3.372308842**	**3.75661044**	**6.762404619**	**2.924660306**	**4.74575035**
Percent retained 2000 micron sieve (#10)	D422	--	--	**2.085216218**	**1.919620164**	**2.3959943415 J**	**3.3281025309 J**	**1.885756655**	**1.859661413**	**3.912189288**
Percent retained 4750 micron sieve (#4)	D422	--	--	**4.916436514**	**0.950016102**	**1.251961007**	**1.017509054**	**2.098929147**	**1.171278459**	**6.432049201**
Percent retained 0.375 inch (3/8 inch sieve)	D422	--	--	0.1 U	0.1 U	0.1 U	0.1 U	**1.721777816**	0.1 U	**5.757239259**
Percent retained 0.5 inch (1/2 inch sieve)	D422	--	--	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Percent retained 0.75 inch (3/4 inch sieve)	D422	--	--	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Percent passing 1.3 micron sieve	D422	--	--	**2.770467027**	**1.367165571**	**4.203708908**	**4.210985088**	**1.786746847**	**1.45707013**	**1.221676919**
Metals (mg/kg)										
Arsenic	SW6010C	20	a	**6.23 J**	**7.01 J**	**38.2**	**33.6**	**12 J**	**5.17 J**	**12.5**
Cadmium	SW6010C	4	b	**0.408**	**0.324**	**1.47**	**1.37**	**0.903**	**0.447 J**	**0.393**
Chromium	SW6010C	42	b	**26.9**	**23.4**	**27.6**	**24**	**15.8**	**29.5**	**27.2**
Chromium VI	SW7196A	0.34	e	**-- R**	**-- R**	**-- R**	**-- R**	**-- R**	**-- R**	**-- R**
Iron	SW6010C	--	--	**11000**	**11300**	**14800**	**12700**	**8010**	**13000**	**12200**
Lead	SW6010C	50	b	**13.9**	**9.1**	**85.5**	**86.9**	**61.9**	**18.6**	**24.5**
Manganese	SW6010C	1200	a	**296**	**271**	**573**	**565**	**258**	**155**	**341**
Mercury	SW7471B	0.1	c	**0.0667**	**0.0354**	**0.221**	**0.225**	**0.304**	**0.0942**	**0.0749**
Volatile Organics (µg/kg)										
1,1,1,2-Tetrachloroethane	SW8260C	70	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,1,1-Trichloroethane	SW8260C	40	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,1,2,2-Tetrachloroethane	SW8260C	127	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	SW8260C	--		8.06 U	4.25 U	4.46 U	5.26 U	19.5 U	9.32 U	4.25 U
1,1,2-Trichloroethane	SW8260C	320	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,1-Dichloroethane	SW8260C	140	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,1-Dichloroethene	SW8260C	40	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,1-Dichloropropene	SW8260C	--		4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,2,3-Trichlorobenzene	SW8260C	20000	c	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
1,2,3-Trichloropropane	SW8260C	--	--	8.06 U	4.25 U	4.46 U	5.26 U	19.5 U	9.32 U	4.25 U
1,2,4-Trichlorobenzene	SW8260C	20000	c	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
1,2,4-Trimethylbenzene	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,2-Dibromo-3-chloropropane	SW8260C	--	--	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
1,2-Dichlorobenzene	SW8260C	90	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,2-Dichloroethane	SW8260C	400	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,2-Dichloroethene, cis-	SW8260C	40	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,2-Dichloroethene, trans-	SW8260C	40	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,2-Dichloropropane	SW8260C	700000	c	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,3,5-Trimethylbenzene (Mesitylene)	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,3-Dichlorobenzene	SW8260C	80	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,3-Dichloropropane	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,3-Dichloropropene, cis-	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
1,3-Dichloropropene, trans-	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U

Table 8.2a. Soil Chemistry Summary

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Chemical	Method	Lowest Soil Eco SL	Location ID / SL Source	SO-08_1907	SO-09_1907	SO-10_1907	SO-10_FieldQC	SO-11_1907	SO-12_1907	SO-13_1907
1,4-Dichloro-2-butene, trans-	SW8260C	--	--	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
1,4-Dichlorobenzene	SW8260C	20000	c	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
2-Chloroethylvinyl ether	SW8260C	--	--	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
2-Chlorotoluene	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
2-Hexanone (Methyl butyl ketone)	SW8260C	360	e	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
2-Pentanone	SW8260C	--	--	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
4-Chlorotoluene	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
4-Methyl-2-pentanone (Methyl isobutyl ketone)	SW8260C	--	--	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
Acetone	SW8260C	1200	e	**740**	**426**	**651 J**	**1710 J**	**1860**	**1020**	**686**
Acrolein	SW8260C	50	f	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
Acrylonitrile	SW8260C	--	--	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
Benzene	SW8260C	120	e	4.03 U	2.12 U	**0.97 J**	**1.24 J**	9.76 U	4.66 U	2.12 U
Bromobenzene	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Bromochloromethane	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Bromodichloromethane	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Bromoform (Tribromomethane)	SW8260C	70	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Bromomethane (Methyl bromide)	SW8260C	2	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Carbon disulfide	SW8260C	5	e	**13.2**	2.12 U	2.23 U	2.63 U	**8.86 J**	**4.75**	2.12 U
Carbon tetrachloride (Tetrachloromethane)	SW8260C	50	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Chlorobenzene	SW8260C	40000	c	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Chloroethane	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Chloroform	SW8260C	50	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Chloromethane	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Cymene, p- (4-Isopropyltoluene)	SW8260C	--	--	**2 J**	2.12 U	2.23 U	**1.07 J**	**63.2**	**30.5**	**5.55**
Dibromochloromethane	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Dibromomethane	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Dichlorodifluoromethane	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Dichloromethane (Methylene chloride)	SW8260C	210	e	8.06 U	4.25 U	4.46 U	5.26 U	**7.75 J**	9.32 U	4.25 U
Ethyl bromide (Bromoethane)	SW8260C	--	--	8.06 U	4.25 U	4.46 U	5.26 U	19.5 U	9.32 U	4.25 U
Ethylbenzene	SW8260C	270	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Ethylene dibromide (1,2-Dibromoethane)	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Hexachlorobutadiene (Hexachloro-1,3-butadiene)	SW8260C	9	e	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
Isopropylbenzene (Cumene)	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
m,p-Xylene	SW8260C	--	--	8.06 U	4.25 U	4.46 U	5.26 U	19.5 U	9.32 U	4.25 U
Methyl ethyl ketone (2-Butanone)	SW8260C	1000	e	**47.6**	**27.4**	**43.6 J**	**118 J**	**83.1**	**53.3**	**33.4**
Methyl iodide (Iodomethane)	SW8260C	--	--	**1.96 J**	**0.72 J**	2.23 U	2.63 U	**5.58 J**	4.66 U	2.12 U
Methyl tert-butyl ether (MTBE)	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Naphthalene	SW8260C	--	--	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
n-Butylbenzene	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
n-Propylbenzene	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
o-Xylene	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
sec-Butylbenzene	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Styrene	SW8260C	300000	b	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
tert-Butylbenzene	SW8260C	--	--	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Tetrachloroethene (PCE)	SW8260C	60	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Toluene	SW8260C	200000	b	**3.38 J**	**1.25 J**	**0.61 J**	**1.31 J**	**12.6**	**7.17**	**2.09 J**
Trichloroethene (TCE)	SW8260C	60	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Trichlorofluoromethane (Fluorotrichloromethane)	SW8260C	16400	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Vinyl acetate	SW8260C	--	--	20.2 U	10.6 U	11.1 U	13.1 U	48.8 U	23.3 U	10.6 U
Vinyl chloride	SW8260C	30	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Total 1,3-Dichloropropene (U = 1/2)	--	1	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Total Xylene (U = 1/2)	--	100	e	8.06 U	4.25 U	4.46 U	5.26 U	19.5 U	9.32 U	4.25 U
Total 1,3-Dichloropropene (U = 0)	--	1	e	4.03 U	2.12 U	2.23 U	2.63 U	9.76 U	4.66 U	2.12 U
Total Xylene (U = 0)	--	100	e	8.06 U	4.25 U	4.46 U	5.26 U	19.5 U	9.32 U	4.25 U

Table 8.2a. Soil Chemistry Summary

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Chemical	Method	Lowest Soil Eco SL	Location ID / SL Source	SO-08_1907	SO-09_1907	SO-10_1907	SO-10_FieldQC	SO-11_1907	SO-12_1907	SO-13_1907
Total Petroleum Hydrocarbons (mg/kg)										
Diesel range hydrocarbons	NWTPHDx	200	c	104 U	75.3 U	69.6 U	68.8 U	231 U	116 U	56.8 U
Gasoline range hydrocarbons	NWTPHG	100	c	22.9 U	15.2 U	20 U	15.3 U	81.9 U	31.4 U	10.4 U
Motor oil range hydrocarbons	NWTPHDx	--	--	208 U	151 U	**484**	**543**	462 U	232 U	114 U
Total Diesel and Motor Oil (U = 1/2)	--	200	c	208 U	151 U	**553.6**	**611.8**	462 U	232 U	114 U
Total Diesel and Motor Oil (U = 0)	--	200	c	208 U	151 U	**484**	**543**	462 U	232 U	114 U

Notes:
Detected concentration is greater than the ecological screening level for soil (cyan)
Non-detected concentration is greater than the ecological screening level for soil (orange)
Bold : Detected result
EPA Stage 2A validation performed

J: Estimated value
U: Compound analyzed, but not detected above detection limit
UJ: Compound analyzed, but not detected above estimated detection limit
R: Rejected

a. Natural background. For arsenic, WAC 176-340-900 Table 740-1 Method A Soil Cleanup Levels for Unrestricted Land Use. For manganese, Natural Background Soil Metals Concentrations in Washington State (Ecology 1994).
b. Ecology Terrestrial Ecological Evaluations under MTCA – Plants
c. Ecology Terrestrial Ecological Evaluations under MTCA – Soil Biota
d. Ecology Terrestrial Ecological Evaluations under MTCA – Wildlife
e. US EPA Region 4 ERA Guidance - Plants, Biota, or Wildlife
f. Analytic Resources Inc. Practical Quantitation Limit

--: not applicable
µg/kg: micrograms per kilogram
Eco SL: ecological screening level
Ecology: Washington State Department of Ecology
EPA: U.S. Environmental Protection Agency
mg/kg: milligrams per kilogram
MTCA: Model Toxics Control Act
pct: percent
SL: screening level

Table 8.2b. Evaluation of Exposure Pathways

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Chemical	Maximum Detected Exceedance	Location of Maximum Detected Exceedance	Natural Background	Plants	Biota	Wildlife	PQL	Lowest Soil Eco SL (Background or PQL, if Higher)	
Metals (mg/kg)									
Arsenic	59.2	SO-05	20	10	60	7	--	20	a
Lead	86.9	SO-10 (Reference)	--	50	500	118	--	50	b
Manganese	7,010	SO-02	1,200	1,100	450[e]	1,500	--	1,200	a
Mercury	0.324	SO-03	--	0.3	0.1	5.5	--	0.1	c
Volatile Organics (µg/kg)									
Acetone	3,110	SO-04	--	--	40	1,200	--	1,200	e
Acrolein	65.4	SO-02	--	--	0.3	5,270	50	50	f
Bromomethane (methyl bromide)	8.2	SO-05	--	--	2	240	--	2	e
Carbon disulfide	78.2	SO-02	--		5	810	--	5	e
Total Petroleum Hydrocarbons (mg/kg)									
Total diesel and motor oil (U = 0)	543	SO-10 (Reference)	--	1,600	200	6,000	--	200	c

Notes:

a. Natural background. For arsenic, WAC 176-340-900 Table 740-1 Method A Soil Cleanup Levels for Unrestricted Land Use. For manganese, Natural Background Soil Metals Concentrations in Washington State (Ecology 1994).

b. Ecology Terrestrial Ecological Evaluations under MTCA – Plants

c. Ecology Terrestrial Ecological Evaluations under MTCA – Soil Biota

d. Ecology Terrestrial Ecological Evaluations under MTCA – Wildlife

e. US EPA Region 4 ERA Guidance - Plants, Biota, or Wildlife

f. Analytic Resources Inc. Practical Quantitation Limit

Indicates natural background or ecological screening levels that are exceeded by the maximum detected concentration.

µg/kg: micrograms per kilogram

mg/kg: milligrams per kilogram

MTCA: Model Toxics Control Act

PQL: practical quantitation limit

SL: screening level

Table 8.3. Vashon Island and Maury Island EIM Data Summary

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Chemical	Soil Eco SL	Vashon Island and Maury Island Surface Soil Data[1]						Documented Metals Concentrations From Asarco Smelter	Maximum Detected Result from 2019 West Hillslope Soil Investigation	Conclusion
		Result Count	Detect Count	Minimum Detected Result	Maximum Detected Result	Average Detected Result	Median Detected Result			
Metals (mg/kg)										
Arsenic	7	4302	4030	1.7	460	39.8	26	40.1 to 100[A]	59.2	Concentrations detected in soil at West Hillslope Area related to Asarco smelter.
Lead	50	4238	4106	1	4600	75.7	42	>250 ppm[B]	85.5 (Reference Sample)	75% of samples collected from Vashon Island and Maury Island, and along mainland shoreline in West Seattle and the south King County line, had lead exceeding 250 ppm. Concentrations detected at West Hillslope Area are related to the Asarco smelter.
Manganese	1100	13	11	497	1852	1162	1260	N/A	7010	Maximum concentration detected is higher than expected based on Vashon/Maury Island data. Further evaluation of this chemical to be completed.
Mercury	0.1	43	27	0.063	2.6	0.66	0.529	N/A	0.324	Concentrations detected related to elevated background on Vashon Island.

Notes:

1. Data queried from EIM on August 9, 2019, including all surface soil samples, within 0 to 6 inches depth range, collected from 1999 to present.

A. Department of Ecology, Tacoma Smelter Plume Dirt Alert Predicted Arsenic Concentration map, July 31, 2019 (last update). https://apps.ecology.wa.gov/dirtalert/.

B. Department of Ecology, Focus: Arsenic and lead soil contamination in King County, Publication No. 01-09-032, January 2001. https://fortress.wa.gov/ecy/publications/publications/0109032.pdf.

Eco SL - ecological screening level

EIM - Washington State Department of Ecology Environmental Information Management System

mg/kg - milligrams per kilogram

N/A - not applicable

ppm - parts per million

Table 8.4a. Manganese Wildlife TEE Calculation Parameters

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Factors	Definition	Value	Units	Description
T(shrew)	shrew toxicity reference value	624	mg/kg-day	short-tailed shrew LOAEL, based on chronic rat LOAEL (Sample et al. 1996)
FIR(shrew)	food ingestion rate	0.45	kg dry weight/kg body weight day	default
PSb(shrew)	portion of contaminated food (earthworm in diet)	0.5	unitless	default
BAF(worm)	earthworm bioaccumulation factor	0.290	mg/kg / mg/kg (unitless)	Briemer (1989) and Vogel and Ottow (1991) to estimate BAF.
SIR(shrew)	soil ingestion rate	0.0045	kg dry soil/kg body weight -day	default
RGAF(soil, shrew)	relative gut absorption factor	1	unitless	default
T(robin)	robin toxicity reference value	997	mg/kg -day	American robin NOAEL, based on Japanese quail
FIR(robin)	food ingestion rate	0.207	kg dry food/kg body weight -day	default
PSb(robin)	proportion of contaminated food (soil biota) in robin diet	0.52	unitless	default
SIR(robin)	soil ingestion rate	0.0215	kg dry soil/kg body weight -day	default
RGAF(soil, robin)	relative gut absorption factor	1	unitless	default
T(vole)	vole toxicity reference value	477	mg/kg-day	Meadow vole chronic LOAEL, based on chronic rat LOAEL (Sample et al. 1996)
FIR(vole)	food ingestion rate	0.315	kg dry food/kg body weight -day	default
P(plant, vole)	proportion of contaminated food (plants) in vole diet	1	unitless	default
Kplant	plant uptake coefficient	0.183	mg/kg plant/ mg/kg soil	Whitehead (1987) EPA (2007) = 0.079 Ecology (2019) default = 1.01
SIR(vole)	soil ingestion rate	0.0079	kg dry soil/kg body weight day	default
RGAF(soil, vole)	relative gut absorption factor	1	unitless	default

Notes:
BAF = bioaccumulation factor
EPA = United States Environmental Protection Agency
kg = kilogram
LOAEL = lowest obsereved adverse effects level
mg/kg = milligrams per kilogram
mg/kg -day = milligrams per kilogram per day
NOAEL = no observed adverse effects level

Table 8.4b. Manganese Wildlife TEE Calculations

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Receptor	Protective Concentration (mg/kg)
Mammalian Predator	8,946
Avian Predator	18,913
Mammalian Herbivore	7,277

Notes:

mg/kg = milligrams per kilogram

Table 8.5. Soil Protective Concentrations

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Chemical	Plants	Biota	Wildlife
Metals (mg/kg)			
Arsenic	**59.2**	60	**59.2**
Lead	**86.9**	500	118
Manganese	**7,010**	**7,010**	7,277[a]
Mercury	**0.324**	**0.324**	5.5
Volatile Organics (µg/kg)			
Acetone	--	**3,110**	**3,110**
Acrolein	--	**65.4**	5,270
Bromomethane (methyl bromide)	--	**8.2**	240
Carbon disulfide	--	**78.2**	810
Total Petroleum Hydrocarbons (mg/			
Total diesel and motor oil (U = 0)	1,600	**543**	6,000

Notes:

a. Lowest wildlife protective concentration from Table 8.4b.

Bold: Values in bold are the maximum detected concentration for the West Hill Slope area. All other values are literature based as shown in Table 8.2b.

µg/kg: micrograms per kilogram

mg/kg: milligrams per kilogram

Table 9.1. Evaluation of Exposure Pathways

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Medium	Pathway	Receptors	On-Property Current Use	On-Property Potential Future Use	Off-Property Current Use	Off-Property Potential Future Use	Preliminary Cleanup Level (PCUL) Used to Evaluate Complete Pathways	Evaluation Comments
Groundwater	Direct Contact	Above-ground Workers	M	M	●	●	Minimum Groundwater Human Health PCULs	Landfill safety procedures in place to protect workers. Off-property Unit Cc2 groundwater contamination unknown to south beyond property boundary.
		Below-ground Workers	○	○	●	●	Minimum Groundwater Human Health PCULs	Depth to impacted groundwater on-property greater than 70 feet. There is no off-property Unit Cc2 groundwater contamination.
		Residents	○	○	●	●	Minimum Groundwater Human Health Drinking Water Standards	No residential use of landfill property so the pathway is incomplete. Off-property pathway is complete; however, COC exceedances based on protection of groundwater as a drinking water source are contained on-property and do not extend off-property therefor there is no exposure. No evidence of impacts to groundwater based on groundwater sampling of off-property wells performed by KCSWD.
	Ingestion	Residents	○	○	●	●	Minimum Groundwater Human Health Drinking Water Standards	
	Inhalation / Volatilization to Air	Above-ground Workers - Indoor	○	○	○	○	Protection of indoor air (MTCA Method B)	No landfill buildings are located over VOC impacted groundwater area. Landfill safety procedures in place to protect future workers if buildings were constructed. Depth to impacted groundwater greater than 70 feet so volatilization not a complete exposure pathway.
		Above-ground Workers - Outdoor	○	○	○	○	Groundwater protection of ambient air (MTCA Method B)	Depth to impacted groundwater greater than 70 feet so volatilization not a complete exposure pathway.
		Below-Ground Workers - Outdoor	○	○	○	○	Groundwater protection of ambient air (MTCA Method B)	
		Residents - Indoor	○	○	○	○	Protection of indoor air (MTCA Method B)	No residential use of landfill property. No buildings located over VOC-impacted groundwater area and depth to impacted groundwater is greater than 70 feet on property.
		Residents - Outdoor	○	○	○	○	Groundwater protection of ambient air (MTCA Method B)	No residential use of landfill property. Depth to impacted groundwater greater than 70 feet so volatilization not a complete exposure pathway.
	Discharge to Surface Water	See **Surface Water**	●	●	●	●	Minimum Surface Water PCULs	Evidence of impacted Unit Cc2 groundwater discharging via seeps to surface water.
	Soil-to-Groundwater	See **Surface Water**	●	●	●	●	Minimum Surface Water PCULs	Evidence of impacted Unit Cc2 groundwater discharging via seeps to surface water.
Surface Water	Direct Contact	Residents	○	○	●	●	Minimum Surface Water Human Health PCULs	No residential use of landfill property. Vinyl chloride is driver of this potential pathway.
		Recreational Users	●	●	●	●	Minimum Surface Water Human Health PCULs	Vinyl chloride is driver of this potential pathway.
		Aquatic Organisms	●	●	●	●	Minimum Surface Water Ecological PCULs	Pathway is complete; however no exceedances of ecological based cleanup criteria for dissolved metals at VLF property boundary; -no ecological-based cleanup criteria for vinyl chloride or other COCs.
	Ingestion	Aquatic or Terrestrial Organisms	●	●	●	●	Minimum Surface Water Ecological PCULs	
	Ingestion of Aquatic Organisms	Residents	○	○	●	●	Organism Only Human Health PCULs	No residential use of landfill property. Ingestion of aquatic organisms containing bioaccumulative compounds originating from discharge of groundwater to surface water. Steep slope and lack of habitat on-property prevent access to current recreational users on-property.
		Recreational Users	○	○	●	●	Organism Only Human Health PCULs	Ingestion of aquatic organisms containing bioaccumulative compounds originating from discharge of groundwater to surface water. Steep slope and lack of habitat on-property prevent access to current recreational users on-property.
Landfill Gas	Inhalation	Above-ground Workers	M	M	○	○	WAC 173-304 & WAC 173-351	Landfill safety procedures in place to protect workers. No off-property migration of LFG.
		Below-ground Workers	M	M	○	○	WAC 173-304 & WAC 173-351	
		Residents	○	○	○	○	WAC 173-304 & WAC 173-351; Protection of Indoor Air (MTCA Method B)	No residential use of landfill property. No off-property migration of LFG.
	Direct Contact (Explosivity)	Above-ground Workers	M	M	○	○	WAC 173-304 & WAC 173-351	Landfill safety procedures and routine monitoring in place to protect workers. No off-property migration of LFG.
		Below-ground Workers	M	M	○	○	WAC 173-304 & WAC 173-351	
		Residents	○	○	○	○	WAC 173-304 & WAC 173-351	No residential use of landfill property. No off-property migration of LFG.
	Discharge to Groundwater	See **Groundwater**	●	●	○	○	Minimum Groundwater Human Health PCULs	LFG impact to groundwater complete pathway. No evidence of LFG to groundwater pathway off-property as there is no off-property LFG migration.

Table 9.1. Evaluation of Exposure Pathways

Project No. 090057-310.3, Vashon Island Closed Landfill, Vashon Island, King County, Washington

Medium	Pathway	Receptors	On-Property Current Use	On-Property Potential Future Use	Off-Property Current Use	Off-Property Potential Future Use	Preliminary Cleanup Level (PCUL) Used to Evaluate Complete Pathways	Evaluation Comments
Leachate	Direct Contact	Above-ground Workers - Indoor	M	M	○	○	WAC 173-304 & WAC 173-351	Landfill safety procedures in place to protect workers. No evidence of leachate direct contact pathway off-property.
		Below-Ground Workers - Outdoor	M	M	○	○	WAC 173-304 & WAC 173-351	
	Discharge to Groundwater	See **Groundwater**	●	●	○	○	Minimum Groundwater Human Health PCULs	Leachate to groundwater complete pathway historically. Decreasing with time. Limited evidence of leachate to groundwater.
Refuse	Direct Contact	Below-Ground Workers	●	●	○	○	MTCA Direct Contact - Human Health	Geomembrane liner and geotextile fabric and cover soil separates most of the refuse, but potential exposure to refuse during excavation exists. Currently, access to the landfill property is restricted. Average depth to refuse is approximately 10 feet in unlined South Slope Area.
		Burrowing Terrestrial Organisms	○	○	○	○	MTCA Direct Contact - Ecological Receptors	Geomembrane liner and cover soil separates refuse, eliminating burrowing pathway. Average depth to refuse is approximately 10 feet in unlined South Slope Area.
Soil	Direct Contact / Ingestion	Above- and Below-Ground Workers	M	M	○	○	MTCA Direct Contact - Human Health	Landfill safety procedures in place to protect workers. No evidence of off-property soil impact.
		Residents	○	○	○	○	MTCA Direct Contact - Human Health	No residential use of landfill property so the pathway is incomplete. No evidence of off-property soil impact.
		Recreational Users	○	○	○	○	MTCA Direct Contact - Human Health	Pathway to be mitigated in the future with covenant restricting recreational land-use and site access. No evidence of off-property soil impact.
		Terrestrial Organisms (e.g. plants, soil invertebrates, birds and mammals)	●	●	○	○	Ecology TEE Screening Levels under MTCA	Pathway is complete. Arsenic, lead, manganese, and mercury exceed terrestrial ecological screening levels. However no elevated risk is present due to arsenic, lead, and mercury concentrations are consistent with area-wide background concentrations. No observed plant impacts. Site-specific TEE conducted for manganese indicates that soil concentrations are protective and no risk to vole is indicated.
		Burrowing Terrestrial Organisms (e.g. voles)	●	●	○	○	Ecology TEE Screening Levels under MTCA	
	Soil-to-Groundwater	See **Groundwater**	M / ●	M / ●	○	○	Minimum Groundwater Human Health PCULs and WAC 173-340-747(3)(f)	Pathway is potentially complete for on-property direct contract/ingestion receptors. Pathway is mitigated for on-property workers by landfill safety proceedures. Pathway for residents and recreational users to be mitigated in future with covenant restricting access and land-use. Compliance with soil PCULs to be demonstrated empirically.
Biotic Uptake (plants/prey)	Ingestion	Terrestrial Organisms (e.g. herbivorous, insectivorous, and carnivorous birds and mammals)	●	●	○	○	Ecology TEE Screening Levels under MTCA	Pathway is complete. Arsenic, lead, manganese, and mercury exceed terrestrial ecological screening levels. However no elevated risk is present due to arsenic, lead, and mercury concentrations are consistent with area-wide background concentrations. No observed plant impacts. Site-specific TEE conducted for manganese indicates that soil concentrations are protective and no risk to vole is indicated.
		Burrowing Terrestrial Organisms (e.g. shrew and vole)	●	●	○	○	Ecology TEE Screening Levels under MTCA	

Notes:

● = Complete or Potentially Complete Current or Future Pathway Based on Available Remedial Investigation Data

○ = Incomplete Pathway Based on Available Remedial Investigation Data

M = Potential Exposure Route, Currently Mitigated to Prevent Exposure to Receptors Above Acceptable Levels

LFG = Landfill Gas

MTCA = Model Toxics Control Act

VOC = Volatile Organic Compound

PCUL = Preliminary Cleanup Level

WAC = Washington Administrative Code

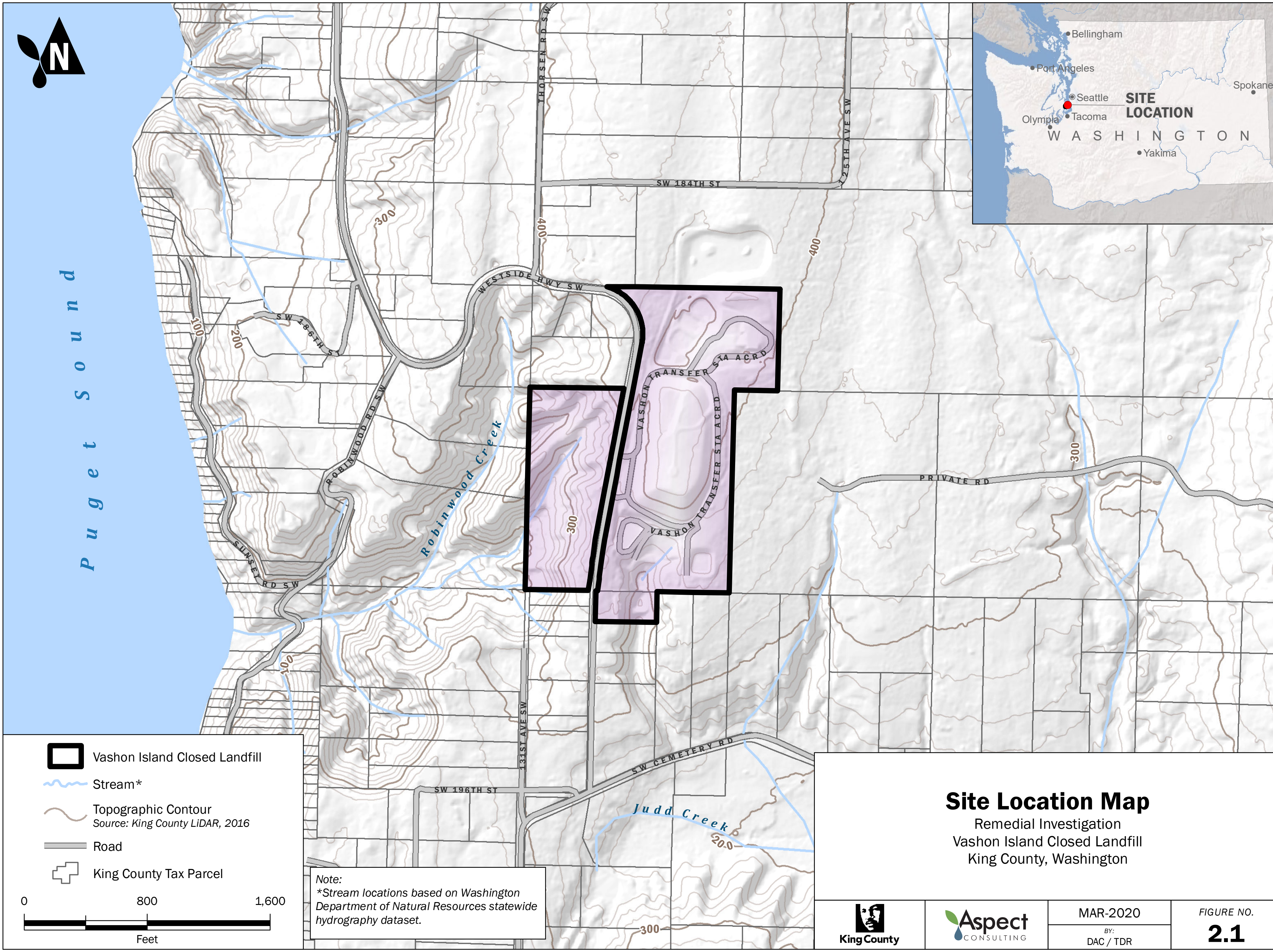
FIGURES

Project Location Map

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County	Aspect CONSULTING	MAR-2020 BY: DLC / TDR	FIGURE NO. 1.1

Basemap Layer Credits || Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



Note:
*Stream locations based on Washington Department of Natural Resources statewide hydrography dataset.

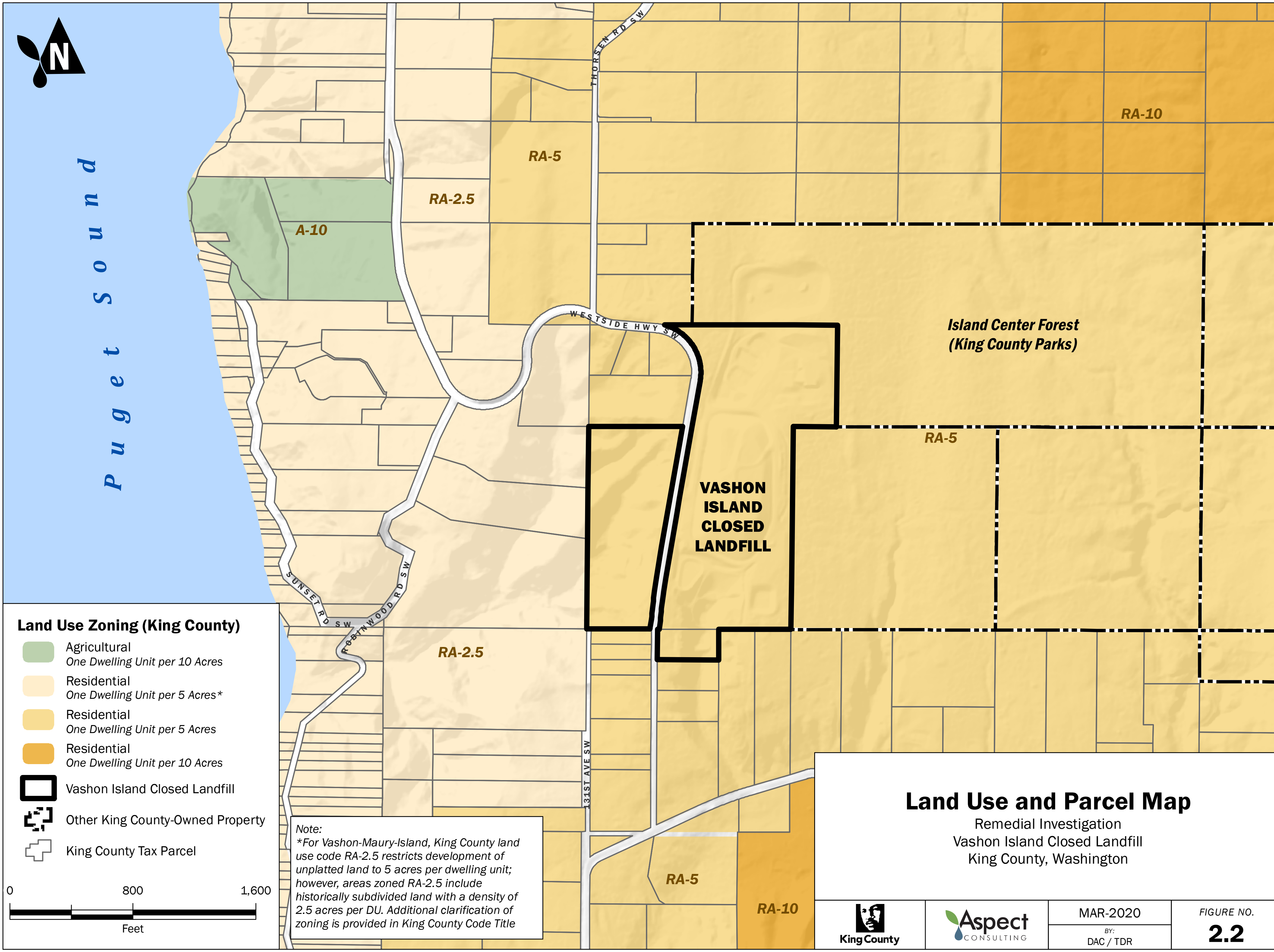
Site Location Map

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

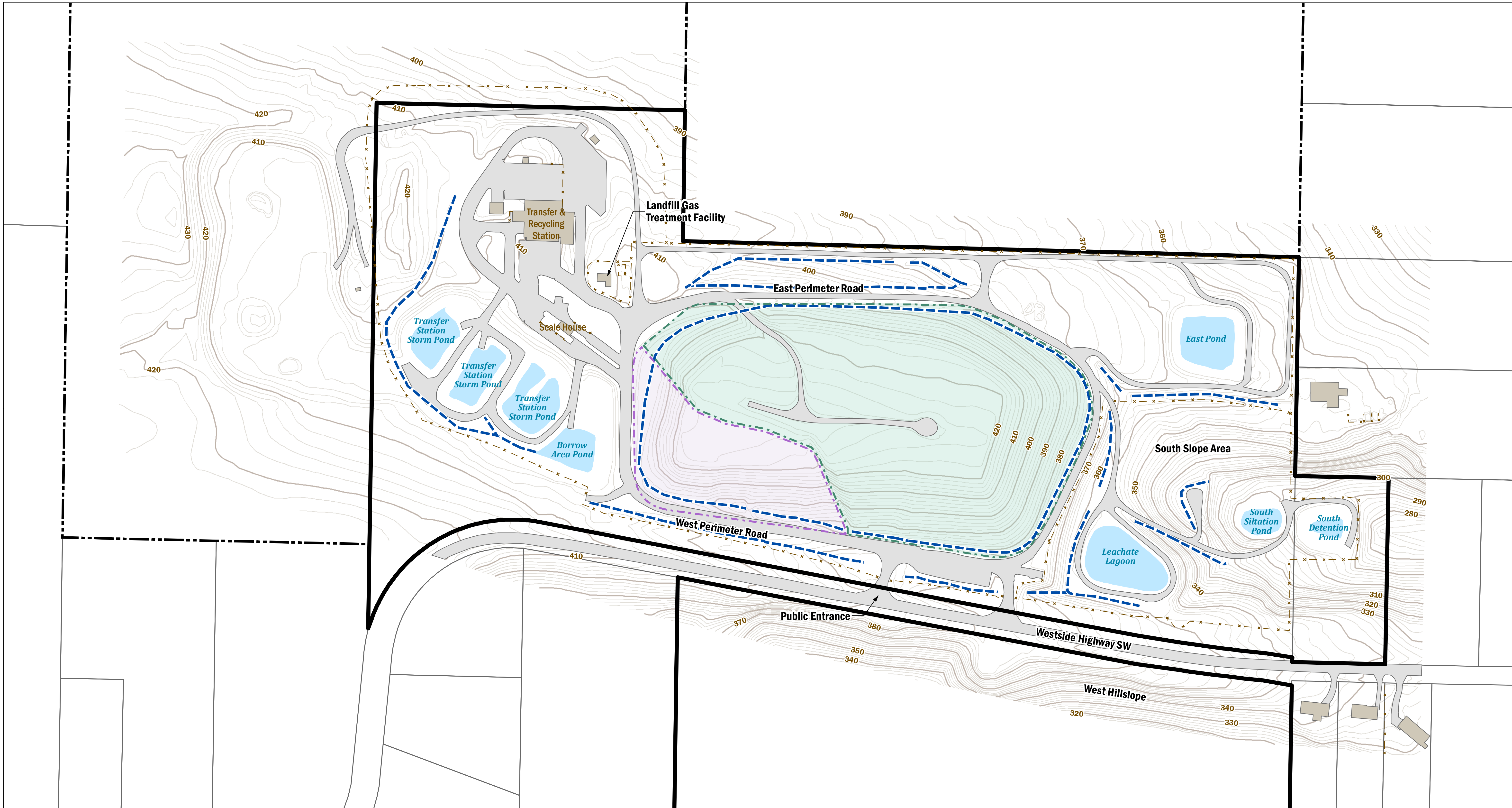
King County	Aspect CONSULTING	MAR-2020 BY: DAC / TDR	FIGURE NO. 2.1

Basemap Layer Credits || Copyright:(c) 2014 Esri

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\2-1 Site Location.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-03-10 || User: trullen || Print Date: 2020-03-10



N
Puget Sound
THORSEN RD SW
WESTSIDE HWY SW
SUNSET RD SW
ROBINWOOD RD SW
131ST AVE SW
A-10
RA-2.5
RA-5
RA-10
RA-5
RA-2.5
RA-5
RA-10
Island Center Forest
(King County Parks)
VASHON ISLAND CLOSED LANDFILL
Land Use Zoning (King County)
Agricultural
One Dwelling Unit per 10 Acres
Residential
One Dwelling Unit per 5 Acres*
Residential
One Dwelling Unit per 5 Acres
Residential
One Dwelling Unit per 10 Acres
Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel
0
800
1,600
Feet
Note:
*For Vashon-Maury-Island, King County land use code RA-2.5 restricts development of unplatted land to 5 acres per dwelling unit; however, areas zoned RA-2.5 include historically subdivided land with a density of 2.5 acres per DU. Additional clarification of zoning is provided in King County Code Title
Land Use and Parcel Map
Remedial Investigation
Vashon Island Closed Landfill
King County, Washington
King County
Aspect CONSULTING
MAR-2020
BY:
DAC / TDR
FIGURE NO.
2.2



Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Pond
Ditch
Building
Road
Fence
Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel

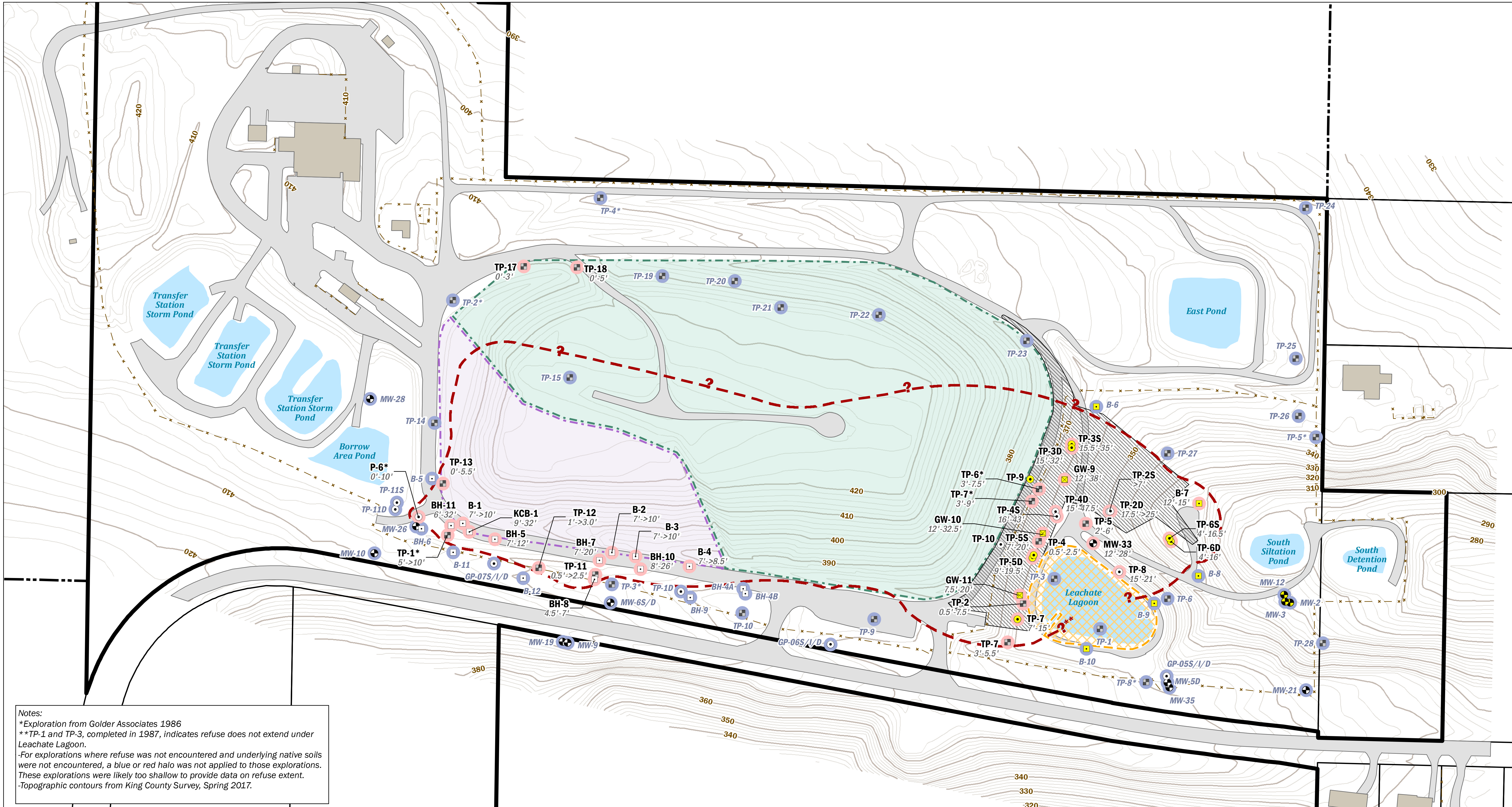
Note: *Topographic contours from King County Survey, Spring 2017.*

0 200 400
Feet

Property Features

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County
Aspect CONSULTING
MAR-2020
BY: DAC / TDR
FIGURE NO. 2.3



Boring
Gas Probe
LFG Extraction Well
Monitoring Well
Test Pit
Boring (Till Absent)
Gas Probe (Till Absent)
LFG Extraction Well (Till Absent)
Monitoring Well (Till Absent)
Estimated Extent of Unlined Refuse
Extent of Geotextile Cover Beyond Landfill Liner
Extent of Geomembrane under Leachate Lagoon
Encountered Refuse
No Refuse, Native Soils Encountered After Fill Unit
Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Pond
Building
Road
Fence
Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel

0 150 300
Feet

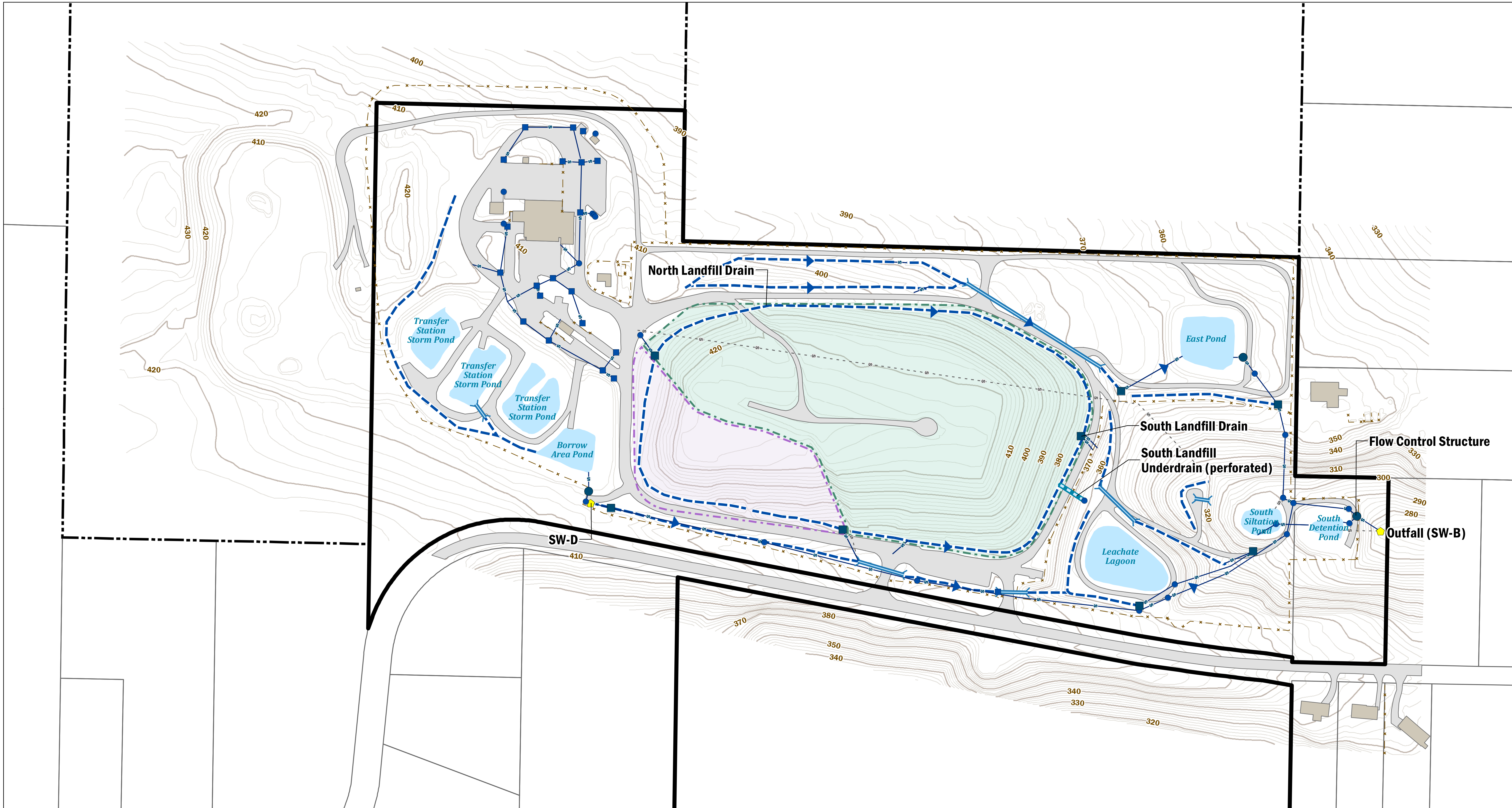
Extent of Solid Waste

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County
Aspect CONSULTING

MAR-2020
BY: DAC / TDR

FIGURE NO.
2.4



Storm Pipe
Storm Pipe (Abandoned)
Culvert
Underdrain
General Direction of Storm Drain Pipe
Ditch (Asphalt or Unlined)

Storm Catch Basin
Storm Manhole
Ponded Stormwater Enters Storm Drain Pipe for Conveyance
Surface Water Flow Enters Storm Pipe for Conveyance
Former Surface Water Monitoring Station
Pond

Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Building
Road
Fence

Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel

0 200 400
Feet

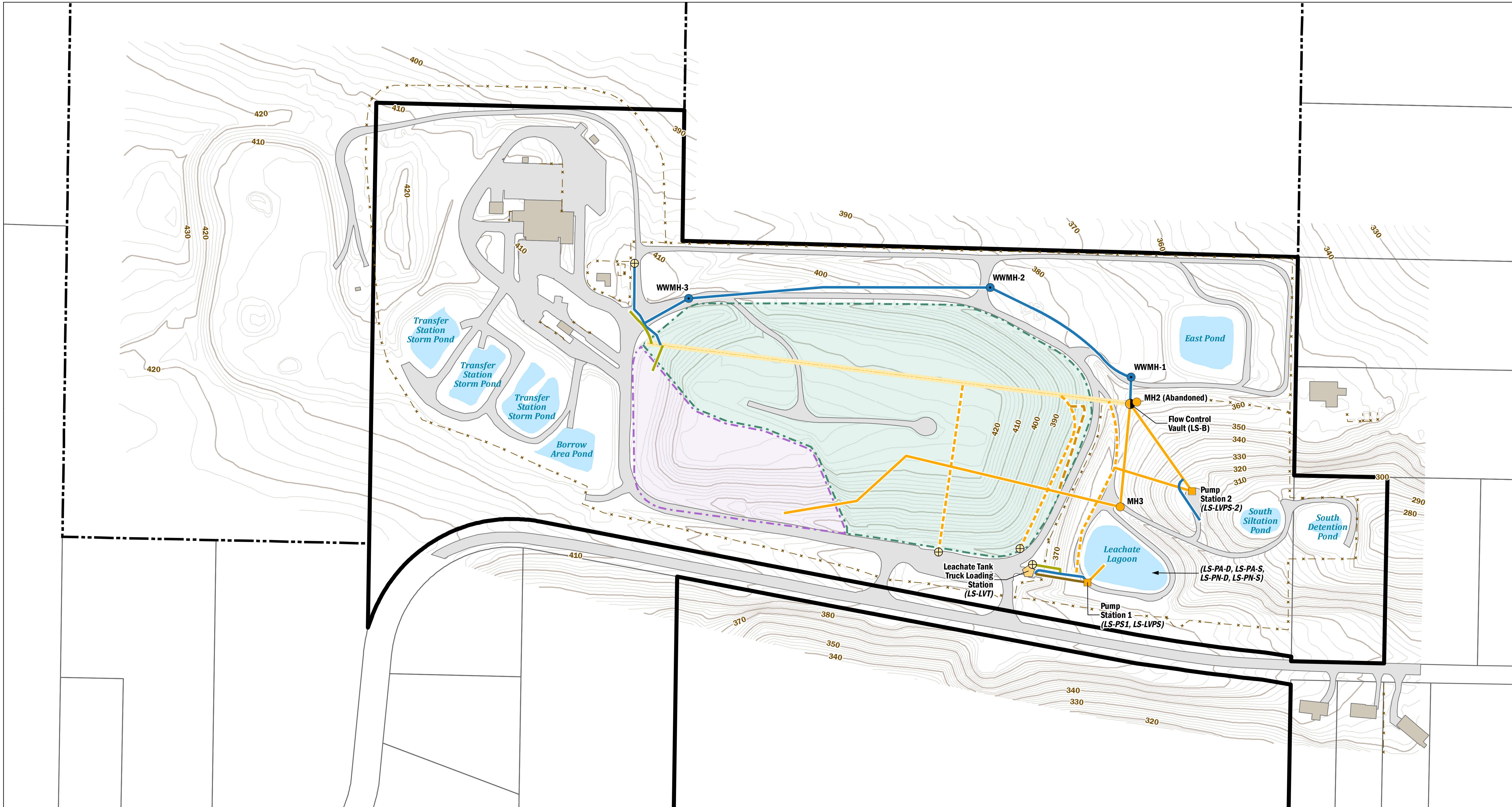
Note: Topographic contours from King County Survey, Spring 2017.

Surface Water Drainage Features

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | MAR-2020 BY: DAC / TDR | FIGURE NO. 2.5

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\2-5 Surface Water Drainage Features.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-03-10 || User: trullen || Print Date: 2020-03-10



- Manhole
- Pump Station
- Loading Station
- Flow Control Vault
- Wastewater Manhole
- Cleanout
- General Direction of Flow
- Leachate Collection Pipe
- Leachate Collection Pipe (Perforated)
- Leachate Collection Trench
- Leachate Forcemain
- Condensate Pipe
- Wastewater Pipe
- Underdrain Pipe
- Phase 1 - 1988 Final Cover
- Phase 2 - 2001 Final Cover
- Pond
- Building
- Road
- Fence
- (LS-LVT) Leachate Sample ID
- Vashon Island Closed Landfill
- Other King County-Owned Property
- King County Tax Parcel

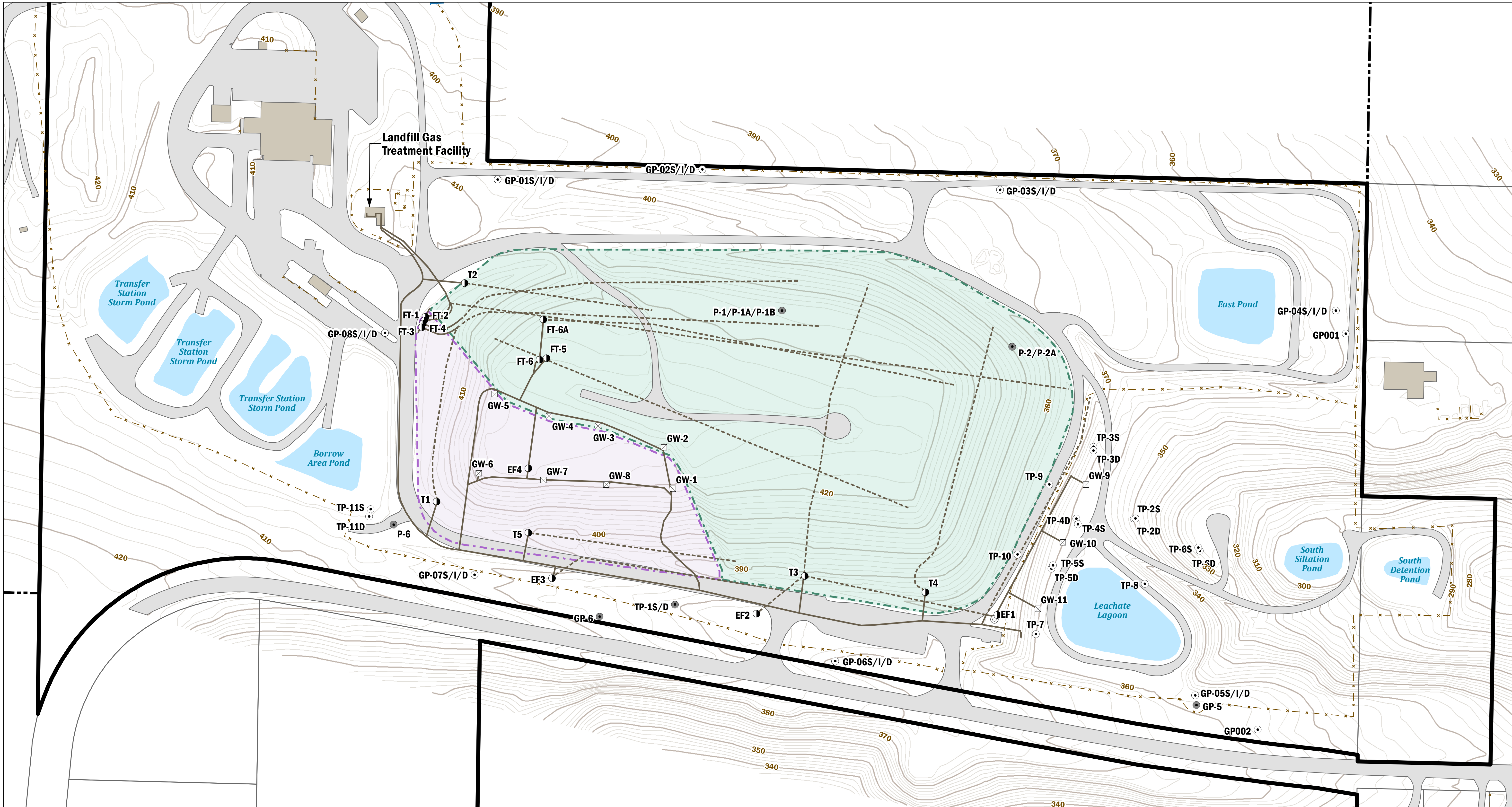
Note: Topographic contours from King County Survey, Spring 2017.

0 200 400
Feet

Leachate Collection and Monitoring Systems

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect Consulting | MAR-2020 | BY: DAC / TDR | FIGURE NO. 2.6



Gas Probe/Piezometer

Decommissioned Gas Probe

LFG Extraction Well

LFG Trench Riser

LFG Cleanout

Pond

LFG Pipe

LFG Underground Pipe

Phase 1 - 1988 Final Cover

Phase 2 - 2001 Final Cover

Building

Road

Fence

Vashon Island Closed Landfill

Other King County-Owned Property

King County Tax Parcel

Notes:
- Topographic contours from King County Survey, Spring 2017. - Landfill gas system features are approximated from as-built locations, and revised to match survey data where available.
- LFG lateral pipes from EF1 to GW-9, GW-10, and GW-11 are above ground.

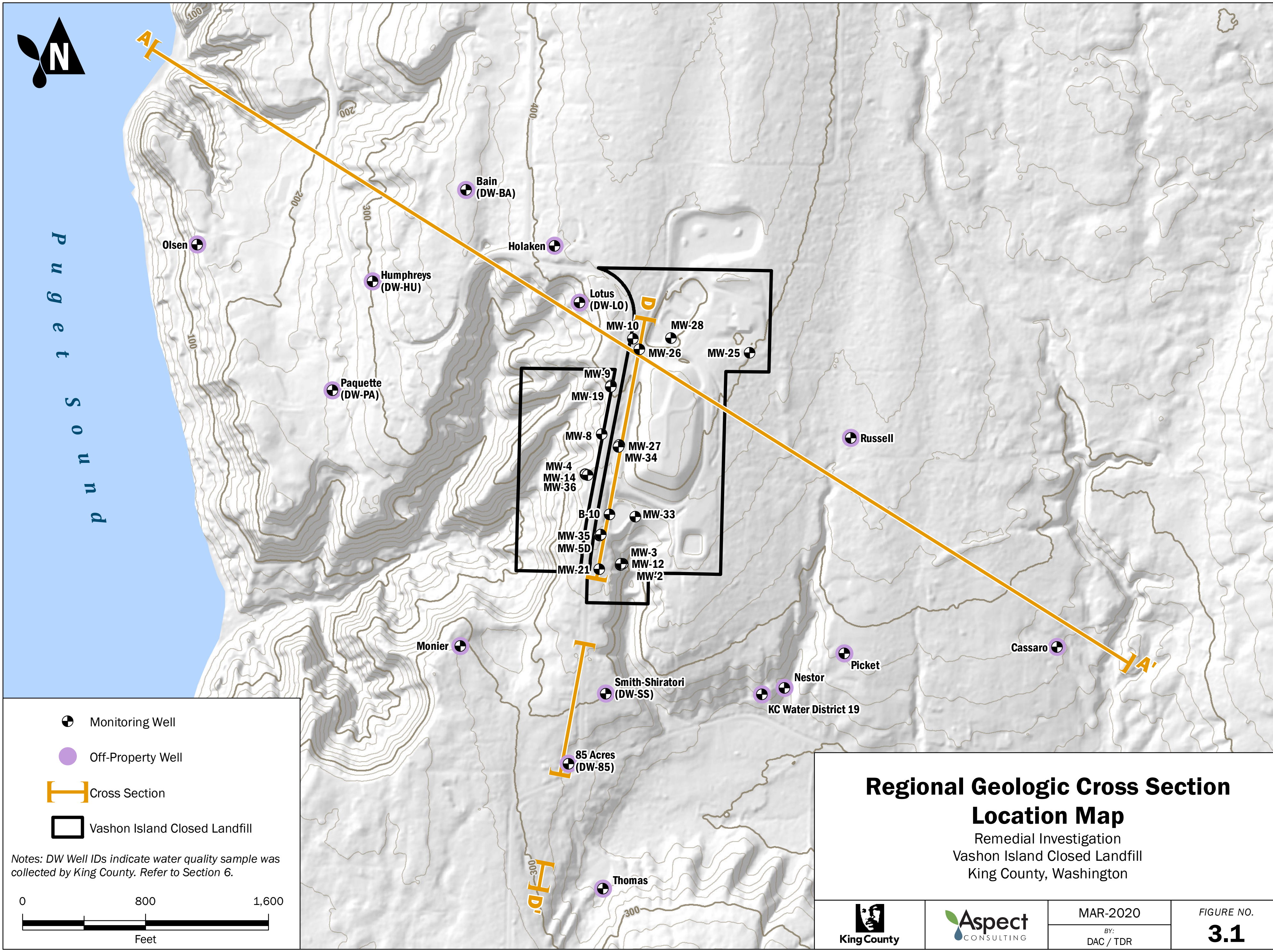
0 140 280
Feet

Landfill Gas Collection and Monitoring Systems

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect Consulting | MAR-2020 | BY: DAC / TDR | FIGURE NO. **2.7**

Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet
Date Saved: 2020-03-10
Print Date: 2020-03-10

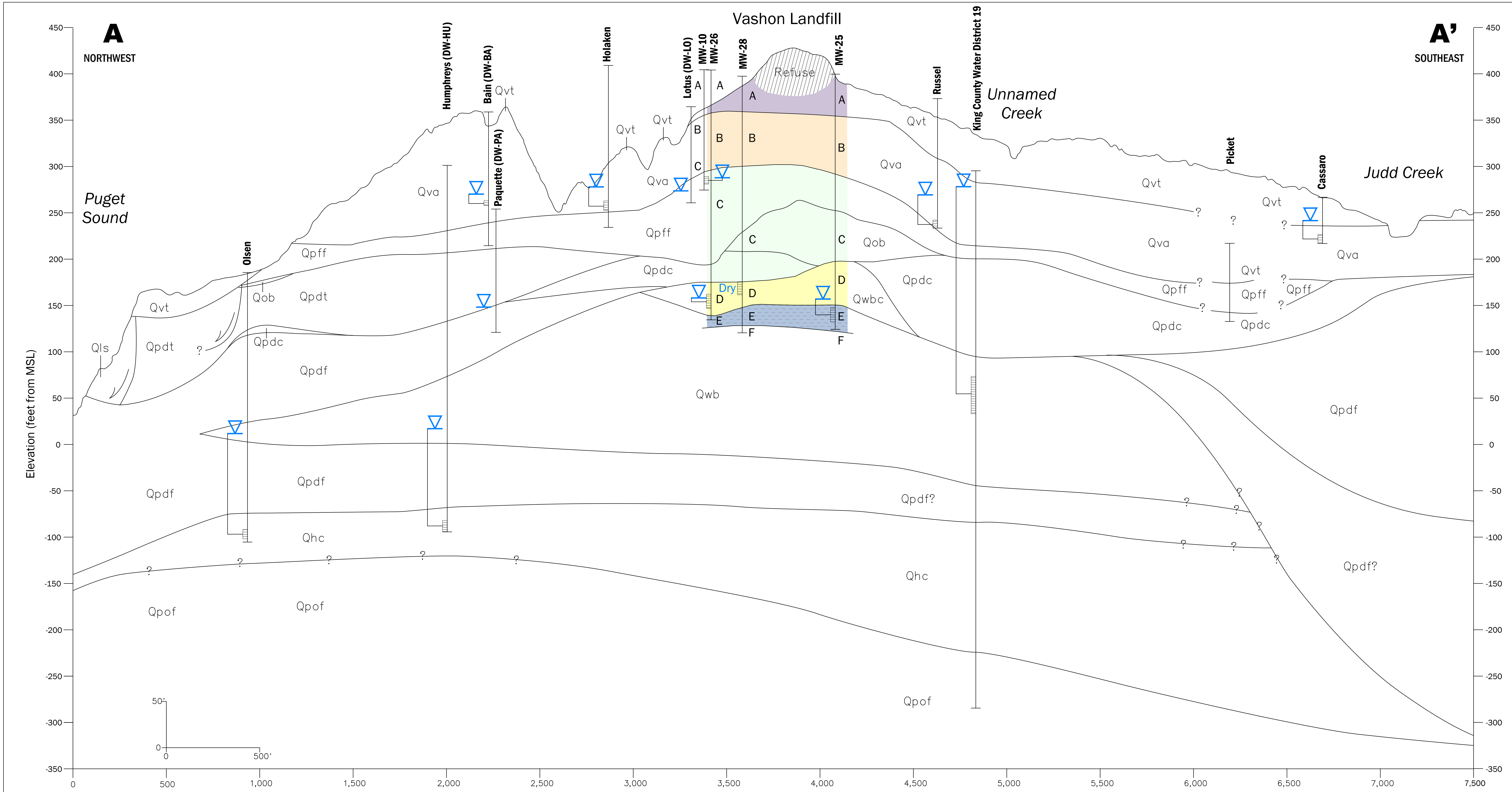


Regional Geologic Cross Section Location Map

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | MAR-2020 BY: DAC / TDR | FIGURE NO. 3.1

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\3-1 Regional Geologic Cross Section Location Map.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-03-10 || User: trullen || Print Date: 2020-03-10



Source: Modified from Troost, 2004.

Geologic Units

Qls	Landslide Deposits (Holocene)
Qvt	Vashon Till
Qva	Advance Outwash
Qob	Olympia Beds
Qpdt	Possession Drift Till
Qpdc	Possession Drift, Coarse-Grained Facies
Qpdf	Possession Drift, Fine-Grained Facies
Qwbc	Whidbey Beds, Coarse-Grained Facies
Qwb	Whidbey Beds, Undifferentiated
Qhc	Hamm Creek Formation
Qpof	Pre-Olympia Deposits, Fine-Grained Facies
Qpff	Pre-Fraser Glaciation Deposits, Fine-Grained Facies

Refuse/Fill
Unit A
Unit B
Unit C
Coarse
Fine
Unit D
Unit E

Static Water Level
Screen Interval

Note: DW well ID's indicate water quality sample was collected by county. Refer to Section 6 for data.

Horizontal Scale: 1" = 500'
Vertical Scale: 1" = 100'
Vertical Exaggeration 5x

0 500 1000 Feet

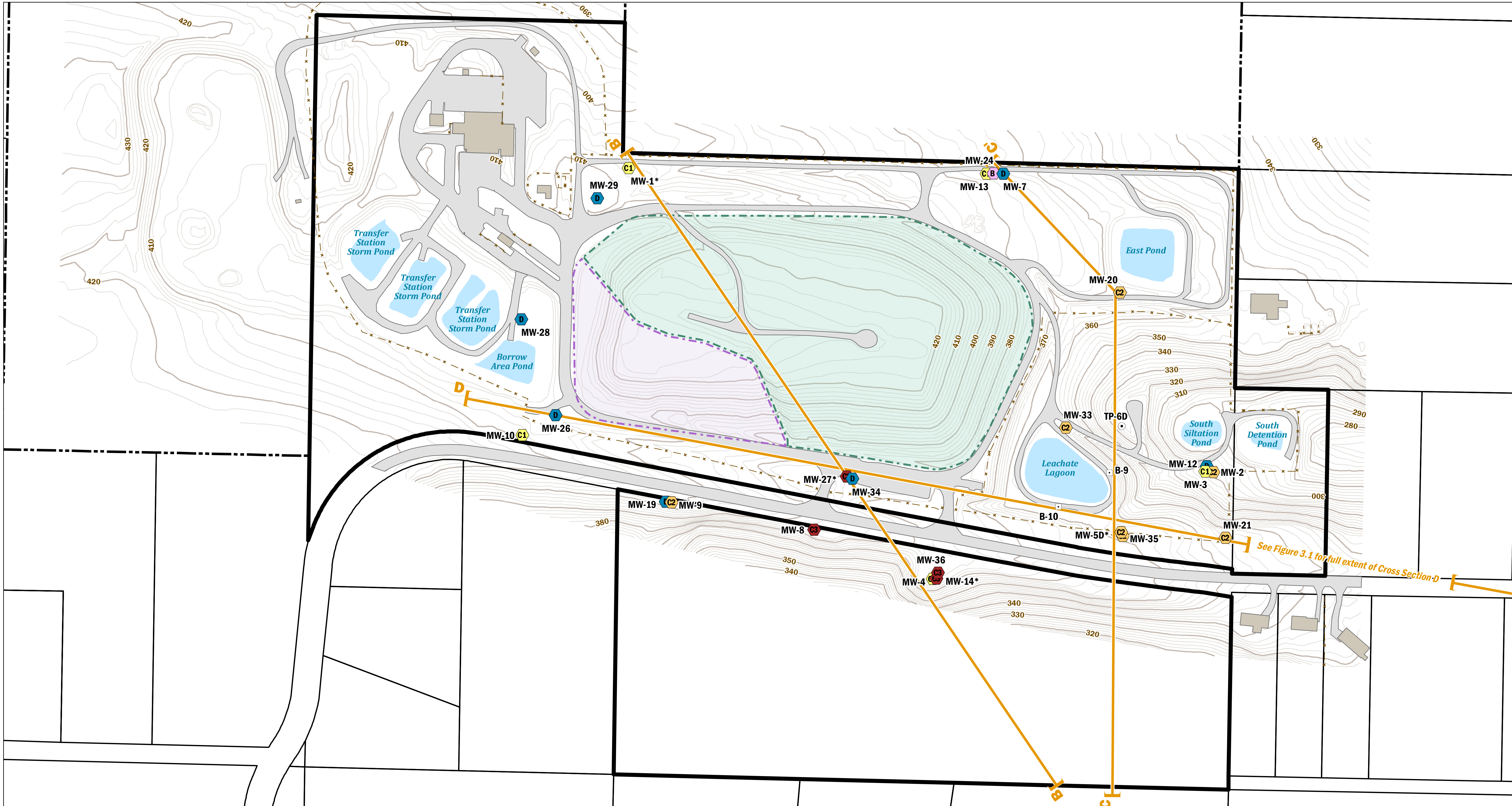
Regional Geologic Cross Section A-A'

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County
Aspect CONSULTING

Apr-2020
BY: DLC/SCC
FIGURE NO. 3.2

CAD Path: \\SEASTORE2\Drafting\King County\090057 Vashon Island Landfill\2018-05 RI-FS Report\090057-AA.dwg Section A-A' || Date Saved: Apr 22, 2020 12:40pm || User: scudd



Monitoring Well Completion Aquifer

- Unit B
- Unit Cc1
- Unit Cc2
- Unit Cc3
- Unit D

- Boring
- Gas Probe
- Cross Section
- Phase 1 - 1988 Final Cover
- Phase 2 - 2001 Final Cover

- Pond
- Building
- Road
- Fence

- Vashon Island Closed Landfill
- Other King County-Owned Property
- King County Tax Parcel

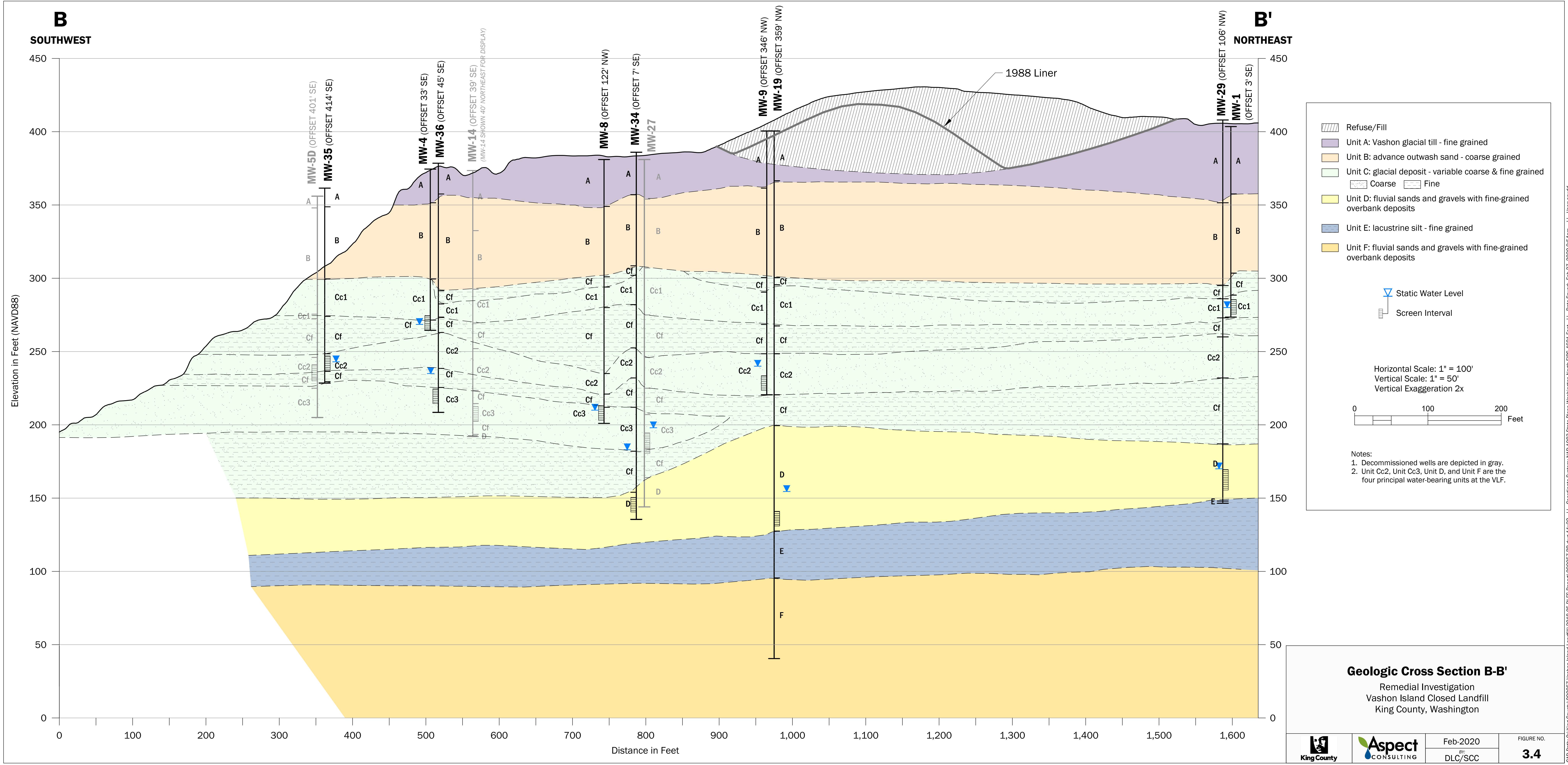
Notes:
Topographic contours from King County Survey, Spring 2017.
**Indicates decommissioned monitoring well.*

0 200 400
Feet

Site Cross Section Locations

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

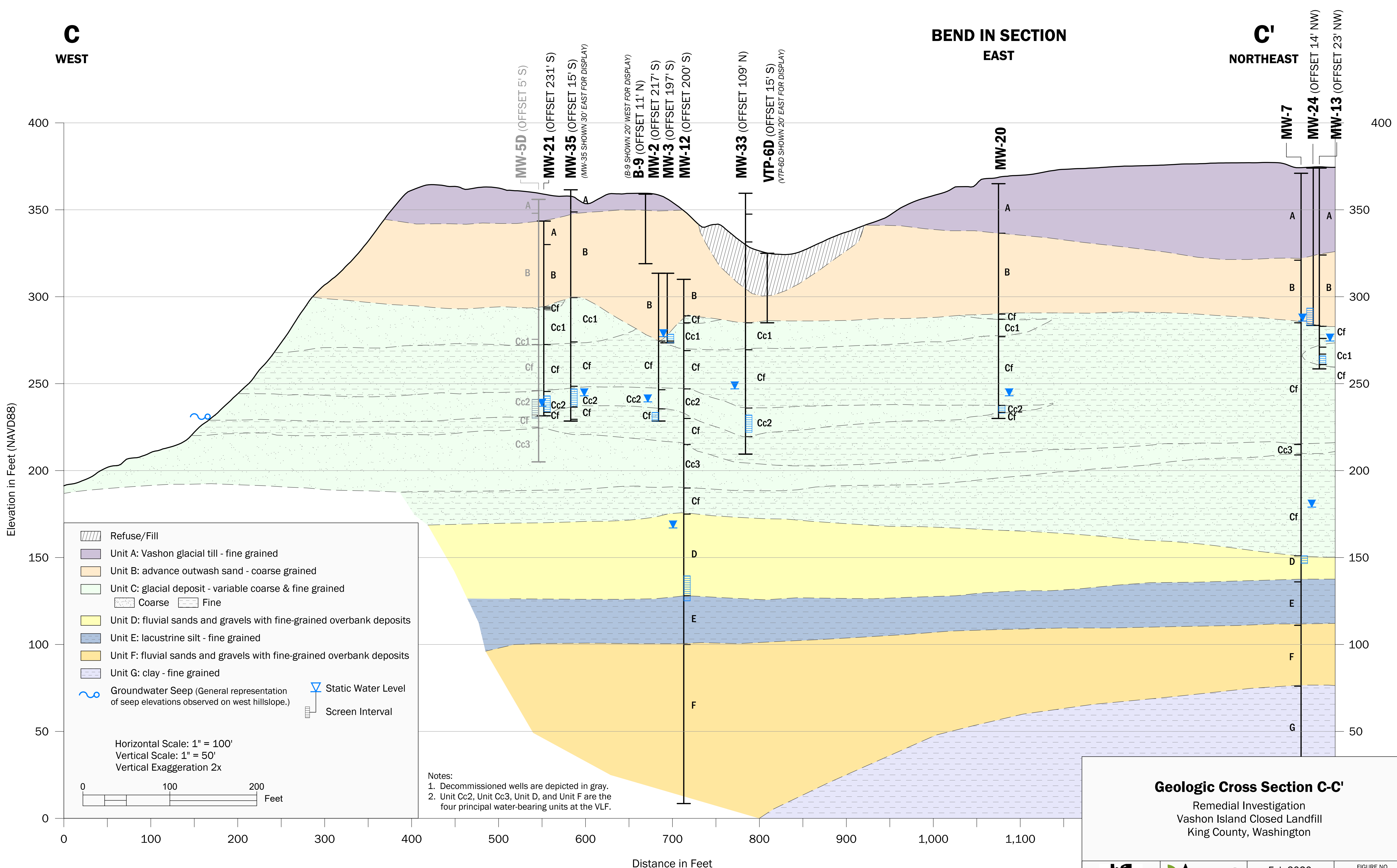
King County | Aspect CONSULTING | MAR-2020 BY: DAC / TDR | FIGURE NO. 3.3



Geologic Cross Section B-B'

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | Feb-2020 | BY: DLC/SCC | FIGURE NO. 3.4



Geologic Cross Section C-C'

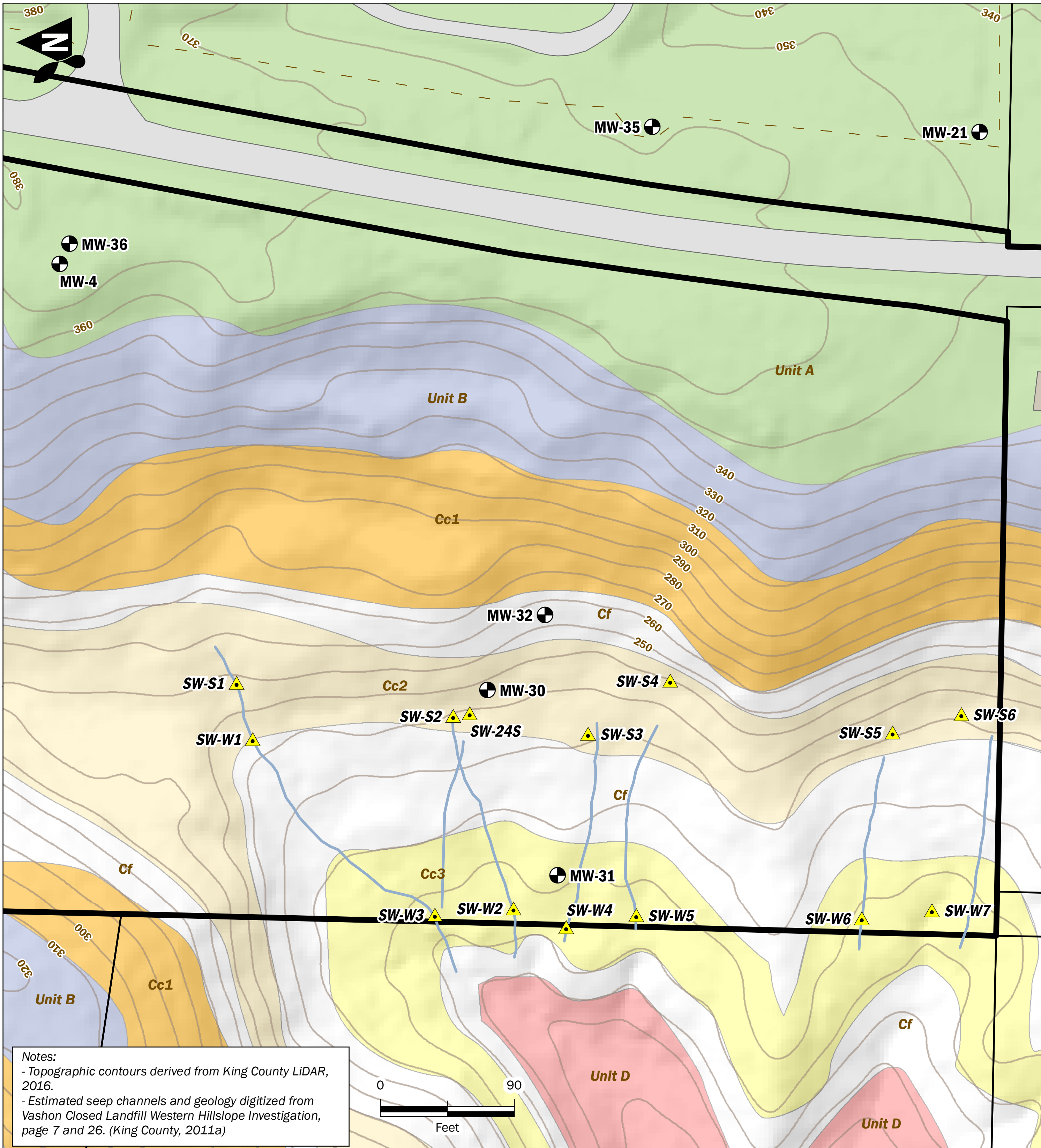
Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | Feb-2020 BY: DLC/SCC | FIGURE NO. 3.5

Geologic Cross Section D-D'

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect Consulting | Feb-2020 BY: DLC/SCC | FIGURE NO. 3.6



Cc1
Cc2
Cc3
Cf
Unit A
Unit B
Unit D

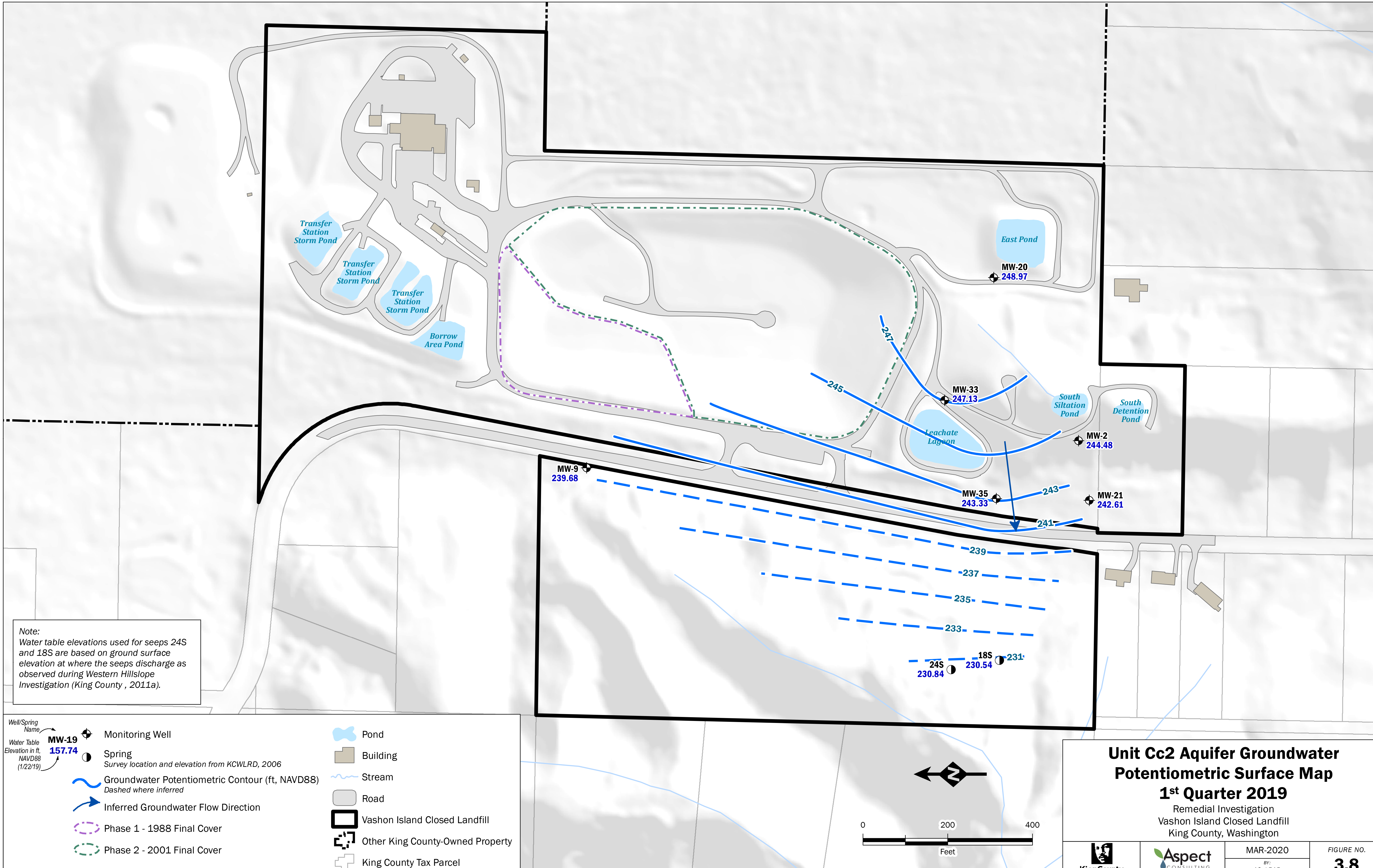
Monitoring Well
Seep/Weir Sampling Location (Aspect)
Estimated Seep Channel
Vashon Island Closed Landfill
King County Tax Parcel

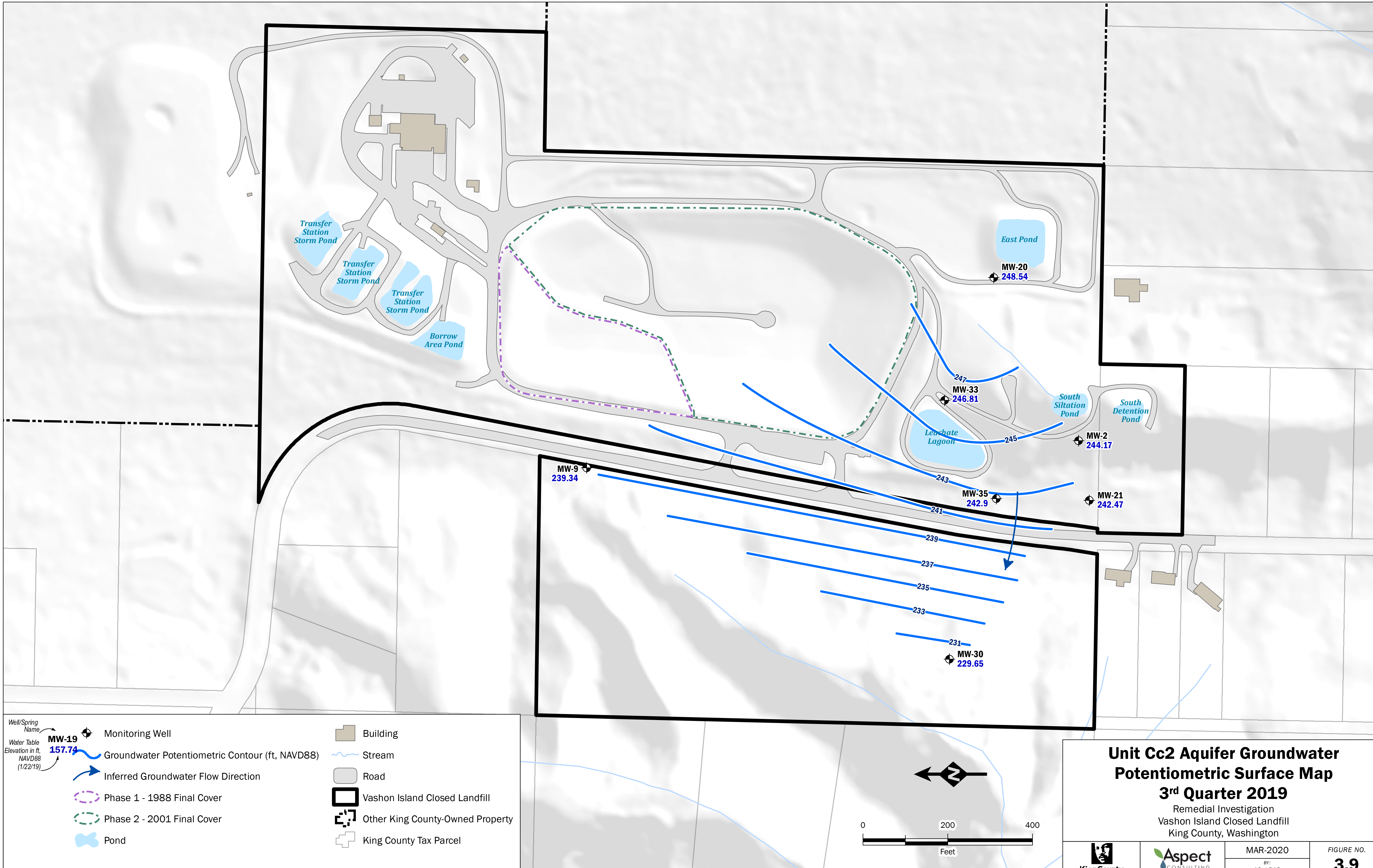
West Hillslope Geologic Map

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | MAR-2020 BY: DAC / TDR | FIGURE NO. 3.7

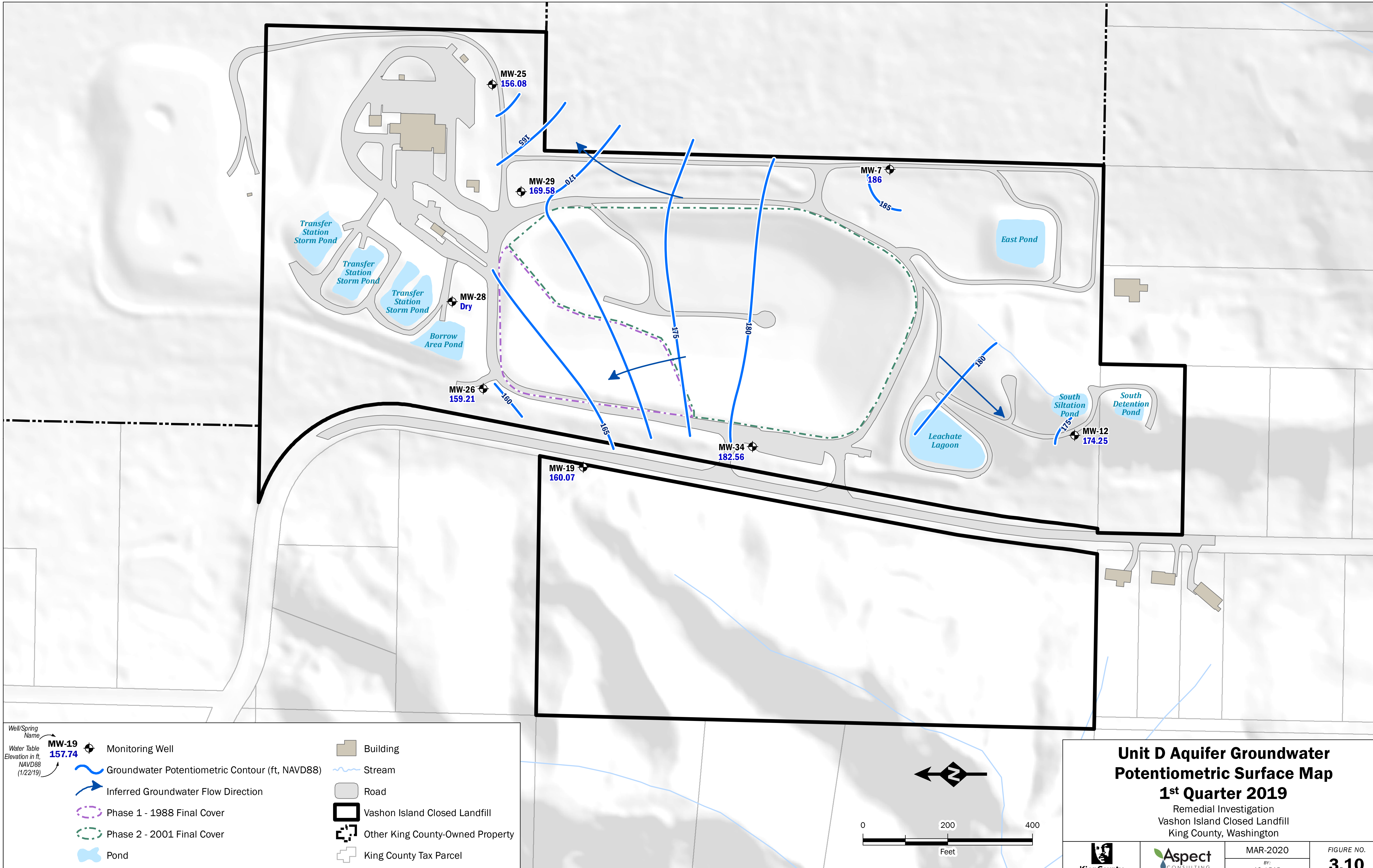
GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\3.7 West Hillslope Geologic Map.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-03-11 || User: trullen || Print Date: 2020-03-11


Transfer Station Storm Pond
Transfer Station Storm Pond
Transfer Station Storm Pond
Borrow Area Pond
East Pond
MW-20
248.97
247
245
MW-33
247.13
South Siltation Pond
South Detention Pond
Leachate Lagoon
MW-2
244.48
MW-9
239.68
MW-35
243.33
243
MW-21
242.61
241
239
237
235
233
18S
230.54
231
24S
230.84
Note:
Water table elevations used for seeps 24S and 18S are based on ground surface elevation at where the seeps discharge as observed during Western Hillslope Investigation (King County , 2011a).
Well/Spring Name
Water Table Elevation in ft, NAVD88 (1/22/19)
MW-19
157.74
Monitoring Well
Spring
Survey location and elevation from KCWLRD, 2006
Groundwater Potentiometric Contour (ft, NAVD88)
Dashed where inferred
Inferred Groundwater Flow Direction
Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Pond
Building
Stream
Road
Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel
N
0
200
400
Feet
Unit Cc2 Aquifer Groundwater Potentiometric Surface Map
1st Quarter 2019
Remedial Investigation
Vashon Island Closed Landfill
King County, Washington
King County
Aspect CONSULTING
MAR-2020
BY:
AO / RAP
FIGURE NO.
3.8



Unit Cc2 Aquifer Groundwater Potentiometric Surface Map 3rd Quarter 2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

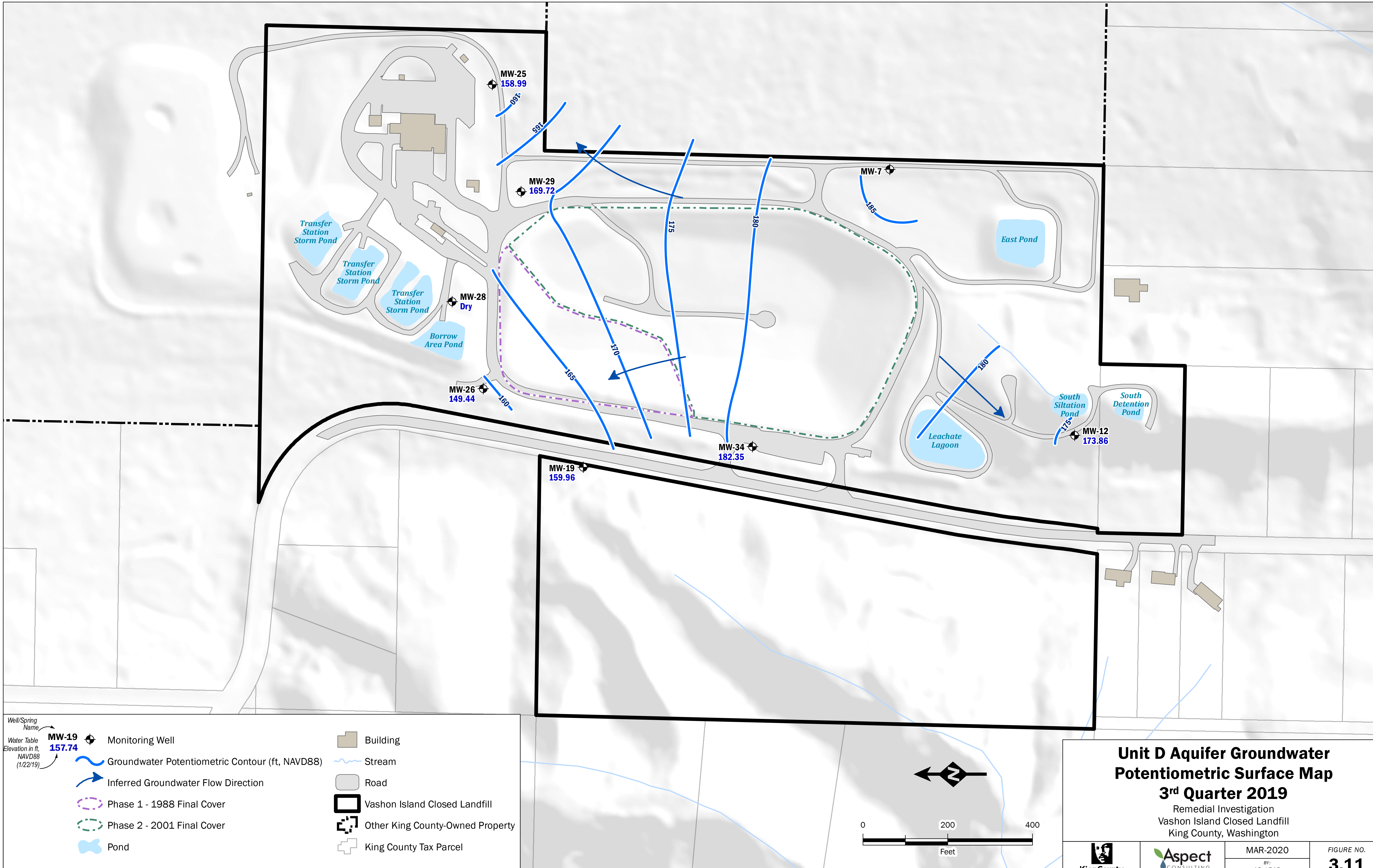


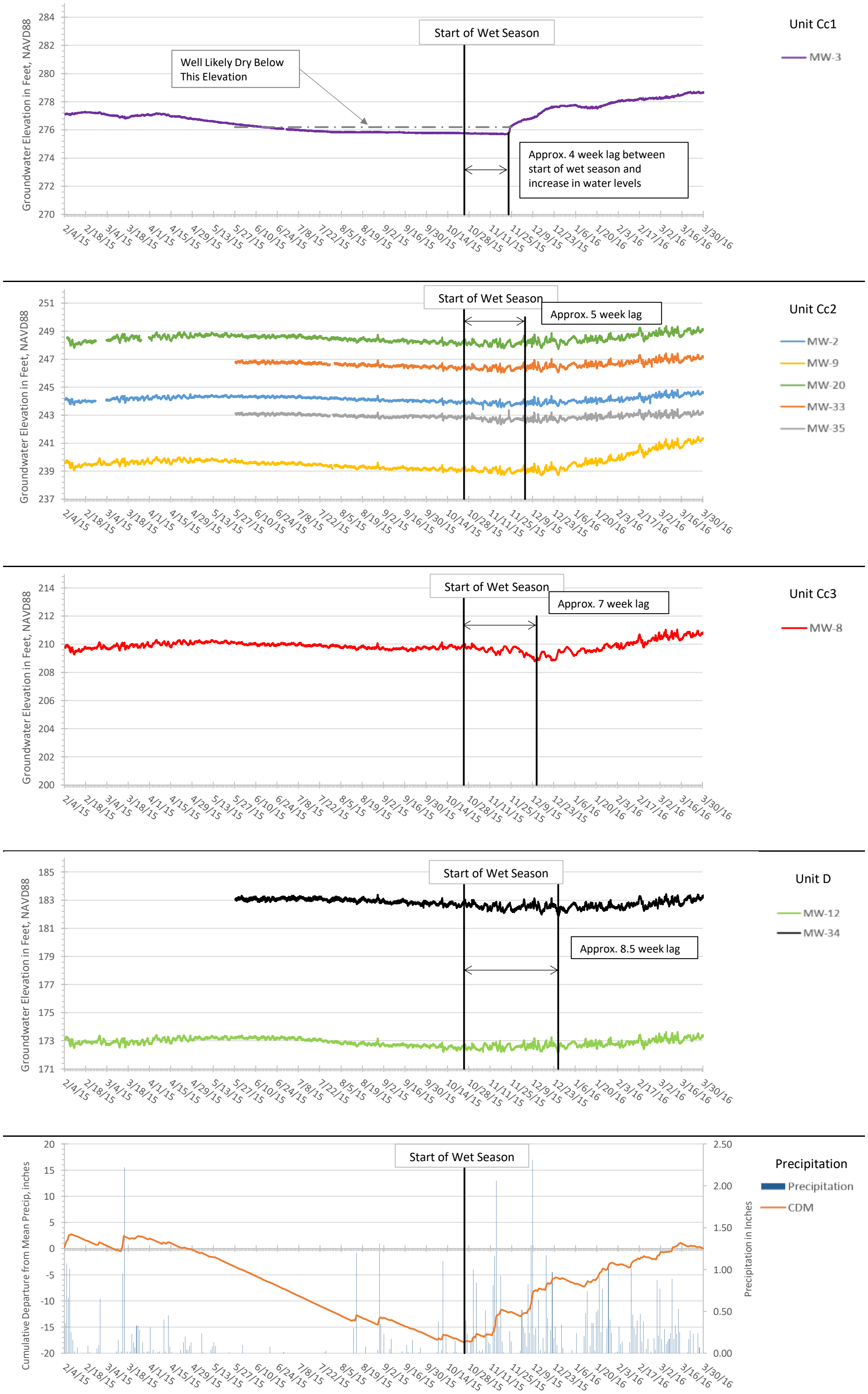
Unit D Aquifer Groundwater Potentiometric Surface Map 1st Quarter 2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | MAR-2020 BY: AO / RAP | FIGURE NO. 3.10

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\3-10 Aquifer D Q1 2019.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-03-10 || User: trullen || Print Date: 2020-03-10

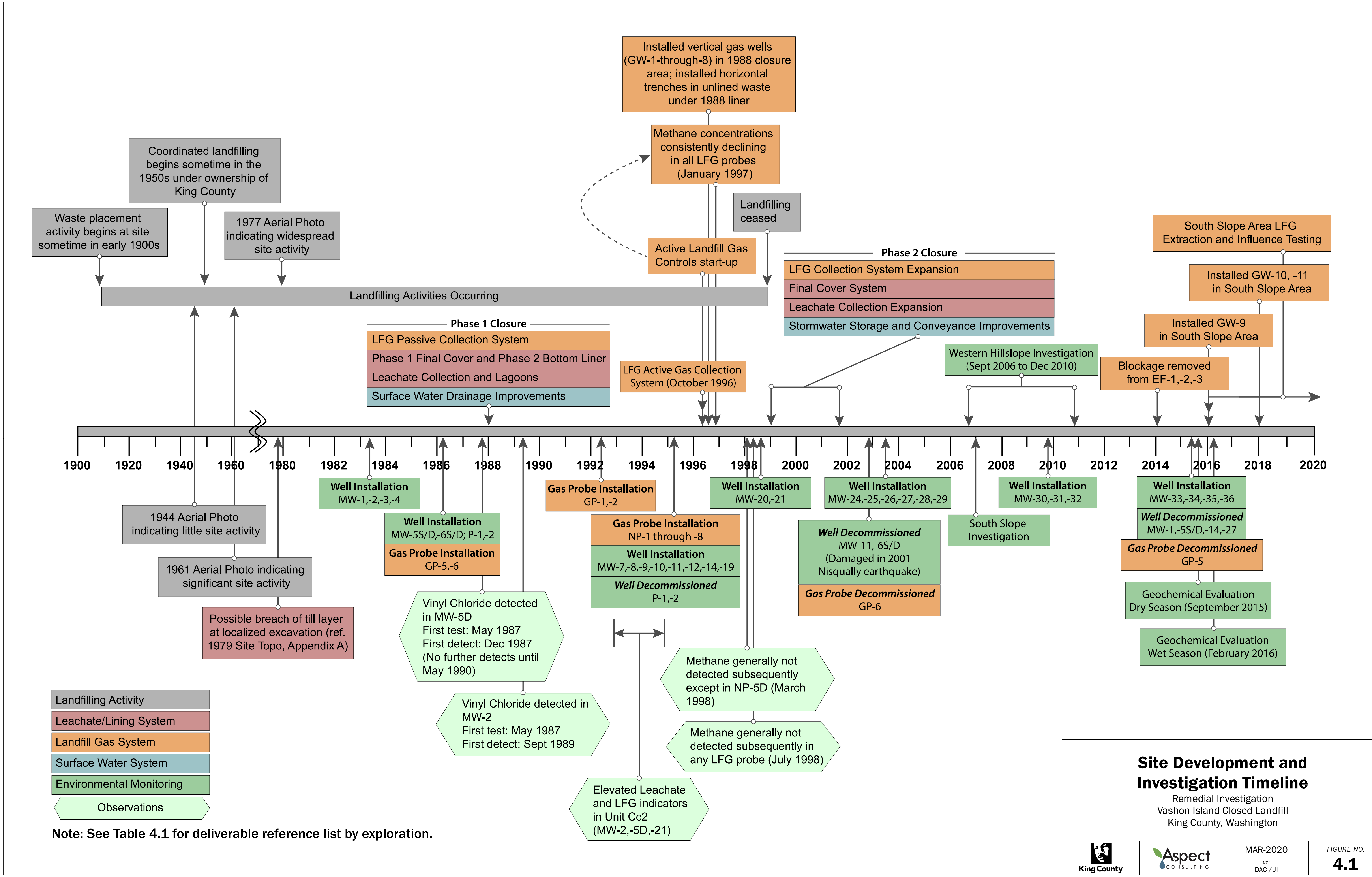

MW-25
158.99
MW-29
169.72
MW-28
Dry
MW-26
149.44
MW-34
182.35
MW-19
159.96
MW-7
MW-12
173.86
160
165
170
175
180
185
Transfer Station Storm Pond
Transfer Station Storm Pond
Transfer Station Storm Pond
Borrow Area Pond
East Pond
Leachate Lagoon
South Siltation Pond
South Detention Pond
Well/Spring Name
Water Table Elevation in ft, NAVD88 (1/22/19)
MW-19
157.74
Monitoring Well
Groundwater Potentiometric Contour (ft, NAVD88)
Inferred Groundwater Flow Direction
Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Pond
Building
Stream
Road
Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel
0
200
400
Feet
N
Unit D Aquifer Groundwater Potentiometric Surface Map
3rd Quarter 2019
Remedial Investigation
Vashon Island Closed Landfill
King County, Washington
King County
Aspect CONSULTING
MAR-2020
BY:
AO / RAP
FIGURE NO.
3.11



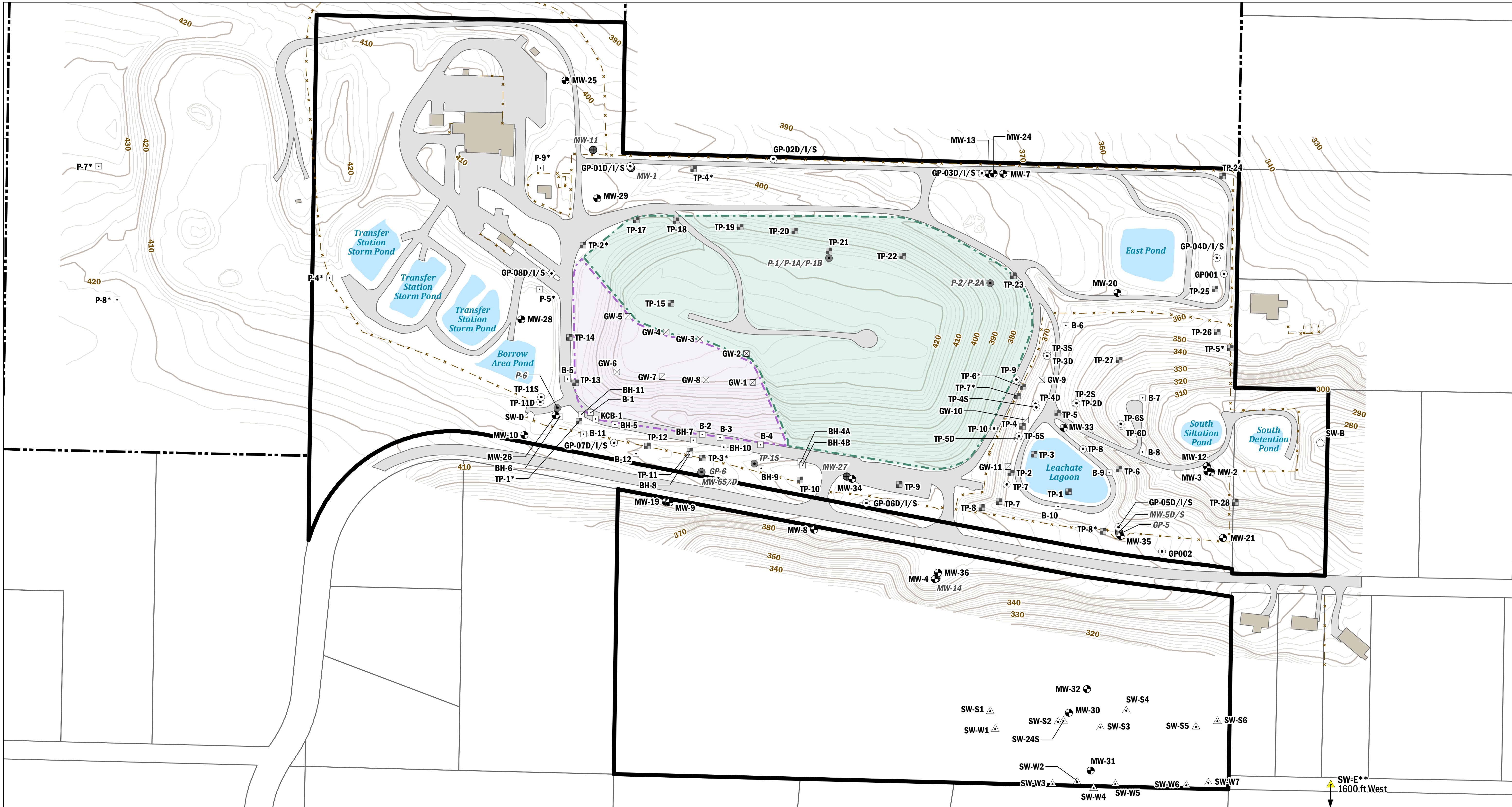
Note: Groundwater elevation values based on pre-2019 survey

Figure 3.12
Groundwater Hydrographs (with Precipitation)
Remedial Investigation

Aspect Consulting
November 2020
V:\090057 ClosedLandfill\Deliverables\Vashon\Task 310\310.3.1 Remedial Investigation\Final\Figures\3.12 Source File - GW Hydrographs_MASTER



Site Development and Investigation Timeline
Remedial Investigation
Vashon Island Closed Landfill
King County, Washington



- Boring
- Gas Probe
- LFG Extraction Well
- Test Pit
- Seep/Weir Sampling Location
- Surface Water Monitoring Station
- Monitoring Well *see Figure 4.3 for well aquifer completion*
- Decommissioned Gas Probe
- Decommissioned Monitoring Well
- Phase 1 - 1988 Final Cover
- Phase 2 - 2001 Final Cover
- Pond
- Building
- Road
- Fence
- Vashon Island Closed Landfill
- Other King County-Owned Property
- King County Tax Parcel

Notes:
Topographic contours from King County Survey, Spring 2017.
** Indicates exploration from Golder, 1986.*
*** See Figure 4.4 for SW-E location.*

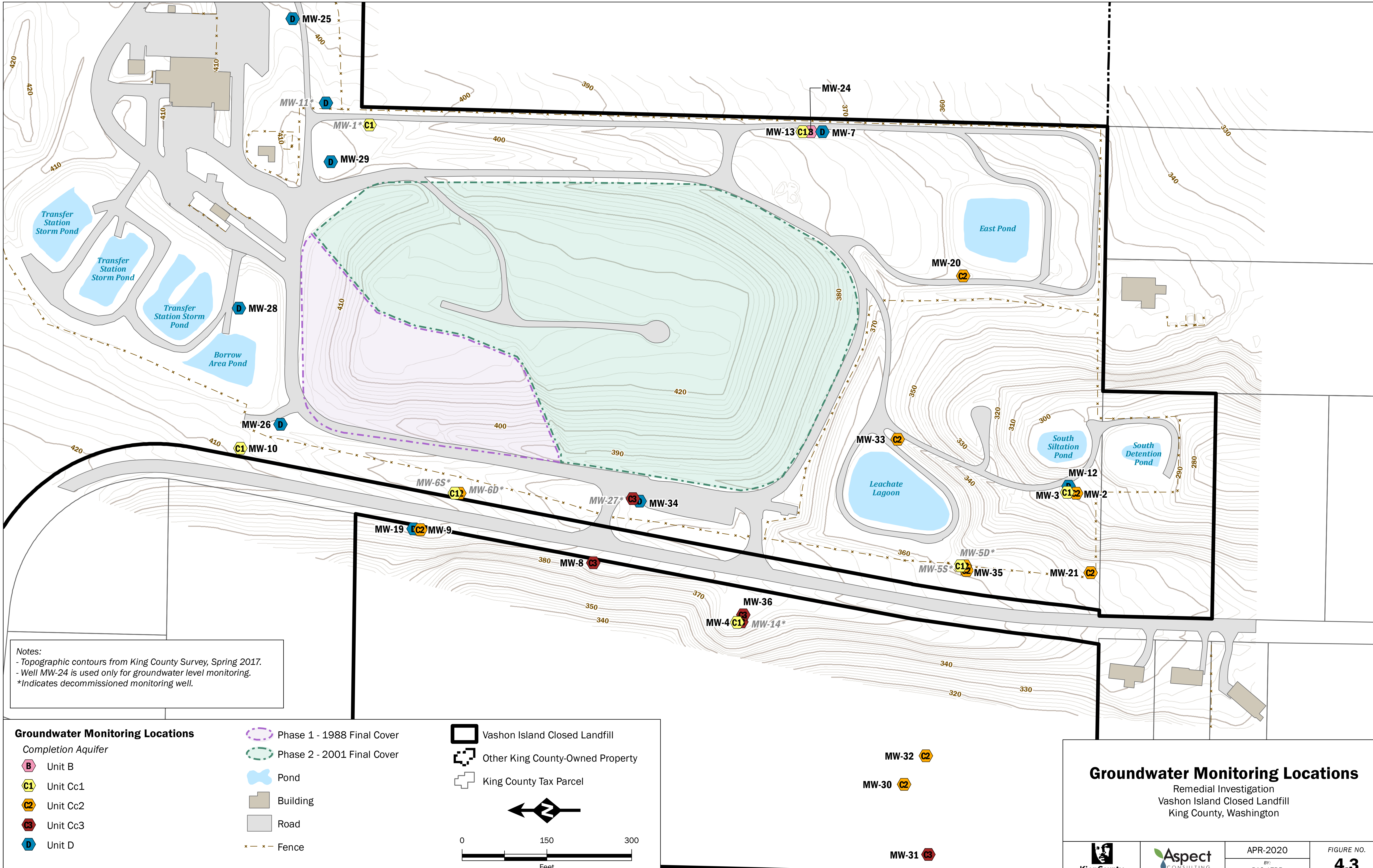
0 200 400
Feet

Exploration Locations

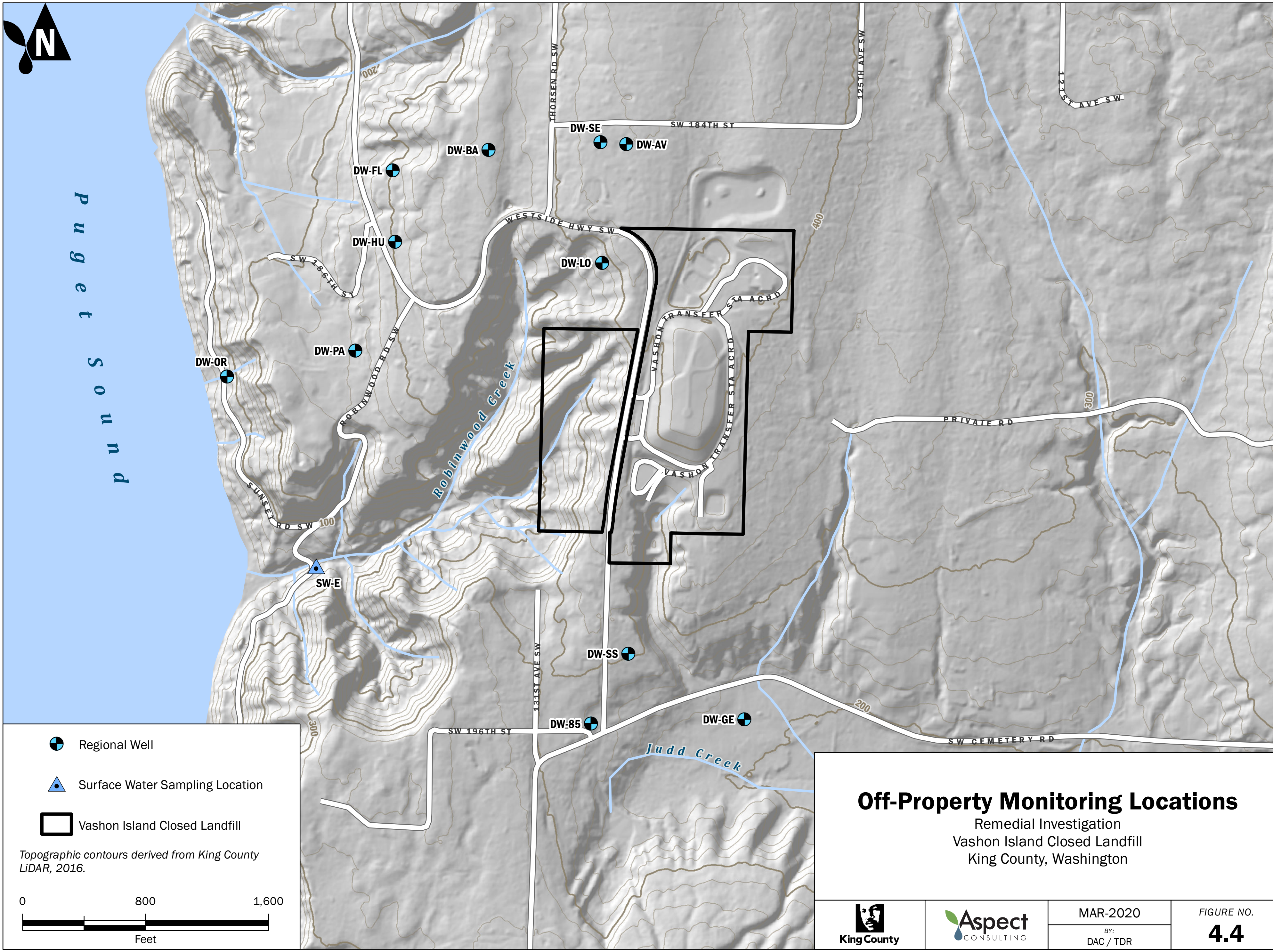
Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | APR-2020 | BY: DAC / TDR | FIGURE NO. 4.2

Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-04-20 || Print Date: 2020-04-20



Groundwater Monitoring Locations
Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

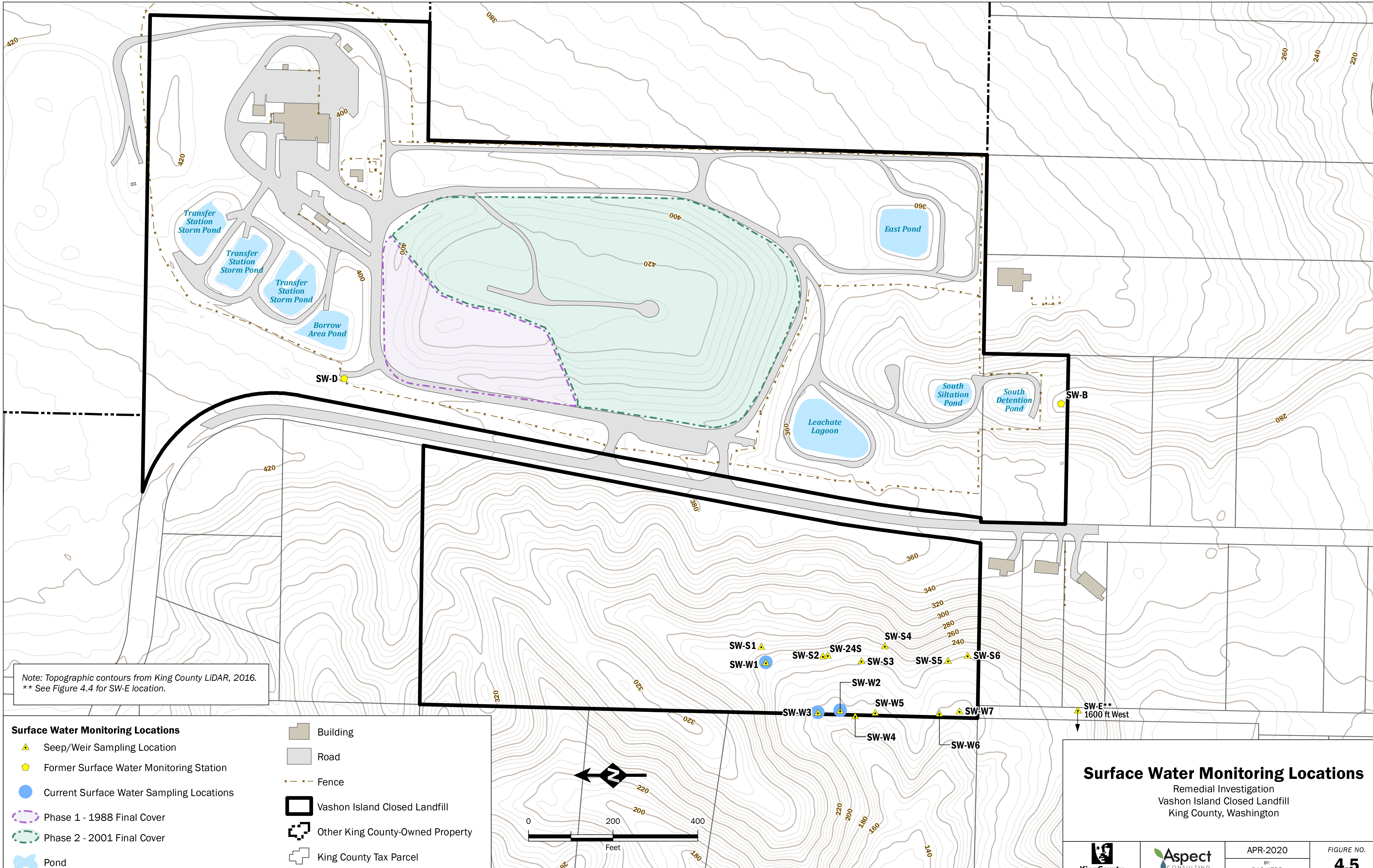


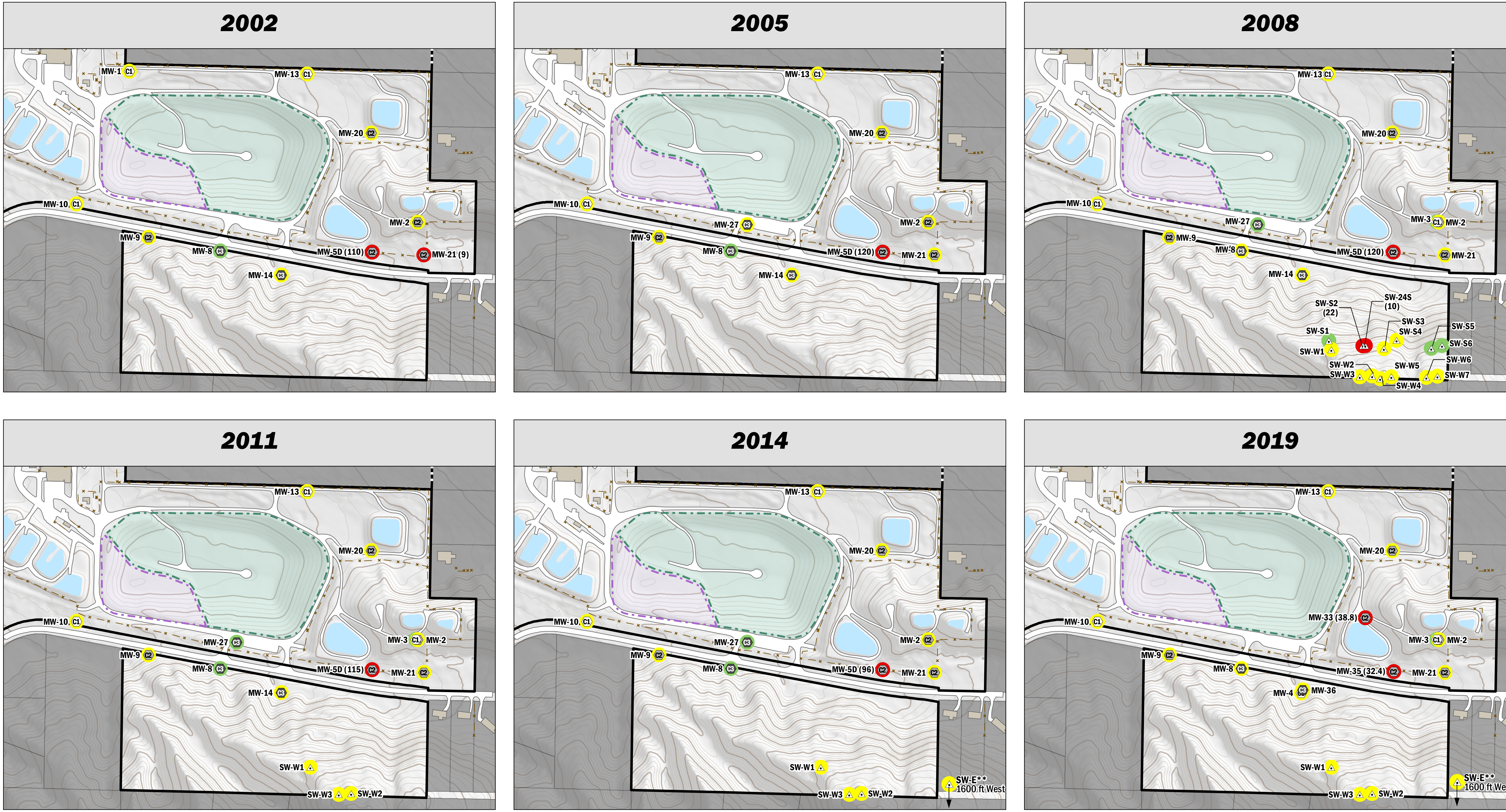
Off-Property Monitoring Locations

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | MAR-2020 BY: DAC / TDR | FIGURE NO. 4.4

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\4-4 Off-Property Monitoring Locations.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-03-10 || User: trulien || Print Date: 2020-03-10


Surface Water Monitoring Locations
Remedial Investigation
Vashon Island Closed Landfill
King County, Washington
APR-2020
BY: DAC / TDR
FIGURE NO. 4.5
King County
Aspect CONSULTING
Note: Topographic contours from King County LiDAR, 2016.
** See Figure 4.4 for SW-E location.
Surface Water Monitoring Locations
Seep/Weir Sampling Location
Former Surface Water Monitoring Station
Current Surface Water Sampling Locations
Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Pond
Building
Road
Fence
Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel
0
200
400
Feet
Transfer Station Storm Pond
Transfer Station Storm Pond
Transfer Station Storm Pond
Borrow Area Pond
East Pond
South Siltation Pond
South Detention Pond
Leachate Lagoon
SW-D
SW-B
SW-S1
SW-W1
SW-S2
SW-24S
SW-S3
SW-S4
SW-S5
SW-S6
SW-W2
SW-W3
SW-W4
SW-W5
SW-W6
SW-W7
SW-E**
1600 ft West



- Monitoring Well (Unit Cc1)
- Monitoring Well (Unit Cc2)
- Monitoring Well (Unit Cc3)
- Seep/Weir Sampling Location
- Analyte Exceeds Screening Level
- Analyte Detected, No Screening Level Exceedance
- Analyte Not Detected
- Fence
- Pond
- Phase 1 - 1988 Final Cover
- Phase 2 - 2001 Final Cover
- Building
- Road
- Vashon Island Closed Landfill
- Other King County-Owned Property
- King County Tax Parcel

Notes:
-Screening Level for Arsenic is 8 μg/L.
-All results posted are in μg/L. Only results which exceed the screening level are displayed.
-MW-14 and MW-27 were decommissioned in 2015.
** See Figure 4.4 for SW-E location
-Topographic contours derived from King County LiDAR, 2016.

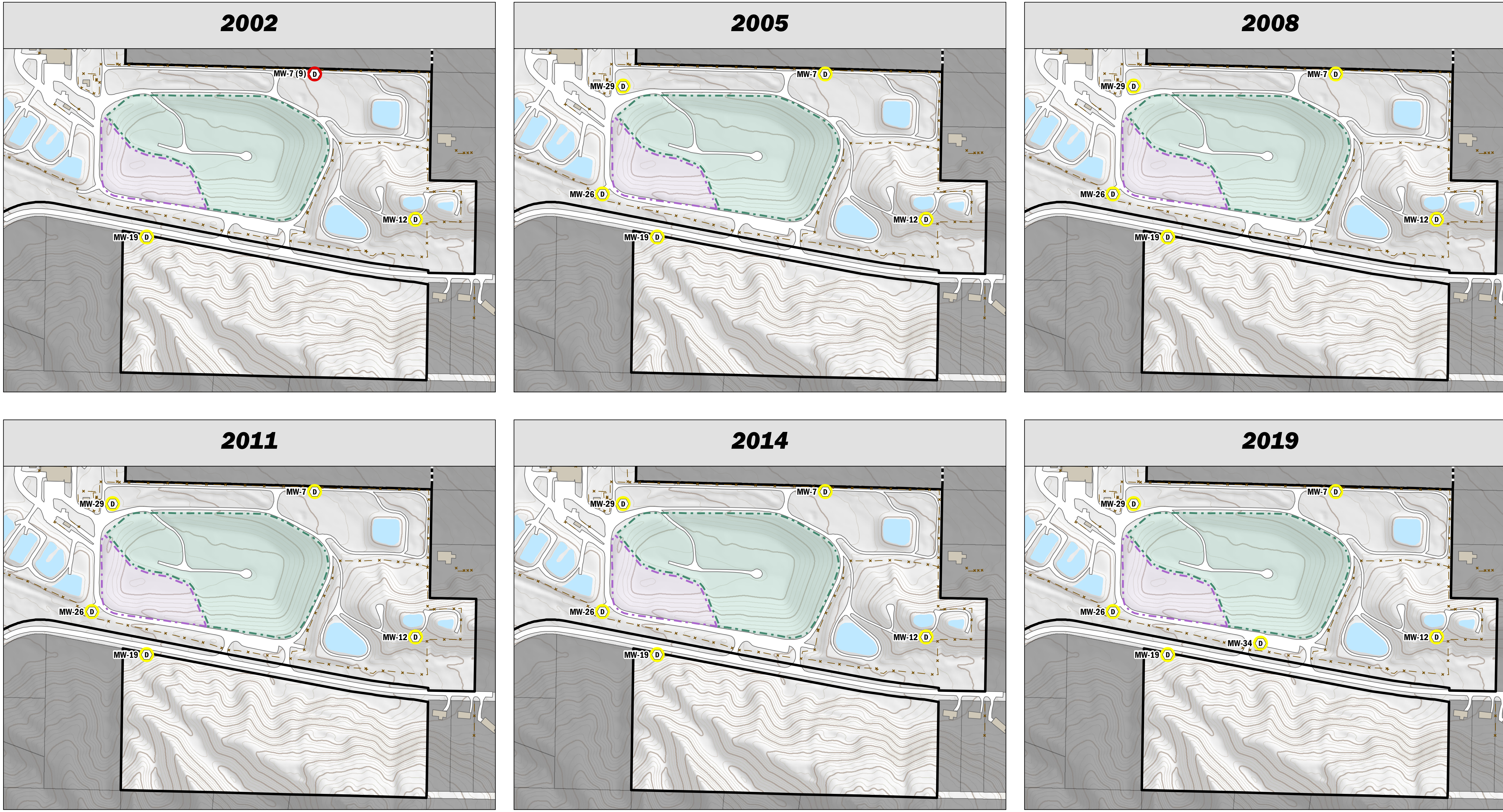
0 400 800
Feet

Extent of Dissolved Arsenic in Unit C Groundwater, 2002-2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect Consulting | MAY-2020 | BY: DAC / TDR | FIGURE NO. 6.1

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\6.1 Extent of Dissolved Arsenic in C Groundwater.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-05-06 || User: truien || Print Date: 2020-05-06



D Monitoring Well (Unit D)
Analyte Exceeds Screening Level
Analyte Detected, No Screening Level Exceedance
Analyte Not Detected

Fence
Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Pond

Building
Road
Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel

Notes:
-Screening Level for Arsenic is 8 µg/L.
-All results posted are in µg/L. Only results which exceed the screening level are displayed.
-Topographic contours derived from King County LiDAR, 2016.

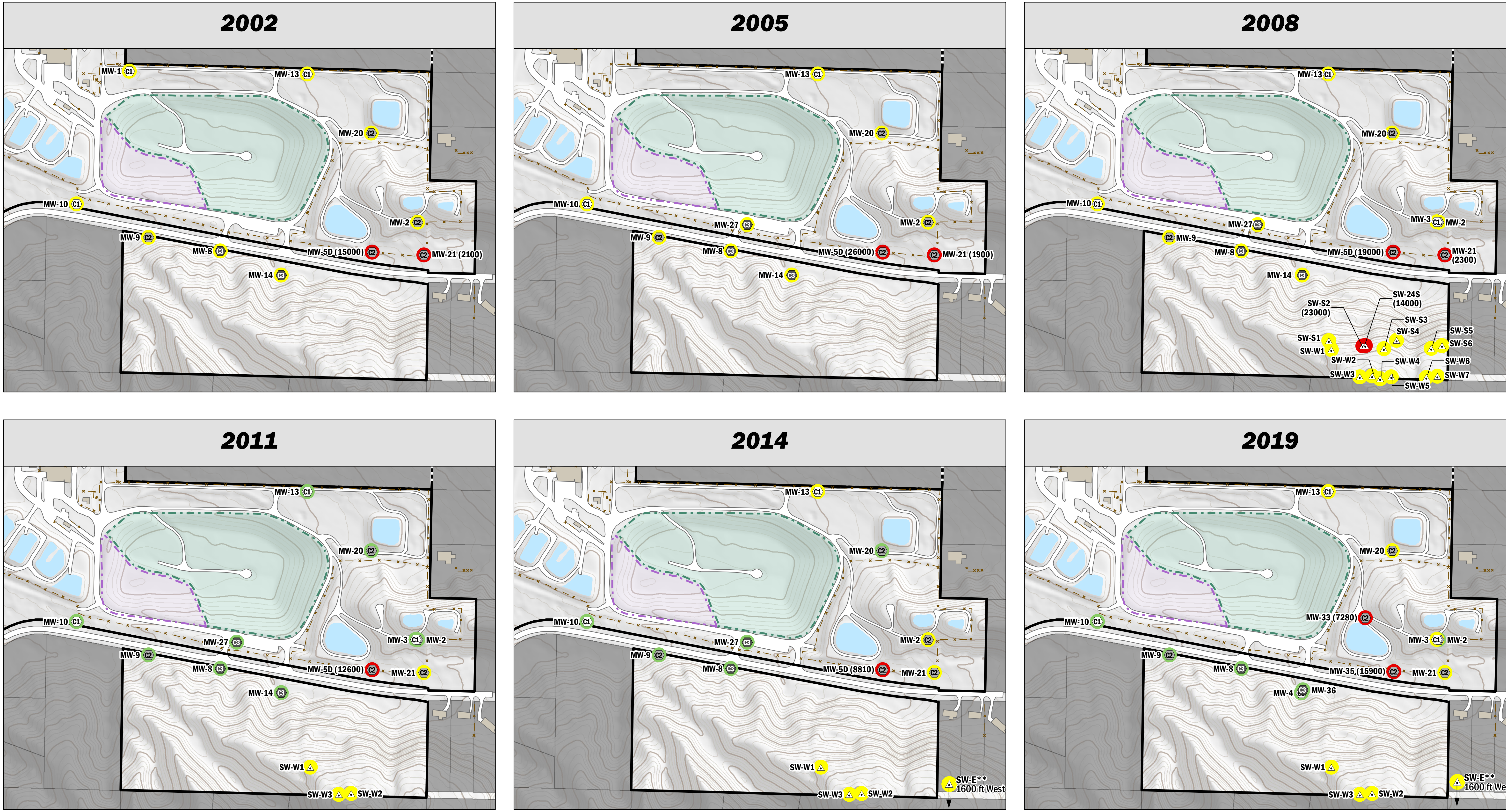
0 400 800
Feet

Extent of Dissolved Arsenic in Unit D Groundwater, 2002-2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | MAR-2020 BY: DAC / TDR | FIGURE NO. 6.2

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\6-2 Extent of Dissolved Arsenic in D Groundwater.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-03-10 || User: trulien || Print Date: 2020-05-06



- C1 Monitoring Well (Unit Cc1)
- C2 Monitoring Well (Unit Cc2)
- C3 Monitoring Well (Unit Cc3)
- Seep/Weir Sampling Location
- Analyte Exceeds Screening Level
- Analyte Detected, No Screening Level Exceedance
- Analyte Not Detected
- Fence
- Pond
- Phase 1 - 1988 Final Cover
- Phase 2 - 2001 Final Cover
- Building
- Road
- Vashon Island Closed Landfill
- Other King County-Owned Property
- King County Tax Parcel

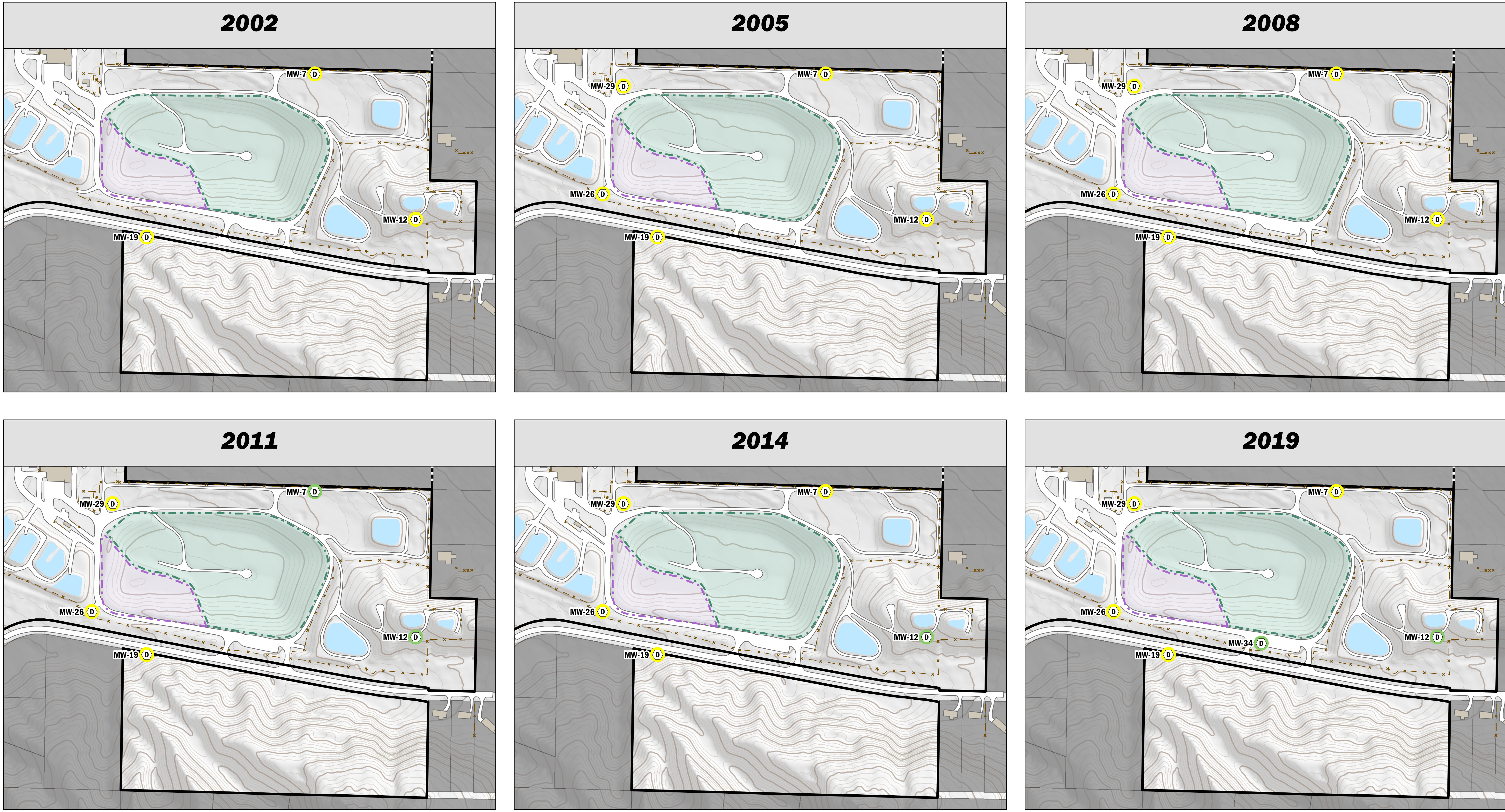
Notes:
-Screening Level for Iron is 1,000 µg/L.
-All results posted are in µg/L. Only results which exceed the screening level are displayed.
-MW-14 and MW-27 were decommissioned in 2015.
*** See Figure 4.4 for SW-E location*
-Topographic contours derived from King County LiDAR, 2016.

0 400 800
Feet

Extent of Dissolved Iron in Unit C Groundwater, 2002-2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect Consulting | MAY-2020 | BY: DAC / TDR | FIGURE NO. 6.3



Monitoring Well (Unit D)
Analyte Exceeds Screening Level
Analyte Detected, No Screening Level Exceedance
Analyte Not Detected

Fence
Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Pond

Building
Road
Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel

Notes:
-Screening Level for Iron is 1,000 µg/L.
-All results posted are in µg/L. Only results which exceed the screening level are displayed.
-Topographic contours derived from King County LiDAR, 2016.
-Only dissolved metals detected above laboratory quantitation levels are reported.

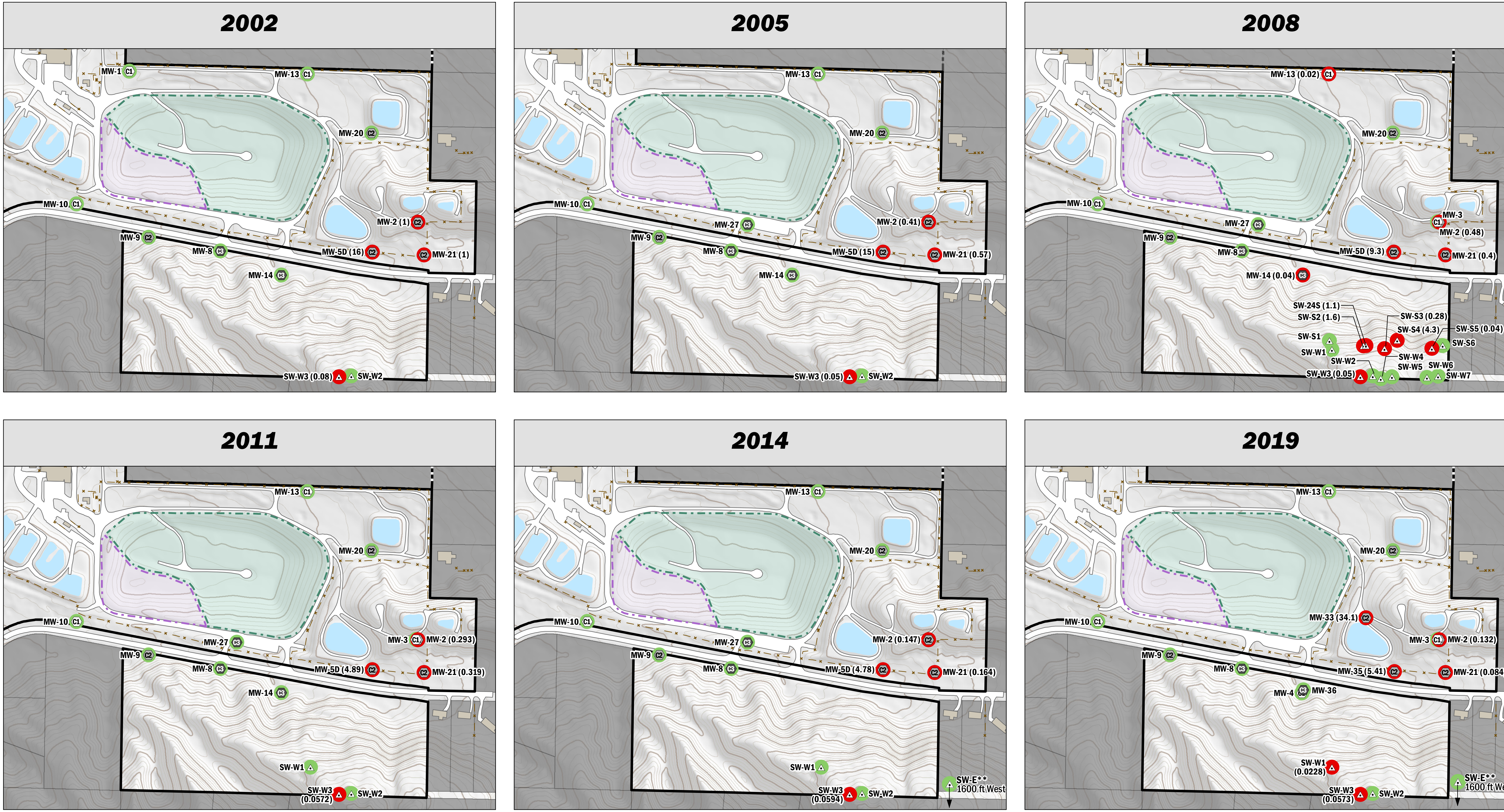
0 400 800
Feet

Extent of Dissolved Iron in Unit D Groundwater, 2002-2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | MAY-2020 BY: DAC / TDR | FIGURE NO. 6.4

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\6.4 Extent of Dissolved Iron in D Groundwater.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-05-06 || User: tkuljen || Print Date: 2020-05-06



C1 Monitoring Well (Unit Cc1)
C2 Monitoring Well (Unit Cc2)
C3 Monitoring Well (Unit Cc3)
Seep/Weir Sampling Location

Analyte Exceeds RDL and Screening Level
Analyte Not Detected above RDL
Fence
Pond

Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Building
Road
Vashon Island Closed Landfill

Other King County-Owned Property
King County Tax Parcel

Notes:
-Screening Level for Vinyl Chloride is 0.02 µg/L.
-All results posted are in µg/L. Only results which exceed the screening level are displayed.
-MW-14 and MW-27 were decommissioned in 2015.
*** See Figure 4.4 for SW-E location*
-Topographic contours derived from King County LiDAR, 2016.
-RDL = Reporting Detection Limit

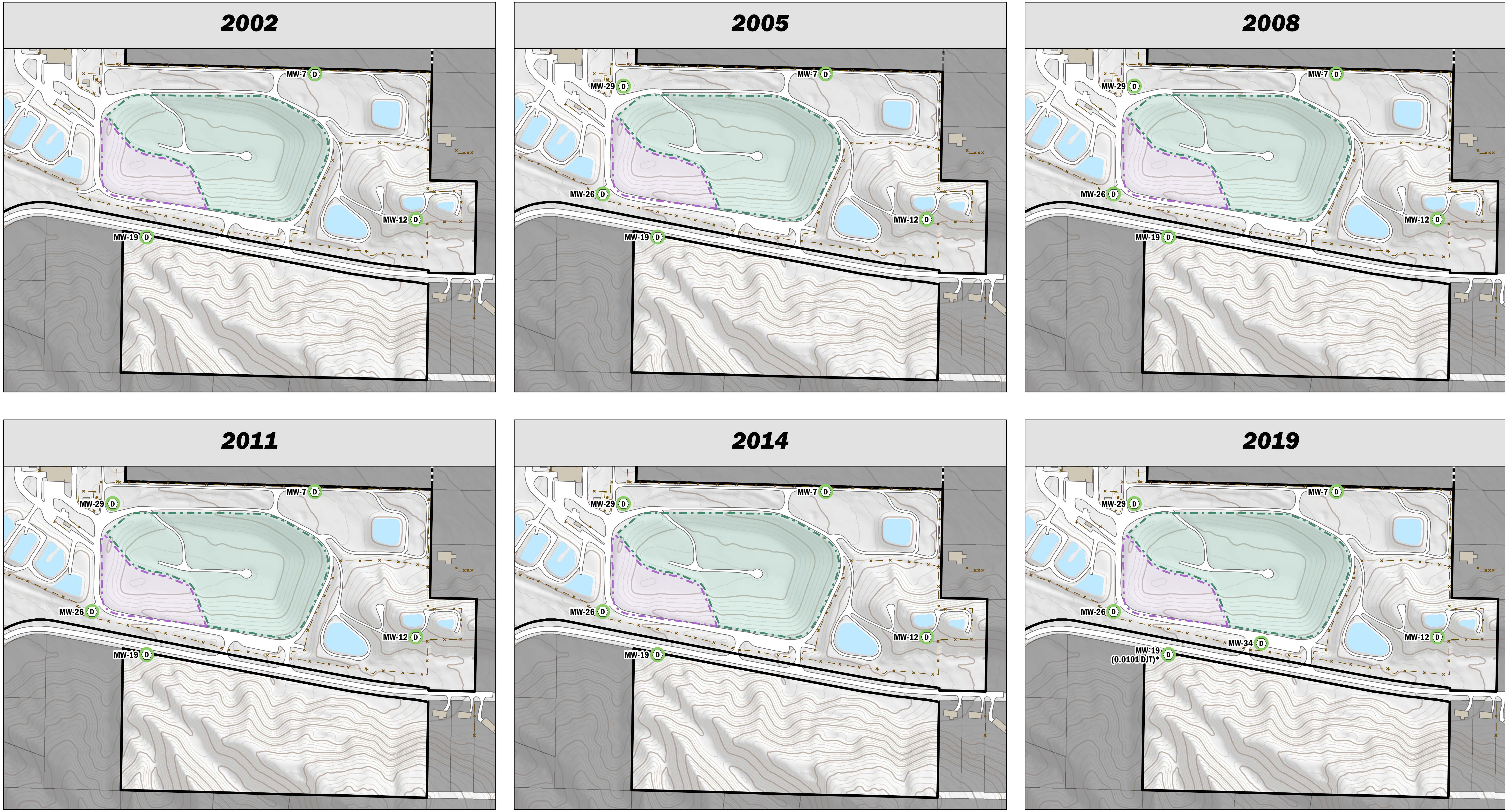
0 400 800
Feet

Extent of Vinyl Chloride in Unit C Groundwater, 2002-2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect Consulting | MAY-2020 | BY: DAC / TDR | FIGURE NO. 6.5

Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet | Date Saved: 2020-05-06 | Print Date: 2020-05-06



Monitoring Well (Unit D)

Analyte Exceeds RDL and Screening Level

Analyte Not Detected above RDL

Fence

Phase 1 - 1988 Final Cover

Phase 2 - 2001 Final Cover

Pond

Building

Road

Vashon Island Closed Landfill

Other King County-Owned Property

King County Tax Parcel

Notes:
-Screening Level for Vinyl Chloride is 0.02 µg/L.
-All results posted are in µg/L. Only results which exceed the screening level are displayed.
-Topographic contours derived from King County LiDAR, 2016.
-RDL = Reporting Detection Limit
*The value measured by the laboratory is less than the RDL.

0 400 800
Feet

Extent of Vinyl Chloride in Unit D Groundwater, 2002-2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County

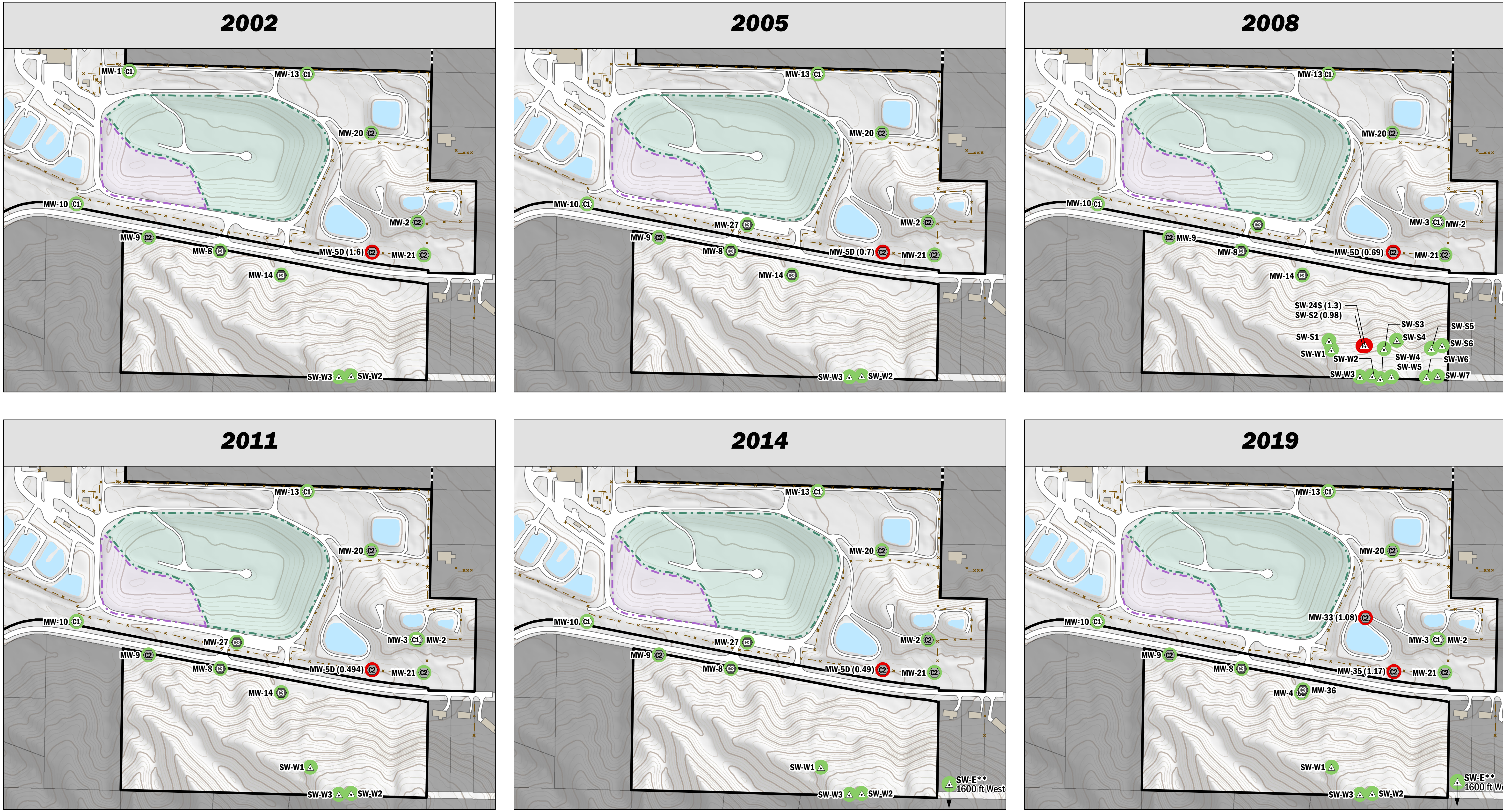
Aspect CONSULTING

MAY-2020

BY:
DAC / TDR

FIGURE NO.
6.6

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\6-6 Extent of Vinyl Chloride in D Groundwater.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-05-06 || User: trulien || Print Date: 2020-05-06



Monitoring Well (Unit Cc1)
Monitoring Well (Unit Cc2)
Monitoring Well (Unit Cc3)
Seep/Weir Sampling Location
Analyte Exceeds Screening Level
Analyte Detected, No Screening Level Exceedance
Analyte Not Detected
Fence
Pond
Phase 1 - 1988 Final Cover
Phase 2 - 2001 Final Cover
Building
Road
Vashon Island Closed Landfill
Other King County-Owned Property
King County Tax Parcel

0 400 800
Feet

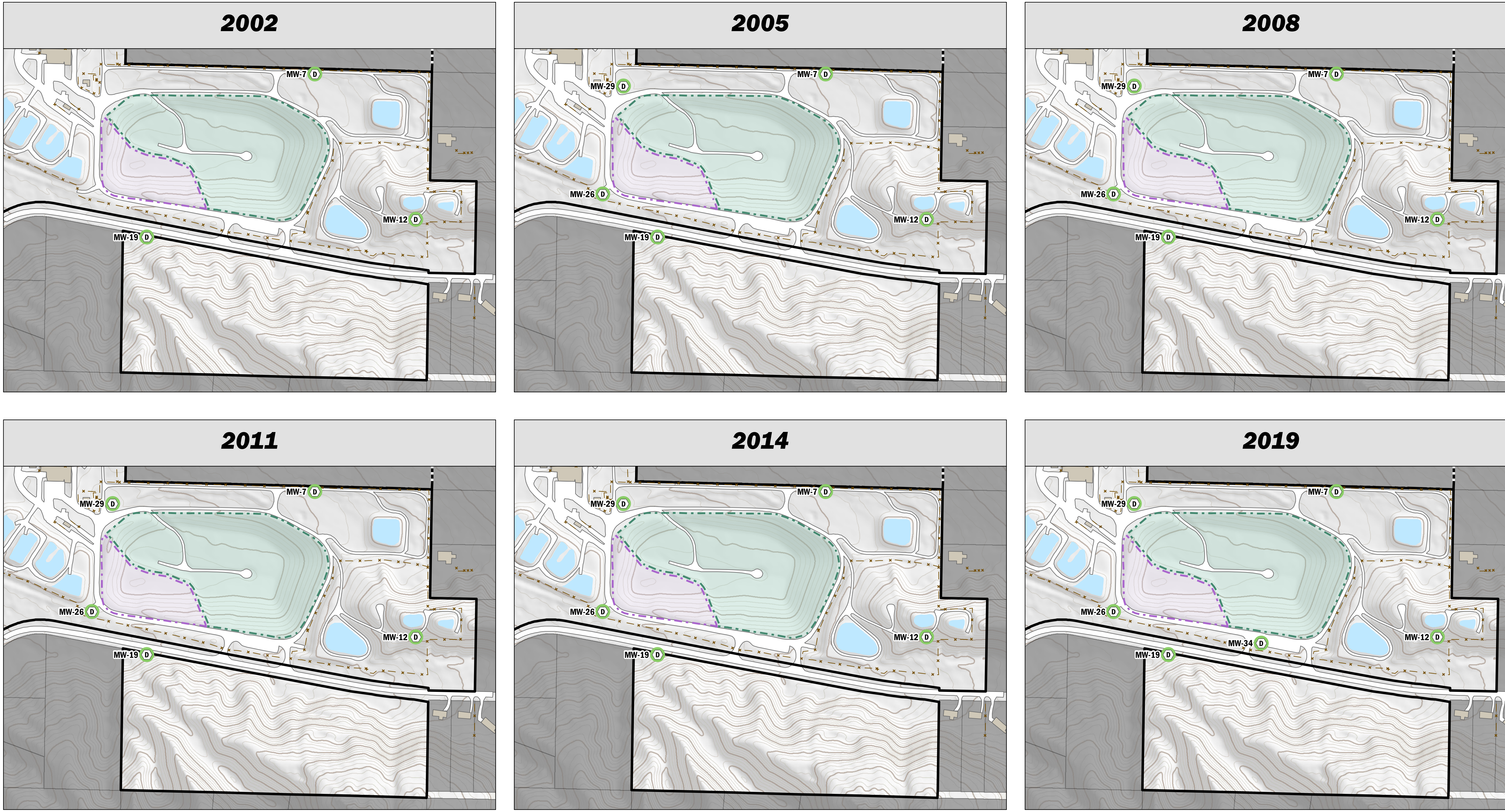
Notes:
-Screening Level for Benzene is 0.44 µg/L.
-All results posted are in µg/L. Only results which exceed the screening level are displayed.
-MW-14 and MW-27 were decommissioned in 2015.
*** See Figure 4.4 for SW-E location*
-Topographic contours derived from King County LiDAR, 2016.

Extent of Benzene in Unit C Groundwater, 2002-2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect Consulting | MAR-2020 | BY: DAC / TDR | FIGURE NO. 6.7

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\6.7 Extent of Benzene in C Groundwater.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-03-10 || User: trullen || Print Date: 2020-05-06



- Monitoring Well (Unit D)
- Analyte Exceeds Screening Level
- Analyte Detected, No Screening Level Exceedance
- Analyte Not Detected
- Fence
- Phase 1 - 1988 Final Cover
- Phase 2 - 2001 Final Cover
- Pond
- Building
- Road
- Vashon Island Closed Landfill
- Other King County-Owned Property
- King County Tax Parcel

Notes:
-Screening Level for Benzene is 0.44 µg/L.
-All results posted are in µg/L. Only results which exceed the screening level are displayed.
-Topographic contours derived from King County LiDAR, 2016.

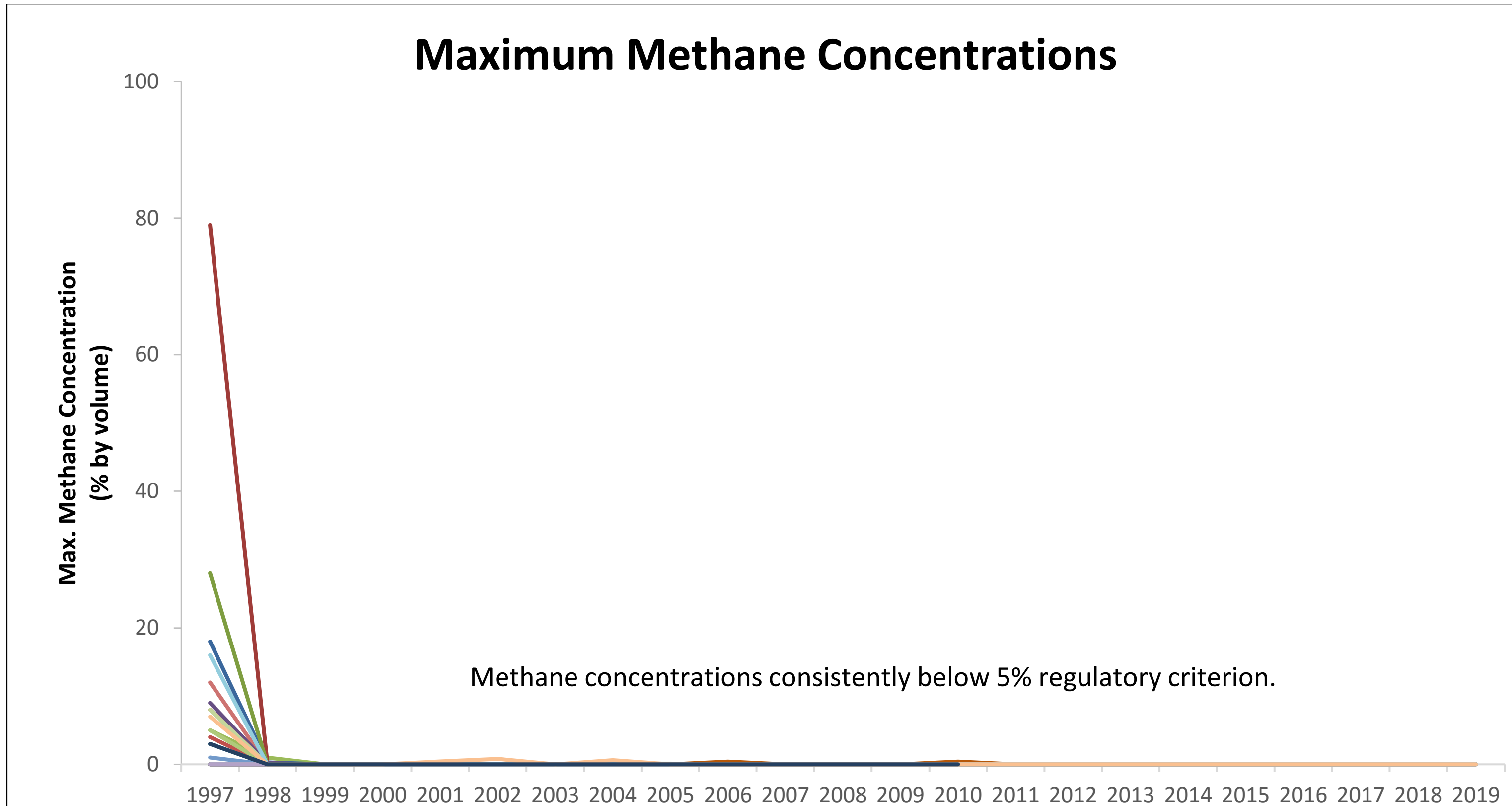
0 400 800
Feet

Extent of Benzene in Unit D Groundwater, 2002-2019

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | MAR-2020 BY: DAC / TDR | FIGURE NO. 6.8

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\6-8 Extent of Benzene in D Groundwater.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-03-10 || User: trulien || Print Date: 2020-05-06



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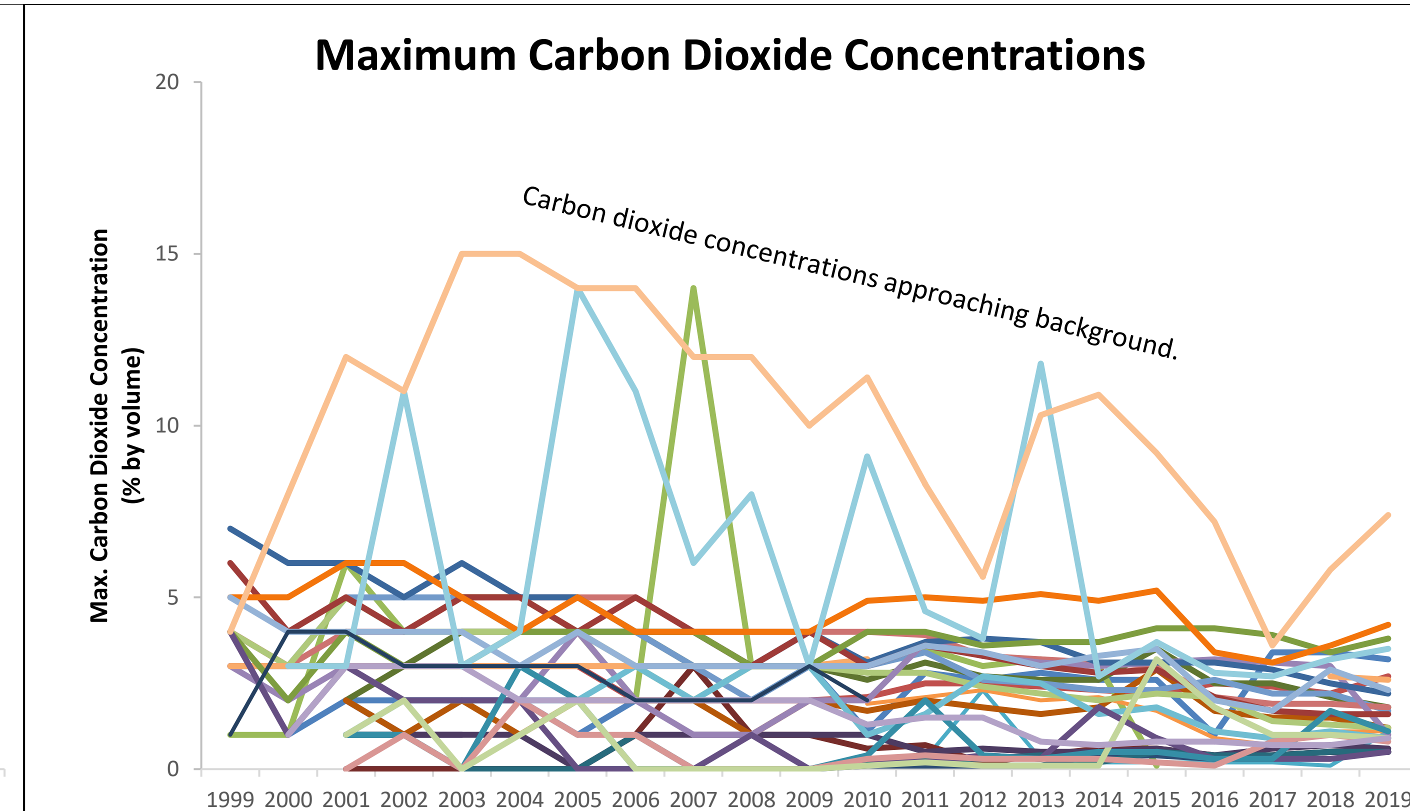
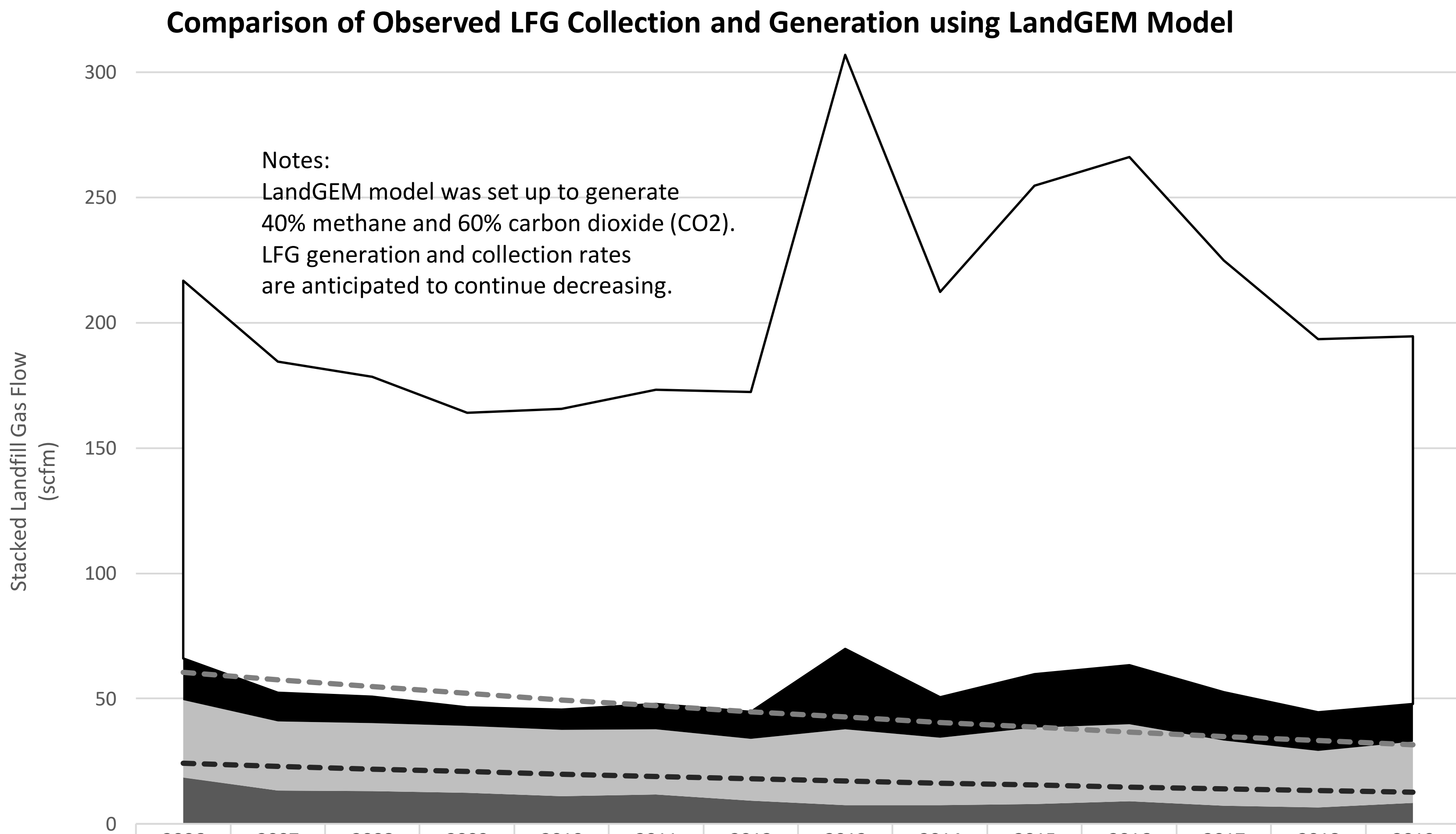
GP001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP002	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-5	5	1	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0				
GP-6	0	0	0	0	0	0	0																
MW-13														0	0	0	0	0	0	0	0	0	0
MW-24														0	0	0	0	0	0	0	0	0	0
GP-01D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-01I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-01S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-02D	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0.4	0	0	0	0	0	0	0	0	0
GP-02I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-02S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-03D	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-03I	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-03S	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-04D	0	0	0	0	0	0	0	0	0	0	0	0	0	0									
GP-04I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-04S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-05D	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-05I	79	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-05S	18	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-06D	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-06I	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-06S	9	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-07D	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-07I	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-07S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-08D	7	0	0	0	0.4	0.8	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-08I	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GP-08S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P-1	3	0	0	0	0	0	0	0	0	0	0	0	0	0									



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
GP001		1	2	2	2	2	1	2	2	2	3	1	3	3	3	3	3	1	3	3	3
GP002	4	3	3	3	3	3	3	2	2	2	2	2	3	3	2	2	2	3	2	2	3
GP-5	1	1	6	4	5	5	4	2	14	3	3	3	4	3	3	3	0				
GP-6			2	1	1																
MW-13												0	0	2	0	0	0	0	0	0	1
MW-24												2	2	2	2	2	2	1	1	1	1
GP-01D	2		2	3	4	4	4	4	3	3	3	3	3	3	3	3	4	3	3	2	2
GP-01I			0	0	0	0	0	1	3	1	1	1	1	0	0	1	1	0	0	1	1
GP-01S			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
GP-02D			2	1	2	1	2	2	2	1	2	2	2	2	2	2	3	2	2	2	1
GP-02I			1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1
GP-02S			1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1
GP-03D	4	3	5	4	4	4	4	3	2	3	3	3	3	2	2	2	2	2	1	1	1
GP-03I	3	3	4	4	5	5	5	5	4	4	4	4	4	3	3	3	3	2	2	2	2
GP-03S	3	3	5	5	5	4	4	4	3	2	3	3	3	3	3	2	2	3	2	2	2
GP-04D	3	3	3	3	3	3	3	3	3	3	3	3									
GP-04I			1	2	2	2	2	3	2	3	3	1	2	3	3	2	2	1	1	1	1
GP-04S	3	2	3	2	2	2	4	2	1	1	2	2	4	3	3	3	3	3	3	3	1
GP-05D	4	2	4	3	3	4	4	4	4	3	3	4	4	4	4	4	4	4	4	3	4
GP-05I	6	4	5	4	5	5	4	5	4	3	4	3	4	3	3	3	3	2	2	2	2
GP-05S	7	6	6	5	6	5	5	4	4	3	4	3	4	4	4	3	3	3	3	3	2
GP-06D	5	5	6	6	5	4	5	4	4	4	4	5	5	5	5	5	5	3	3	4	4
GP-06I			1	1	0	3	2	0	0	0	0	0	2	0	0	1	1	0	0	2	1
GP-06S	4	1	3	2	2	2	0	0	0	1	0	0	0	0	0	2	1	0	0	0	1
GP-07D			1	2	0	1	2	0	0	0	0	0	0	0	0	0	3	2	1	1	1
GP-07I			0	1	0	2	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1
GP-07S	5	4	4	4	4	3	4	3	3	3	3	3	4	3	3	3	4	2	2	3	2
GP-08D	4	8	12	11	15	15	14	14	12	12	10	11	8	6	10	11	9	7	4	6	7
GP-08I		3	3	11	3	4	14	11	6	8	3	9	5	4	12	3	4	3	3	3	4
GP-08S		1	3	3	3	2	2	2	2	2	2	1	2	2	1	1	1	1	1	1	1
P-1	1	4	4	3	3	3	3	2	2	2	3	2									

Aspect Consulting
November 2020
V:\090057 ClosedLandfill\Deliverables\Vashon\Task 310\310.3.1 Remedial Investigation\Final\Figures\Vashon Probes 1997 to 2019_Aspect

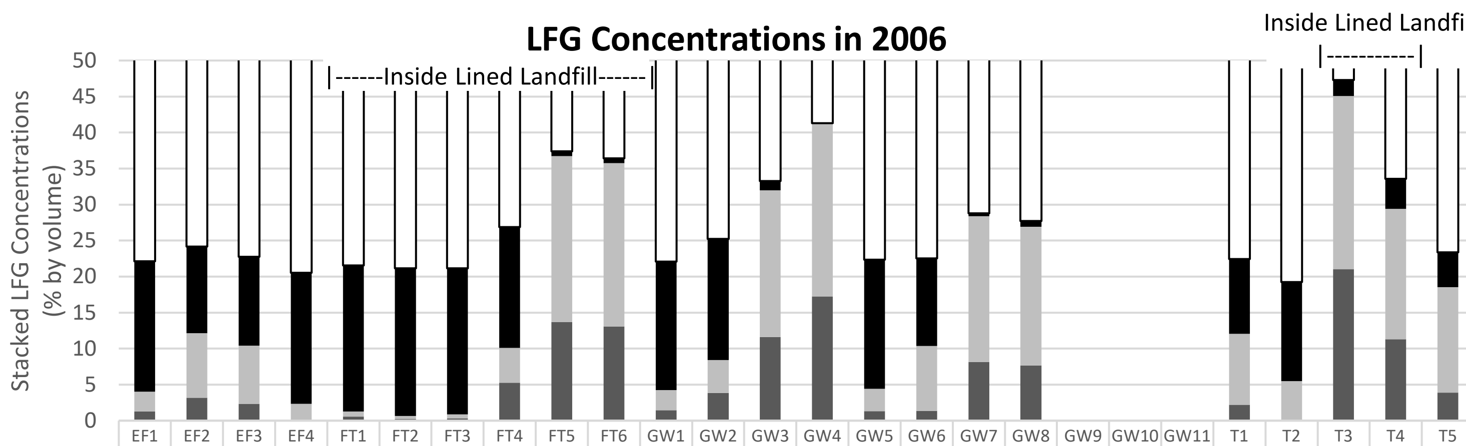
Figure 6.9
Compliance Probe LFG Concentrations Over Time
Vashon Island Closed Landfill Remedial Investigation



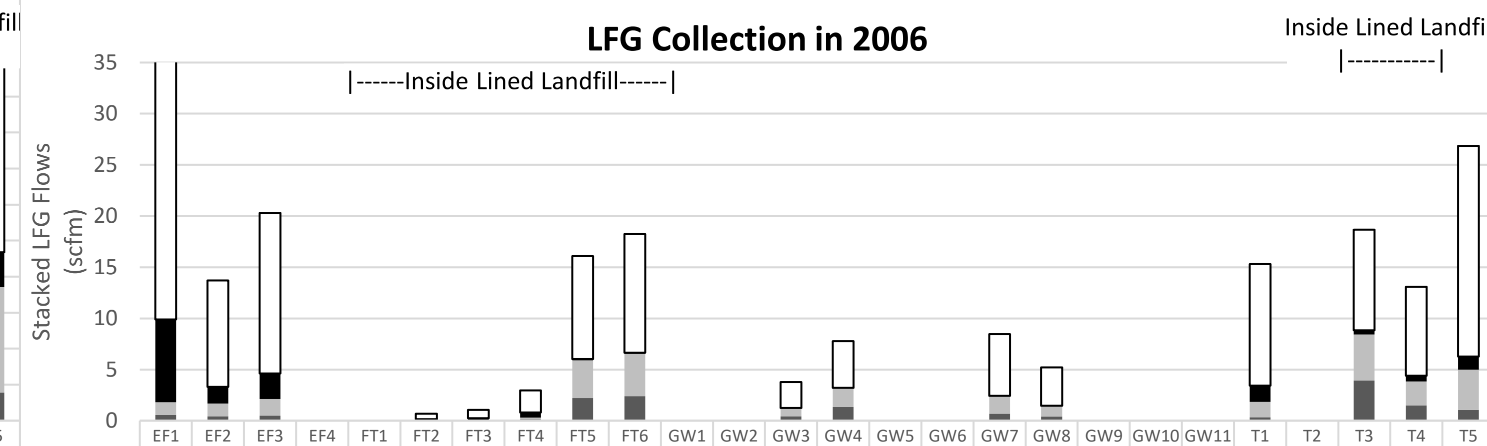
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Balance	151	132	128	118	120	126	128	237	162	195	203	172	149	147
Oxygen	17	11	11	8	8	10	11	32	16	21	24	19	15	15
CO2	31	28	27	27	26	26	25	30	27	30	31	26	23	24
Methane	19	13	13	12	11	12	9	8	7	8	9	7	7	8
LandGEM CO2	36	35	33	31	30	28	27	26	24	23	22	21	20	19
LandGEM CH4	24	23	22	21	20	19	18	17	16	15	15	14	13	13

Aspect Consulting
November 2020
V:\090057 ClosedLandfill\Deliverables\Vashon\Task 310\310.3.1 Remedial Investigation\Final\Figures\GasOperatorFieldReport mar06 to Dec2019_Aspect

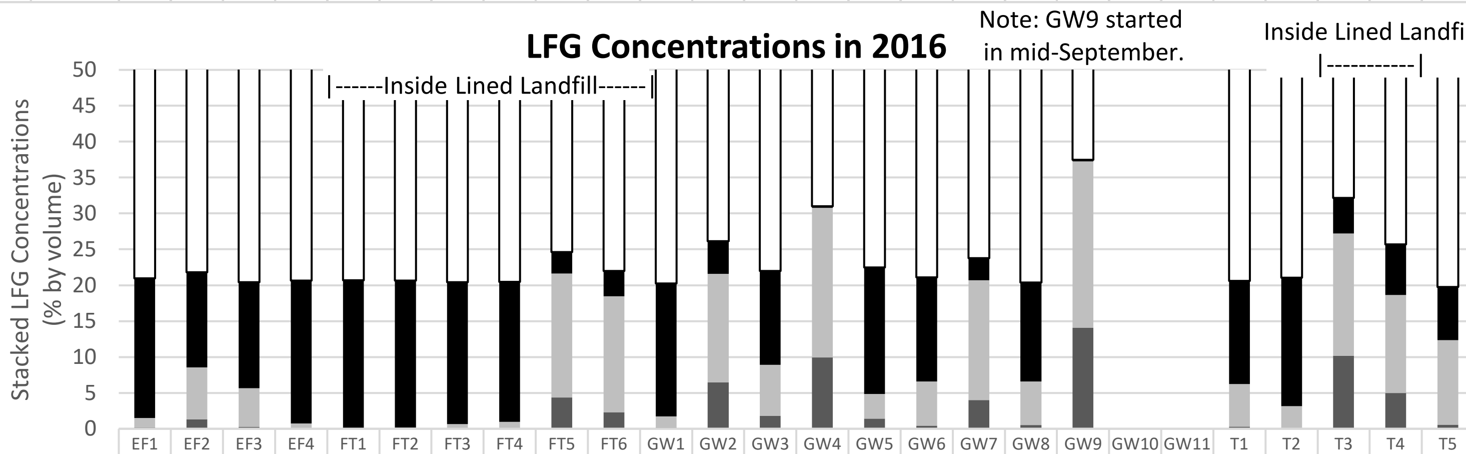
Figure 6.10
Overall LFG Collection Over Time
Vashon Island Landfill Remedial Investigation



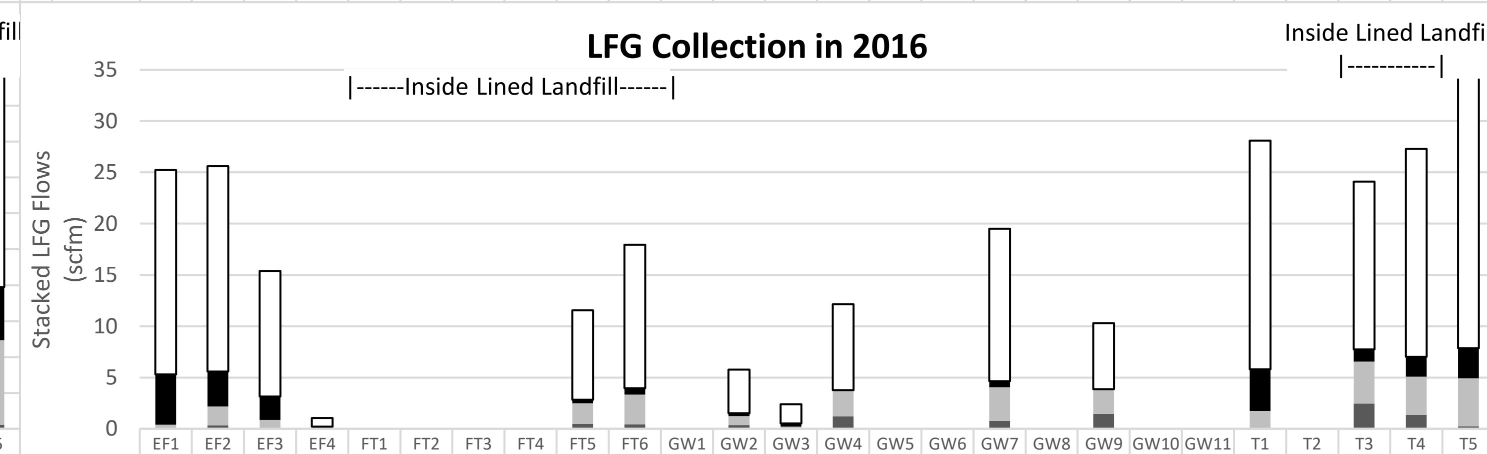
	EF1	EF2	EF3	EF4	FT1	FT2	FT3	FT4	FT5	FT6	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	GW11	T1	T2	T3	T4	T5
Balance	76	74	75	78	76	77	77	71	61	62	76	73	64	57	76	76	69	70				75	78	50	64	73
O2	18	12	12	18	20	20	20	17	1	1	18	17	1	0	18	12	0	1				10	14	2	4	5
CO2	3	9	8	2	1	0	1	5	23	23	3	5	20	24	3	9	20	19				10	5	24	18	15
CH4	1	3	2	0	1	0	0	5	14	13	1	4	12	17	1	1	8	8				2	0	21	11	4



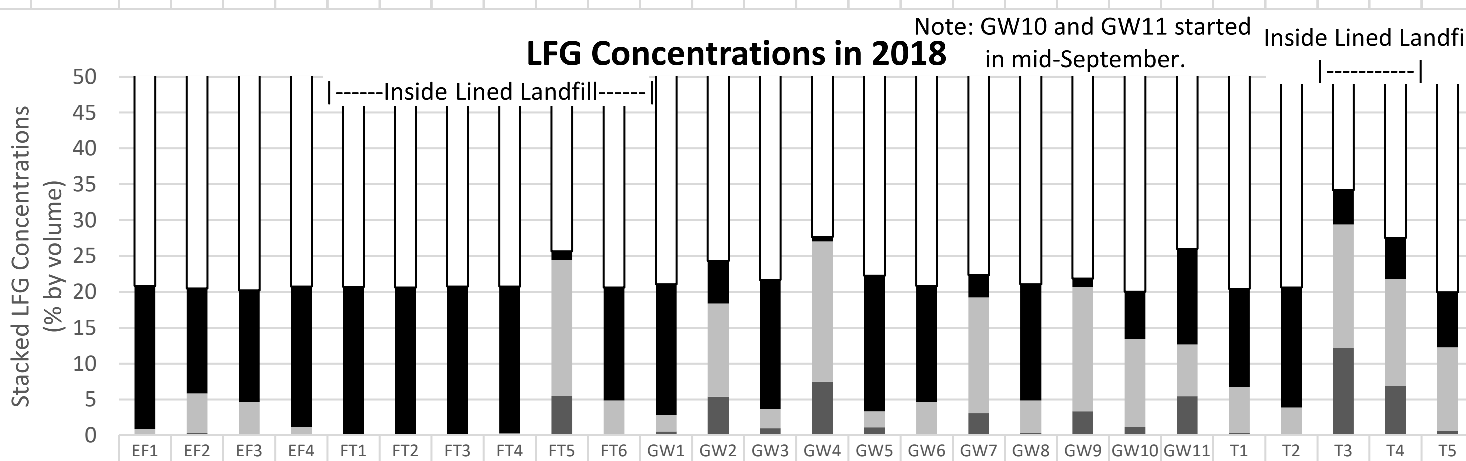
	EF1	EF2	EF3	EF4	FT1	FT2	FT3	FT4	FT5	FT6	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	GW11	T1	T2	T3	T4	T5
Balance	35	10	16	0	0	1	1	2	10	12	0	0	3	5	0	0	6	4				12	0	10	9	21
O2	8.1	1.6	2.5	0.0	0.0	0.1	0.2	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				1.6	0.0	0.4	0.6	1.3
CO2	1.2	1.2	1.6	0.0	0.0	0.0	0.0	0.1	3.7	4.1	0.0	0.0	0.8	1.9	0.0	0.0	1.7	1.0				1.5	0.0	4.5	2.4	3.9
CH4	0.6	0.4	0.5	0.0	0.0	0.0	0.0	0.2	2.2	2.4	0.0	0.0	0.4	1.3	0.0	0.0	0.7	0.4				0.3	0.0	3.9	1.5	1.0



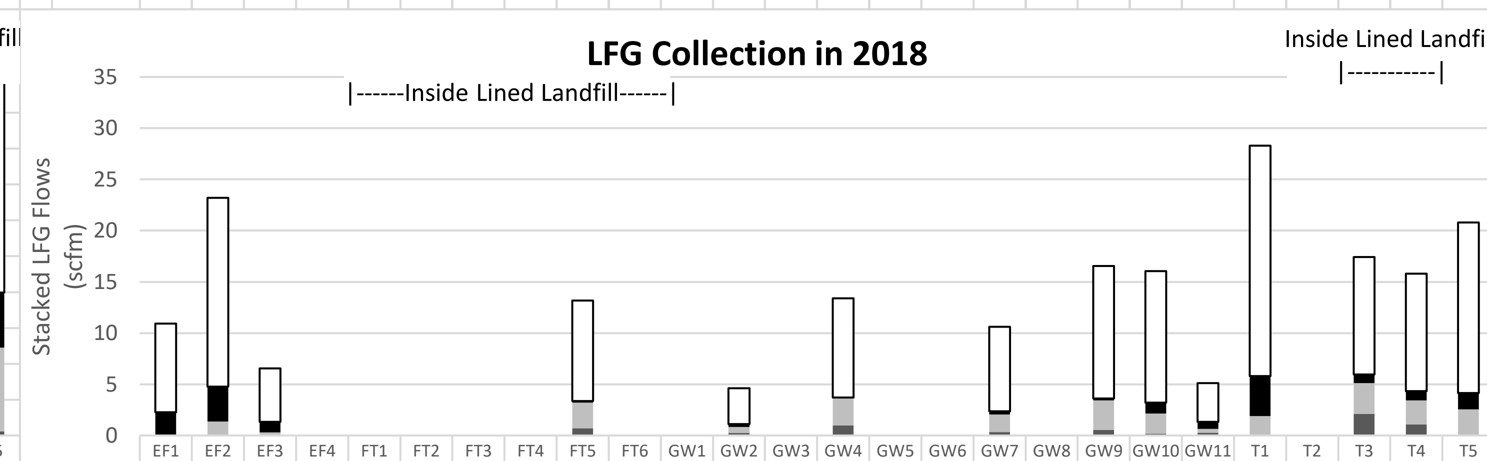
	EF1	EF2	EF3	EF4	FT1	FT2	FT3	FT4	FT5	FT6	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	GW11	T1	T2	T3	T4	T5
Balance	77	76	78	77	77	77	77	77	73	76	78	72	76	66	75	77	72	78	63			77	77	65	72	77
O2	19	13	15	20	21	20	20	20	3	4	19	5	13	0	18	15	3	14	0			14	18	5	7	7
CO2	1	7	5	1	0	0	1	1	17	16	2	15	7	21	3	6	17	6	23			6	3	17	14	12
CH4	0	1	0	0	0	0	0	0	4	2	0	6	2	10	1	0	4	1	14			0	0	10	5	1



	EF1	EF2	EF3	EF4	FT1	FT2	FT3	FT4	FT5	FT6	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	GW11	T1	T2	T3	T4	T5
Balance	20	20	12	1	0	0	0	0	9	14	0	4	2	8	0	0	15	0	6			22	0	16	20	32
O2	4.9	3.4	2.3	0.2	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.3	0.3	0.0	0.0	0.0	0.6	0.0	0.0			4.0	0.0	1.2	1.9	2.9
CO2	0.3	1.8	0.8	0.0	0.0	0.0	0.0	0.0	2.0	2.9	0.0	0.9	0.2	2.5	0.0	0.0	3.3	0.0	2.4			1.7	0.0	4.1	3.7	4.7
CH4	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0	0.4	0.0	1.2	0.0	0.0	0.8	0.0	1.5			0.1	0.0	2.4	1.4	0.2

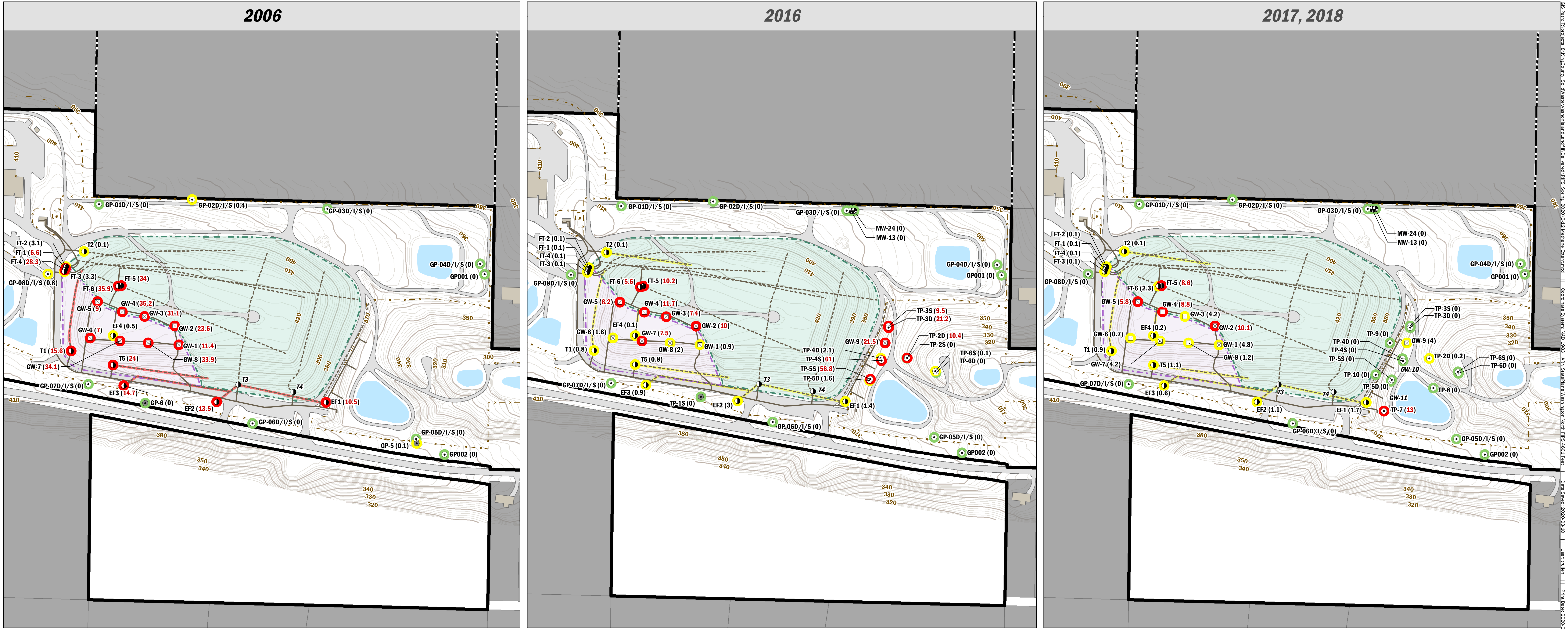


	EF1	EF2	EF3	EF4	FT1	FT2	FT3	FT4	FT5	FT6	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	GW11	T1	T2	T3	T4	T5
Balance	77	77	78	77	77	77	77	77	72	77	77	73	76	70	76	77	73	77	78	80	74	77	77	63	70	77
O2	20	15	15	20	21	20	21	20	1	16	18	6	18	1	19	16	3	16	1	7	13	14	17	5	6	8
CO2	1	6	5	1	0	0	0	0	19	5	2	13	3	20	2	4	16	5	17	12	7	6	4	17	15	12
CH4	0	0	0	0	0	0	0	0	5	0	1	5	1	7	1	0	3	0	3	1	5	0	0	12	7	1



	EF1	EF2	EF3	EF4	FT1	FT2	FT3	FT4	FT5	FT6	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8	GW9	GW10	GW11	T1	T2	T3	T4	T5
Balance	9	18	5	0	0	0	0	0	10	0	0	3	0	10	0	0	8	0	13	13	4	23	0	11	11	17
O2	2.2	3.4	1.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.3	0.0	0.2	1.1	0.7	3.9	0.0	0.8	0.9	1.6
CO2	0.1	1.3	0.3	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.6	0.0	2.6	0.0	0.0	1.7	0.0	2.9	2.0	0.4	1.8	0.0	3.0	2.4	2.4
CH4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.2	0.0	1.0	0.0	0.0	0.3	0.0	0.6	0.2	0.3	0.1	0.0	2.1	1.1	0.1

Figure 6.11
LFG Concentrations and Collection at Individual Points
Vashon Island Closed Landfill Remedial Investigation



Maximum Methane Detected

- > 5 % by volume
- > 0 - 5 % by volume
- 0 % by volume

VTP-5D (1.6) Exploration Name (Methane Concentration, %)
*Methane concentration in **red, bold** font where concentration exceeds 5%*

- Boring
- Gas Probe
- LFG Extraction Well
- LFG Trench Riser
- Monitoring Well
- Decommissioned Monitoring Well
- LFG Pipe
- LFG Pipe (Perforated)
- Phase 1 - 1988 Final Cover
- Phase 2 - 2001 Final Cover
- Pond
- Building
- Road
- Fence
- Vashon Island Closed Landfill
- Other King County-Owned Property
- King County Tax Parcel

Note: Exploration locations without a colored halo have no results for a particular time period if a location was not yet installed, has been decommissioned, or location was not monitored. Topographic contours from King County Survey, Spring 2017. Landfill gas system features are approximated from as-built locations, and revised to match survey data where available.

0 240 480
Feet

Methane Extent
Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | MAR-2020 BY: PSB / RAP | FIGURE NO. **6.12**

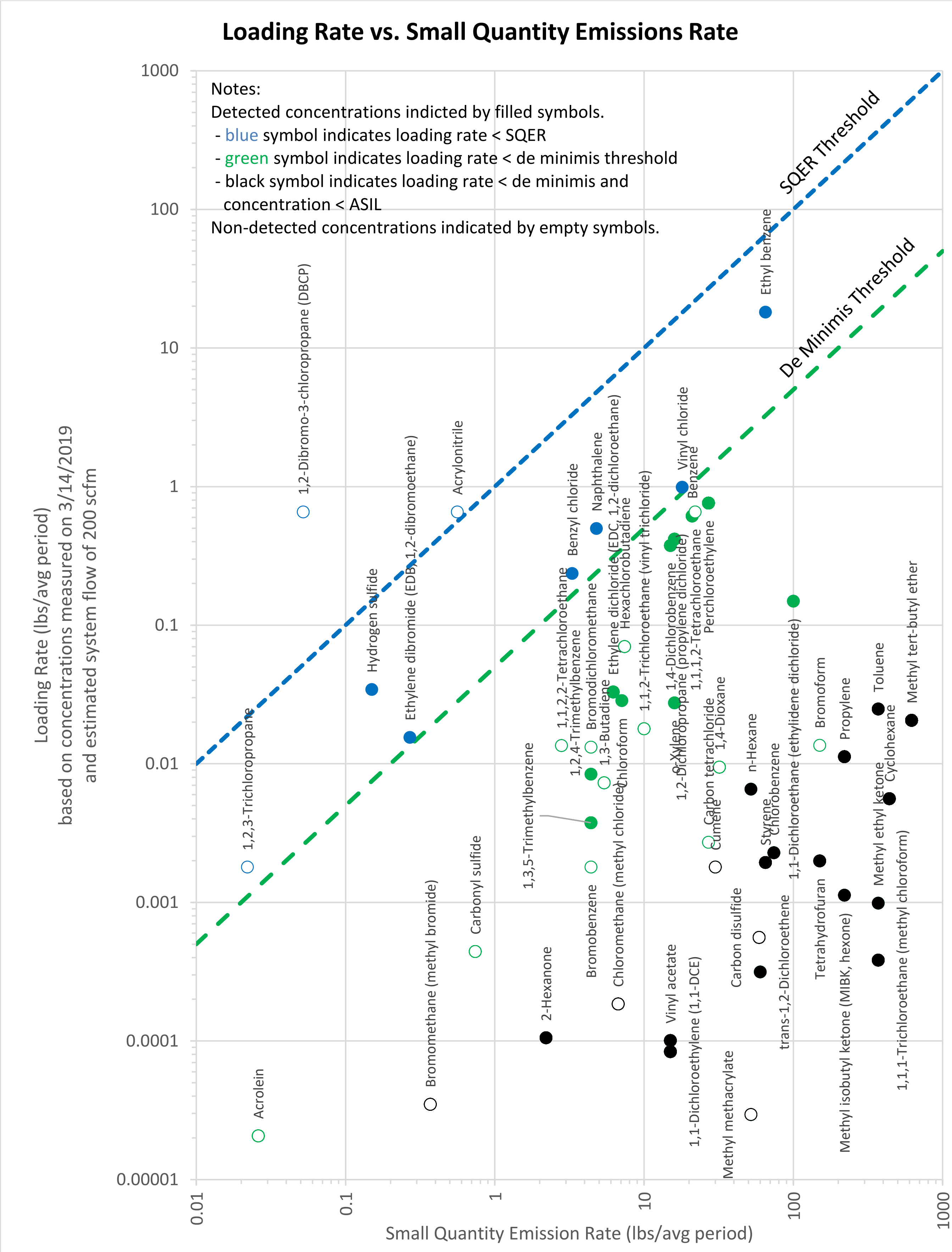


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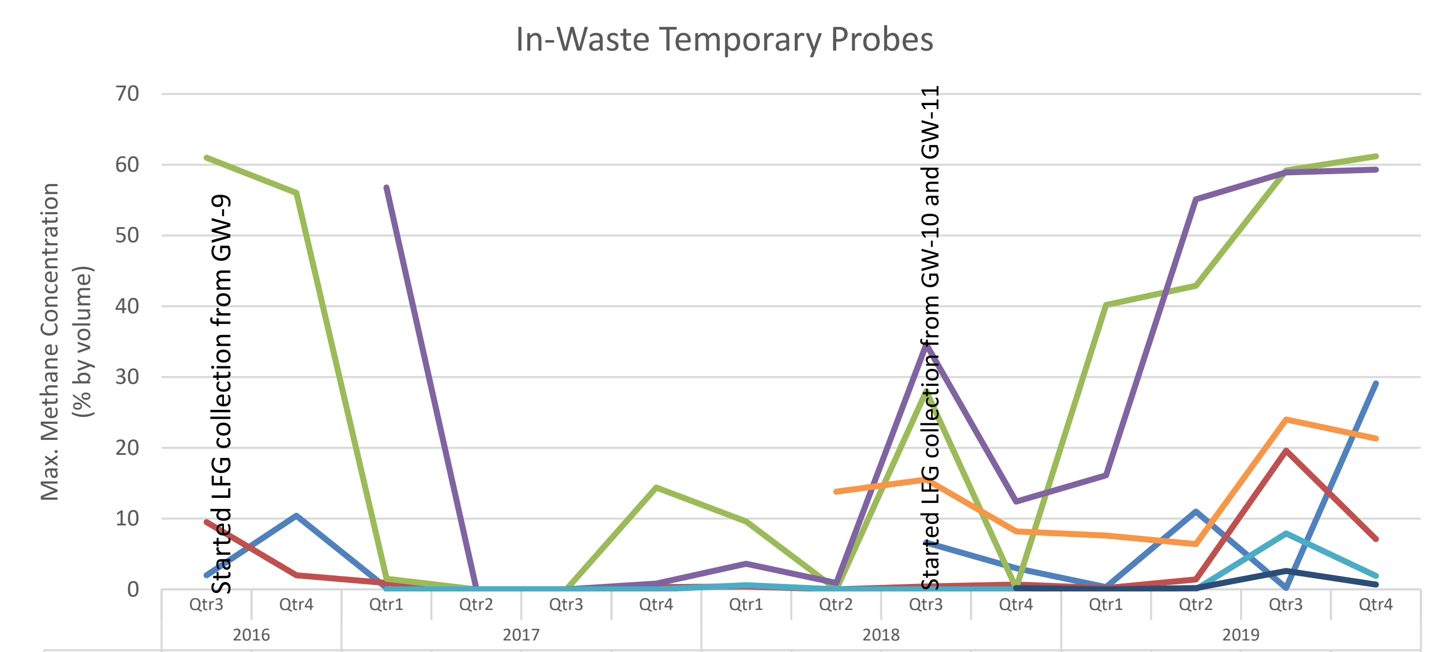
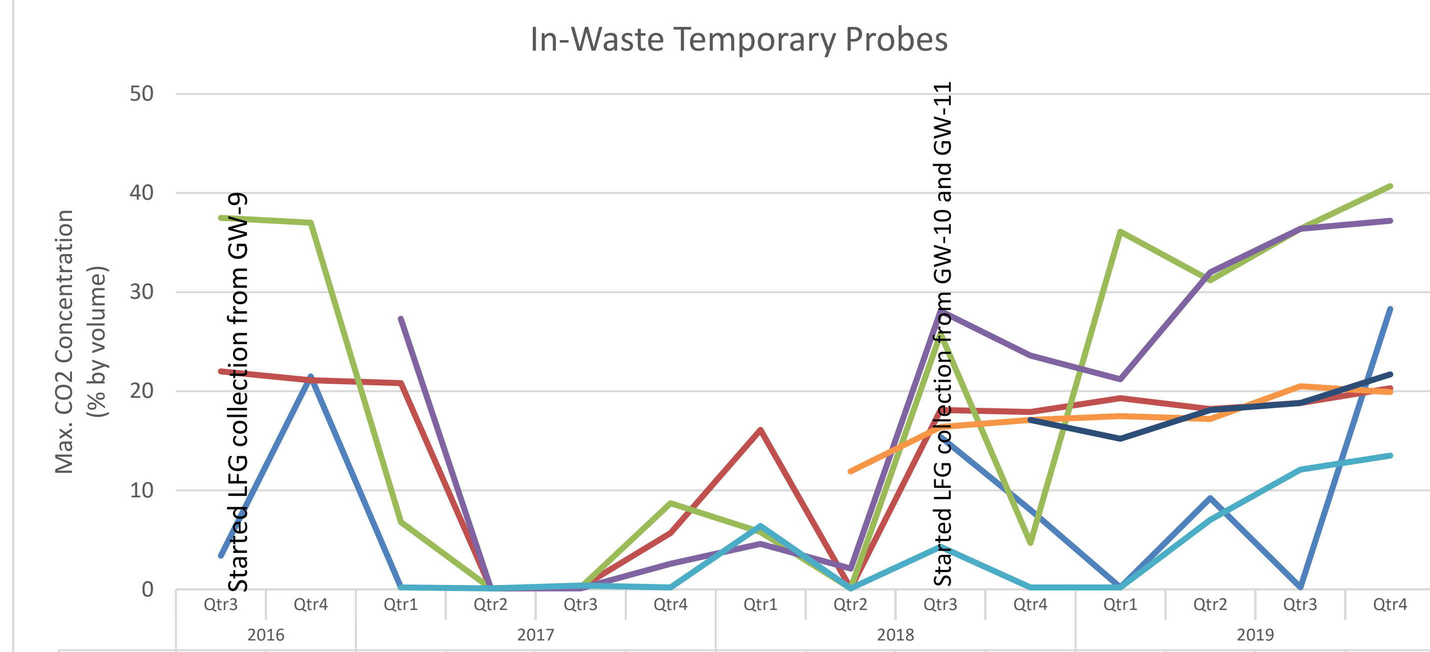
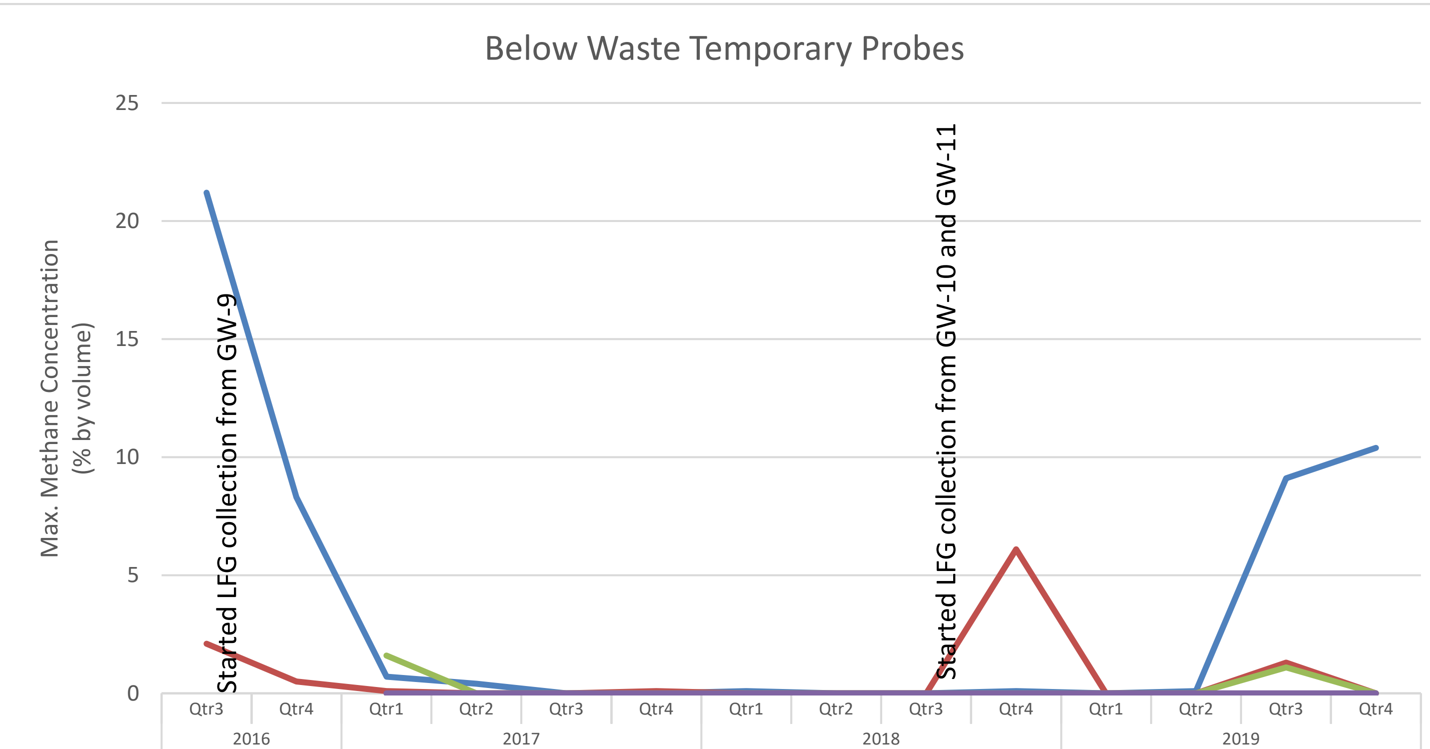
Figure 6.13
Analysis of Observed VOCs in Landfill Gas
Vashon Island Closed Landfill Remedial Investigation



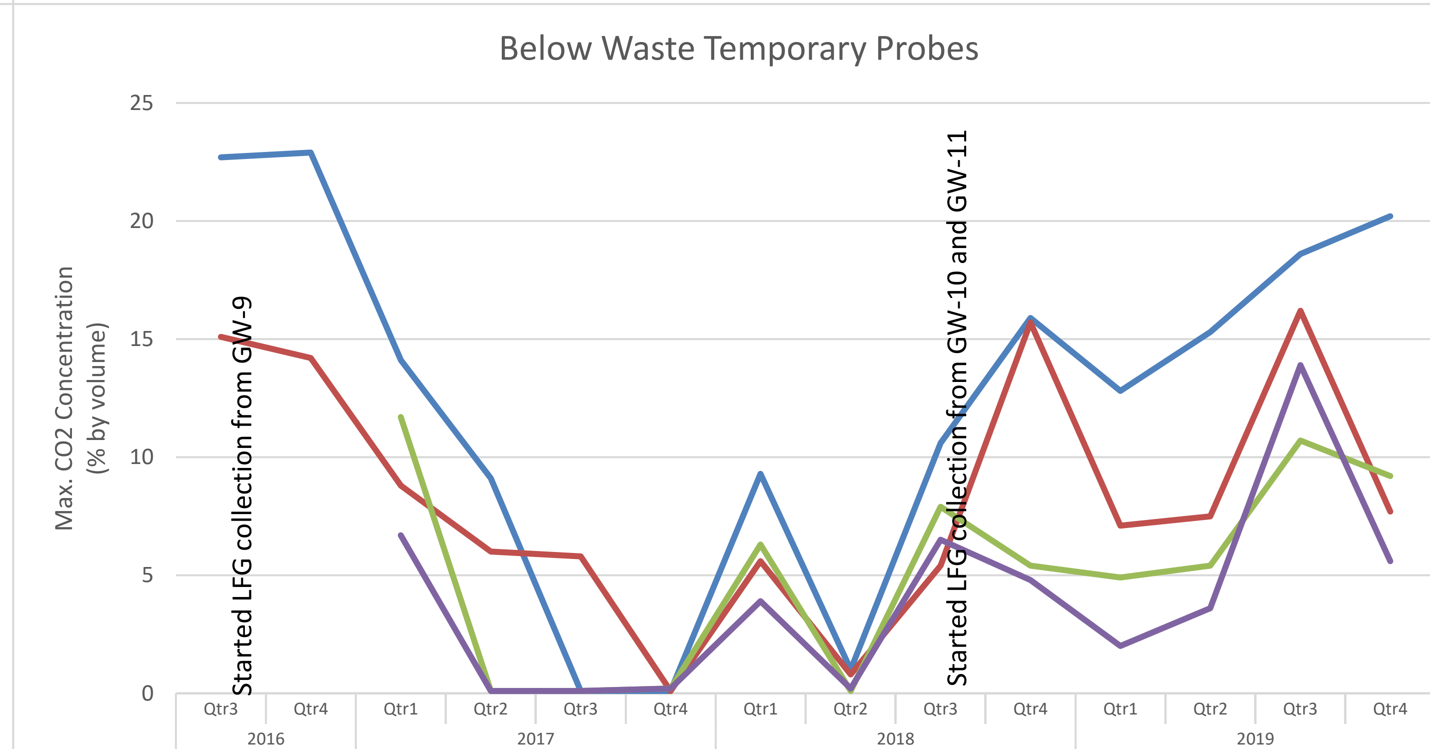
	2016 Qtr3	2016 Qtr4	2017 Qtr1	2017 Qtr2	2017 Qtr3	2017 Qtr4	2018 Qtr1	2018 Qtr2	2018 Qtr3	2018 Qtr4	2019 Qtr1	2019 Qtr2	2019 Qtr3	2019 Qtr4
TP-2D	2	10	0						7	3	0	11	0	29
TP-3S	10	2	1	0	0	0	0	0	0	1	0	1	20	7
TP-4S	61	56	2	0	0	14	10	0	28	0	40	43	59	61
TP-5S			57	0	0	1	4	1	35	12	16	55	59	59
TP-6S			0	0	0	0	1	0	0	0	0	0	8	2
TP-7								14	16	8	8	6	24	21
TP-8								0		0	0	0	3	1



	2016 Qtr3	2016 Qtr4	2017 Qtr1	2017 Qtr2	2017 Qtr3	2017 Qtr4	2018 Qtr1	2018 Qtr2	2018 Qtr3	2018 Qtr4	2019 Qtr1	2019 Qtr2	2019 Qtr3	2019 Qtr4
TP-2D	3	22	0						15	8	0	9	0	28
TP-3S	22	21	21	0	0	6	16	0	18	18	19	18	19	20
TP-4S	38	37	7	0	0	9	6	0	26	5	36	31	36	41
TP-5S			27	0	0	3	5	2	28	24	21	32	36	37
TP-6S			0	0	0	0	6	0	4	0	0	7	12	14
TP-7								12	16	17	18	17	21	20
TP-8								11		17	15	18	19	22



	2016 Qtr3	2016 Qtr4	2017 Qtr1	2017 Qtr2	2017 Qtr3	2017 Qtr4	2018 Qtr1	2018 Qtr2	2018 Qtr3	2018 Qtr4	2019 Qtr1	2019 Qtr2	2019 Qtr3	2019 Qtr4
TP-3D	21	8	1	0	0	0	0	0	0	0	0	0	9	10
TP-4D	2	1	0	0	0	0	0	0	0	6	0	0	1	0
TP-5D			2	0	0	0	0	0	0	0	0	0	1	0
TP-6D			0	0	0	0	0	0	0	0	0	0	0	0



	2016 Qtr3	2016 Qtr4	2017 Qtr1	2017 Qtr2	2017 Qtr3	2017 Qtr4	2018 Qtr1	2018 Qtr2	2018 Qtr3	2018 Qtr4	2019 Qtr1	2019 Qtr2	2019 Qtr3	2019 Qtr4
TP-3D	23	23	14	9	0	0	9	1	11	16	13	15	19	20
TP-4D	15	14	9	6	6	0	6	1	5	16	7	8	16	8
TP-5D			12	0	0	0	6	0	8	5	5	5	11	9
TP-6D			7	0	0	0	4	0	7	5	2	4	14	6

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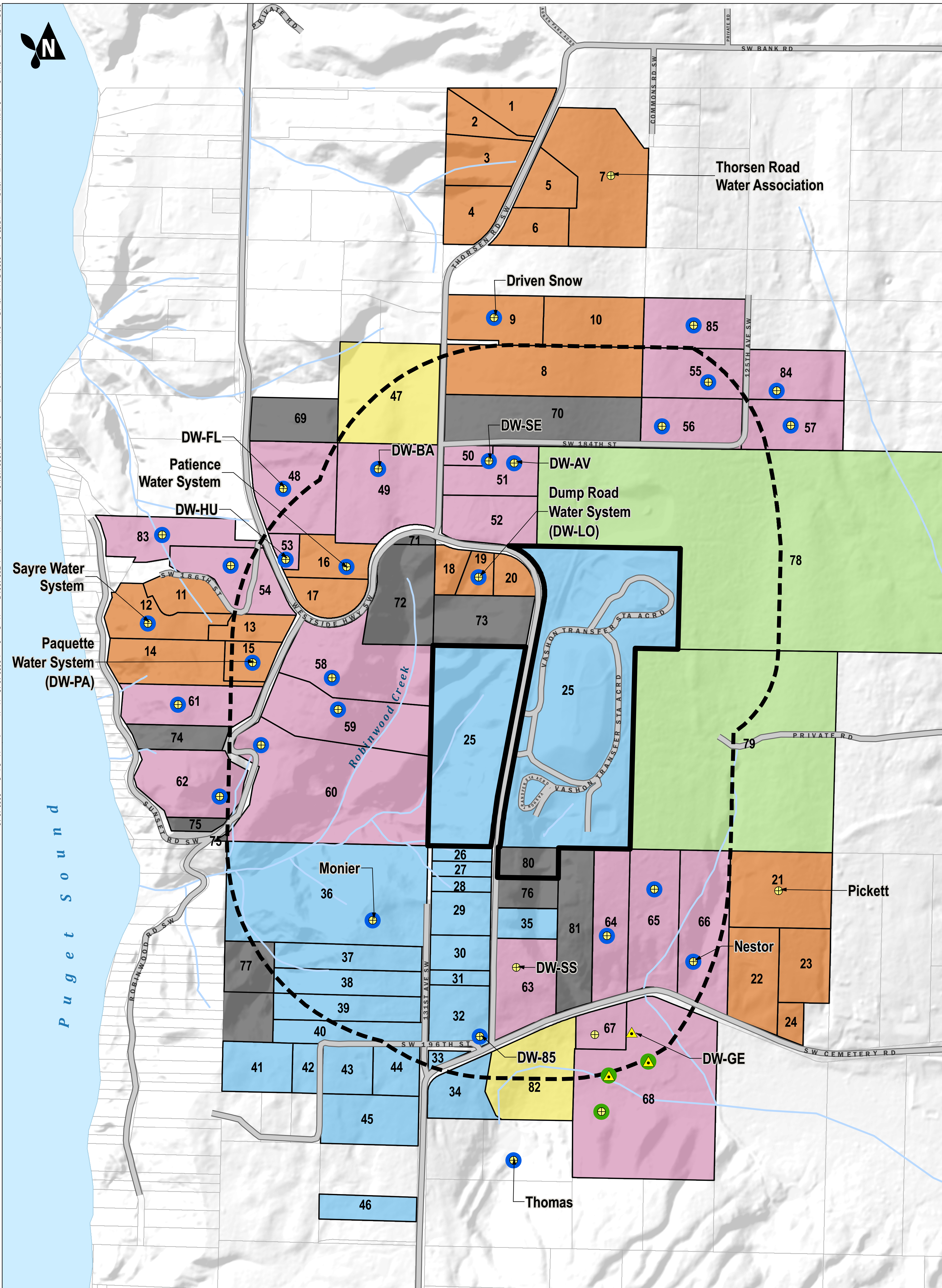
Figure 6.14
Performance Monitoring - Methane Concentrations
Vashon Island Closed Landfill Remedial Investigation



Parcel Water Source

- Group A System
- Group B System
- Private
- Unknown
- Island Center Forest
- Vacant Parcel

27 Study Reference Number
Well Location
Surface Water Resource
Ecology Well Log Available
Water Right/Claim

Vashon Island Closed Landfill
Domestic Well Survey Boundary
Road
King County Tax Parcel

0 300 600 1,200
Feet

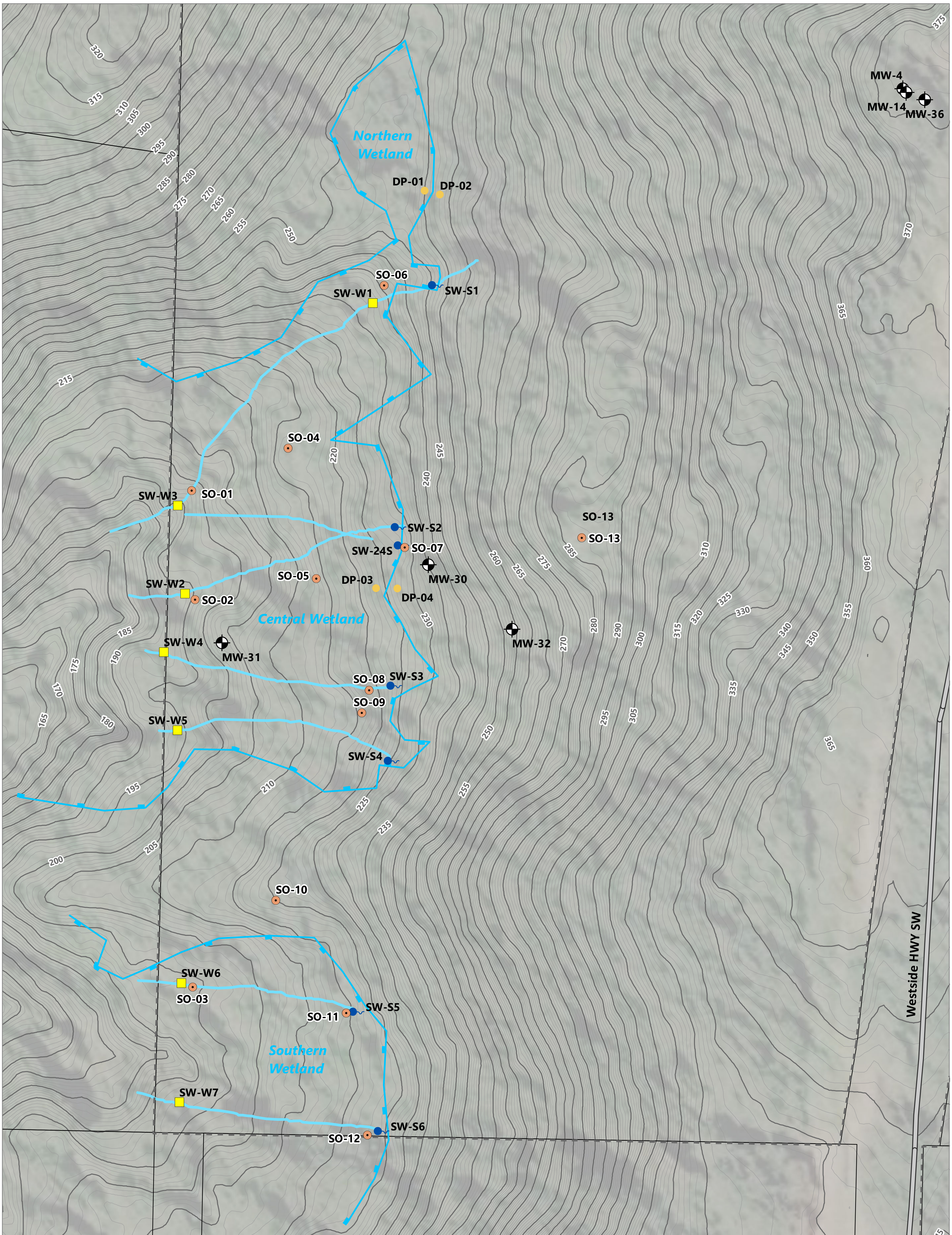
Notes:
1) Refer to Tables 1 and 2 for property and well information, listed by Study Reference Number.
2) Well locations based on best available information. Field location of wells was not performed. See text for discussion.
3) Water sources, if any, on vacant land and Island Center Forest parcels are unknown.
4)) Water right information from Ecology's Water Right Application Tracking System (WRATS) database.

Identified Beneficial Uses

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect CONSULTING | OCT-2020 | BY: DAC / TDR | FIGURE NO. **7.1**

GIS Path: T:\projects_8\KingCounty_SolidWaste\VashonIslandLandfill\Delivered\RIFS_Spring_2020\7-1 Identified Beneficial Uses.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2020-10-13 || User: trullen || Print Date: 2020-10-13



LEGEND:

- Actual Sampling Location
- Wetland Delineation Data Plot Location
- Seep[1, 2]
- Weir
- Monitoring Well
- Roads
- Estimated Seep Channel[2]
- Wetland Boundary
- 1-Foot Contours
- Landfill Boundary
- Tax Parcel

NOTES:
1. Seeps SW-S1 and SW-S3 were derived from Figure 8.1, Extent of Contamination, Aspect Consulting, October 2018.
2. Seep SW-24S and estimated stream channels were derived from Figure 2b, Vashon Closed Landfill Western Hillslope Investigation, King County, March 2011.

0 60
Feet

Publish Date: 2020/02/07, 9:45 AM | User: adowell
Filepath: \\orcas\GIS\Jobs\AspectConsulting_0204\KC_Closed_Landfill_Vashon\Maps\Remedial_Investigation\AQ_RI_ActualSamplingLocations.mxd

ANCHOR QEA

Figure 8.1
West Hillslope Groundwater, Seep, Surface Water and Soil Sample Locations - Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

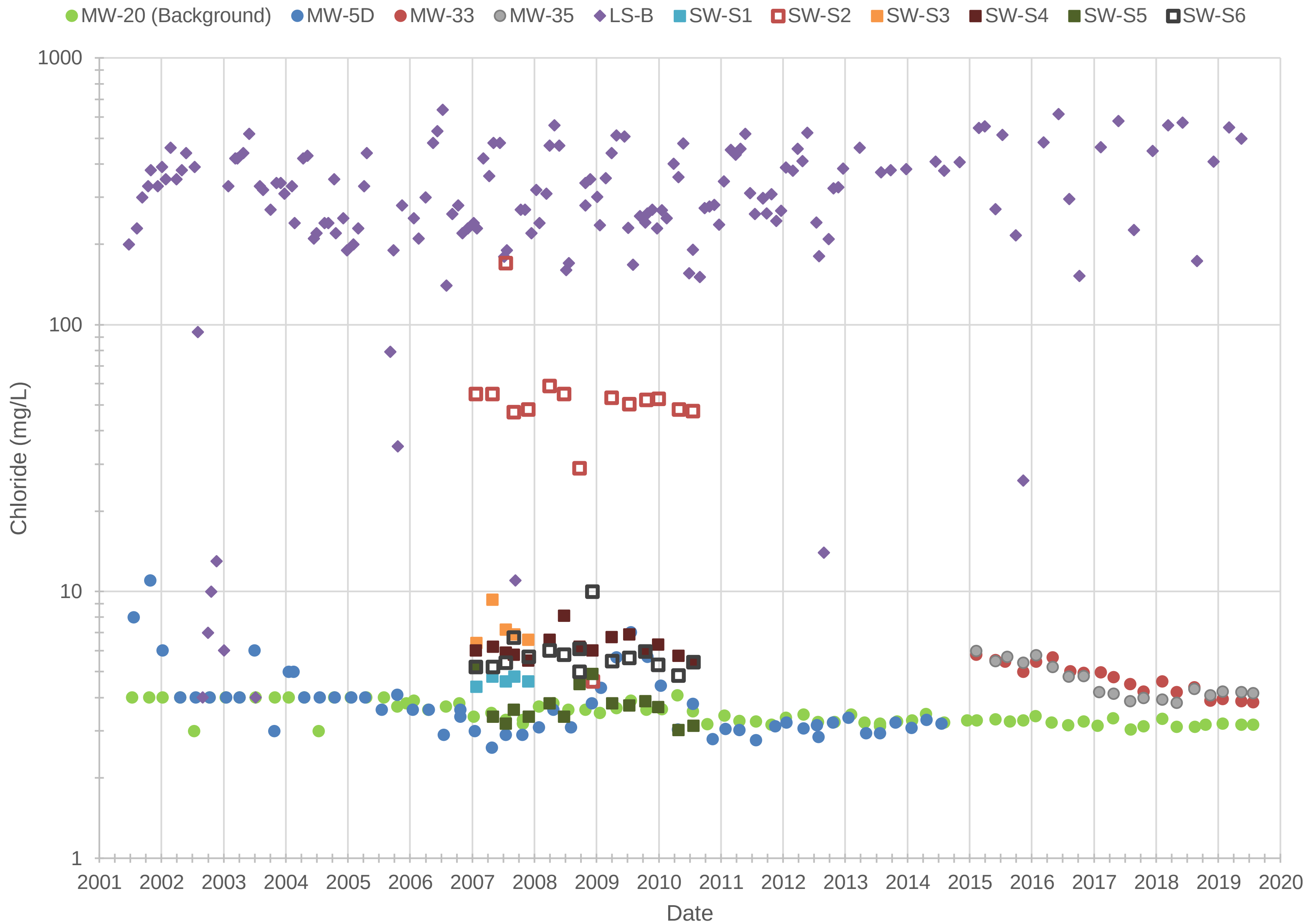


Figure 9.1
Chloride Time Series
Remedial Investigation
Vashon Island Closed Landfill, King County, Washington

Aspect Consulting
November 2020
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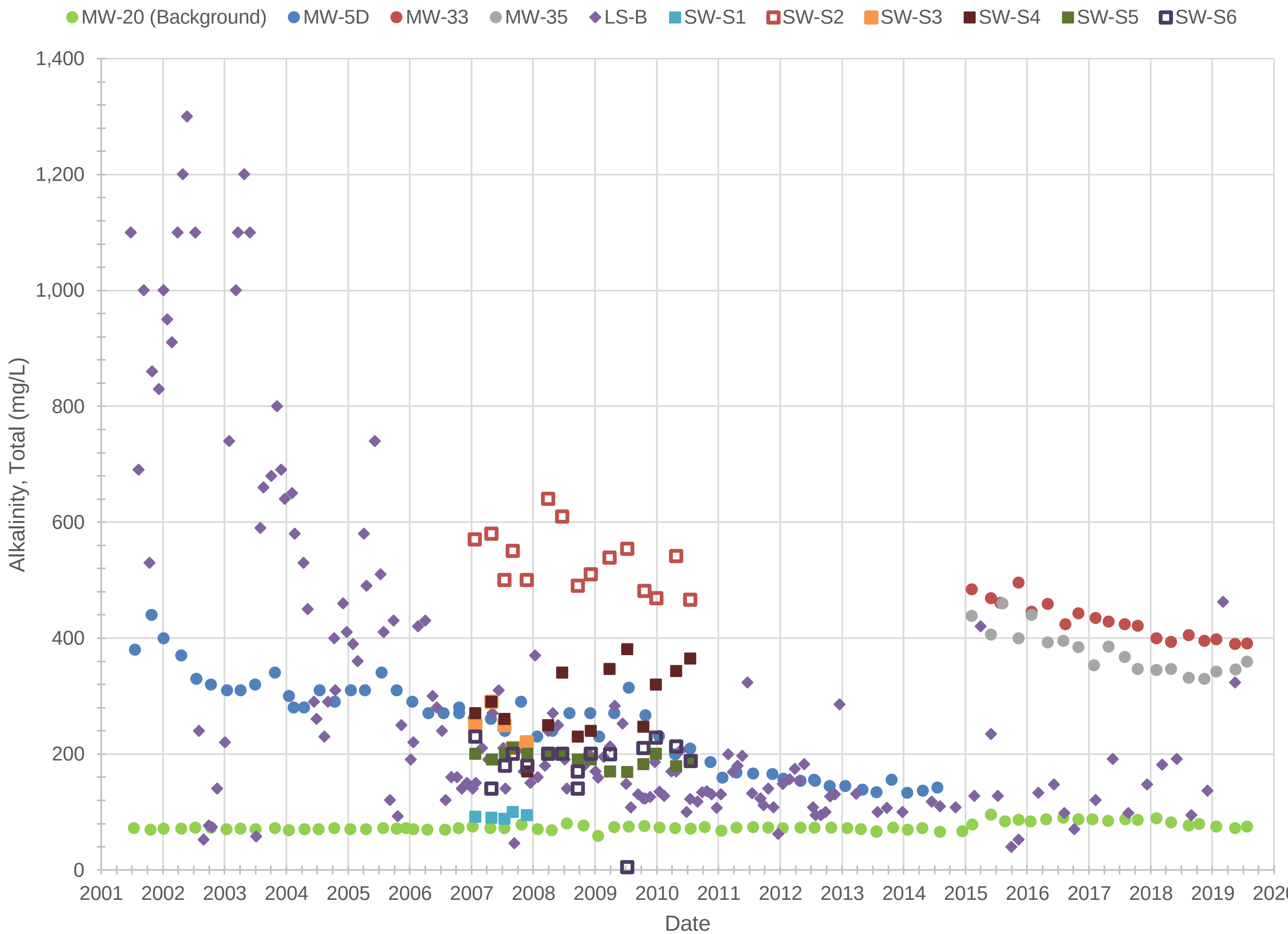

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November 2020

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Figure 9.2
Alkalinity Time Series

Remedial Investigation

Vashon Island Closed Landfill, King County, Washington

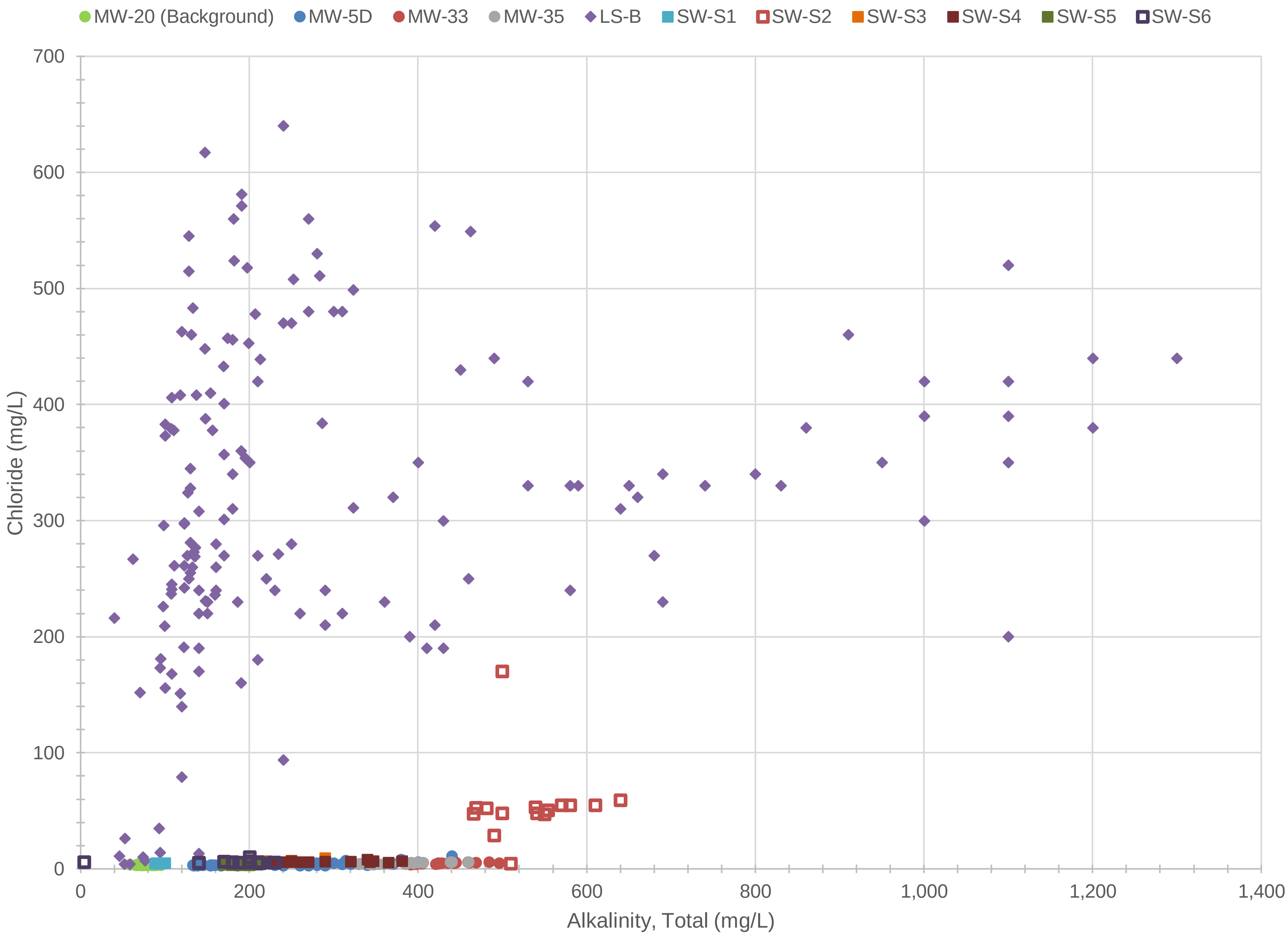


Figure 9.3
Chloride vs Alkalinity
Remedial Investigation
Vashon Island Closed Landfill, King County, Washington

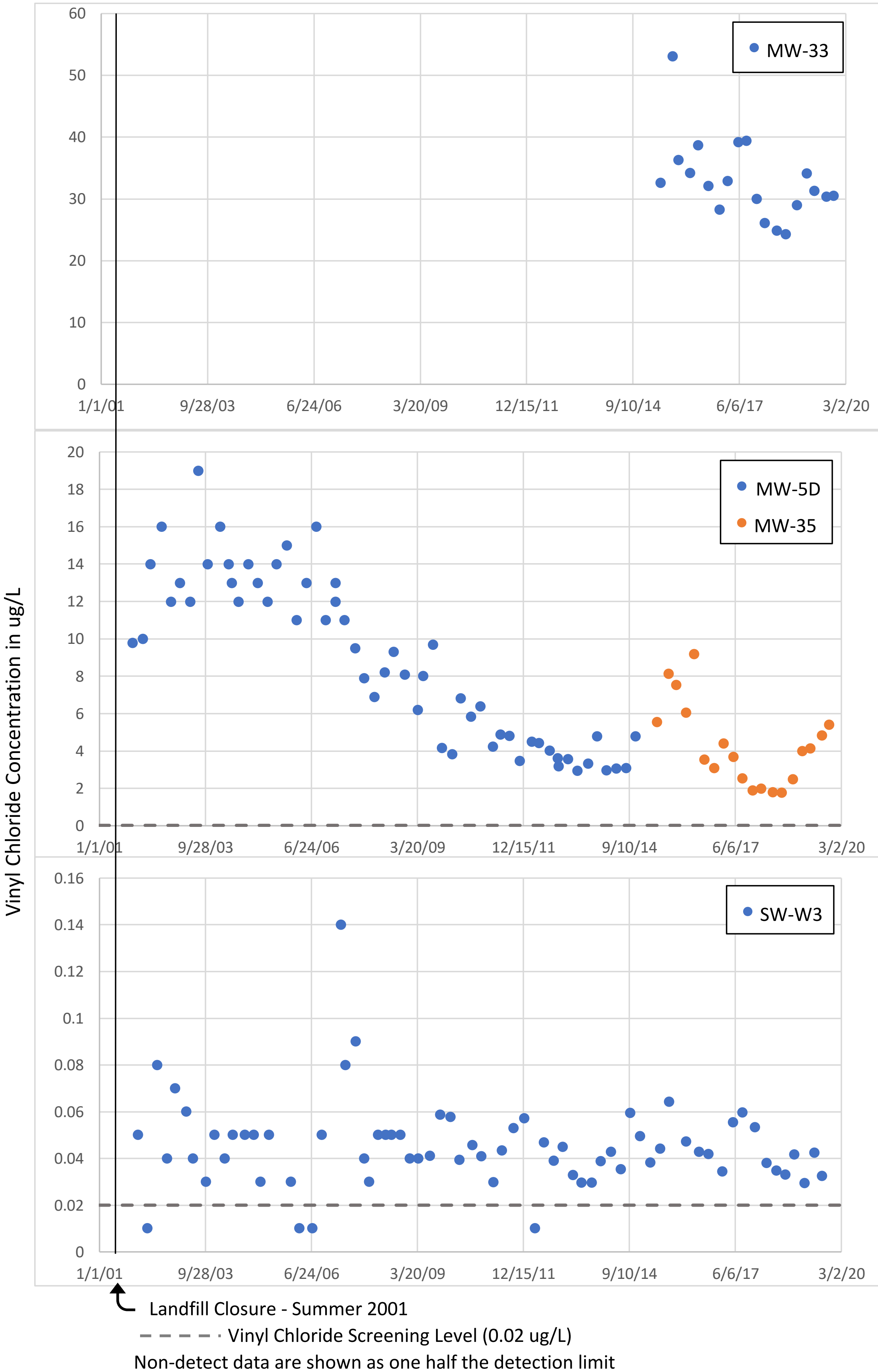
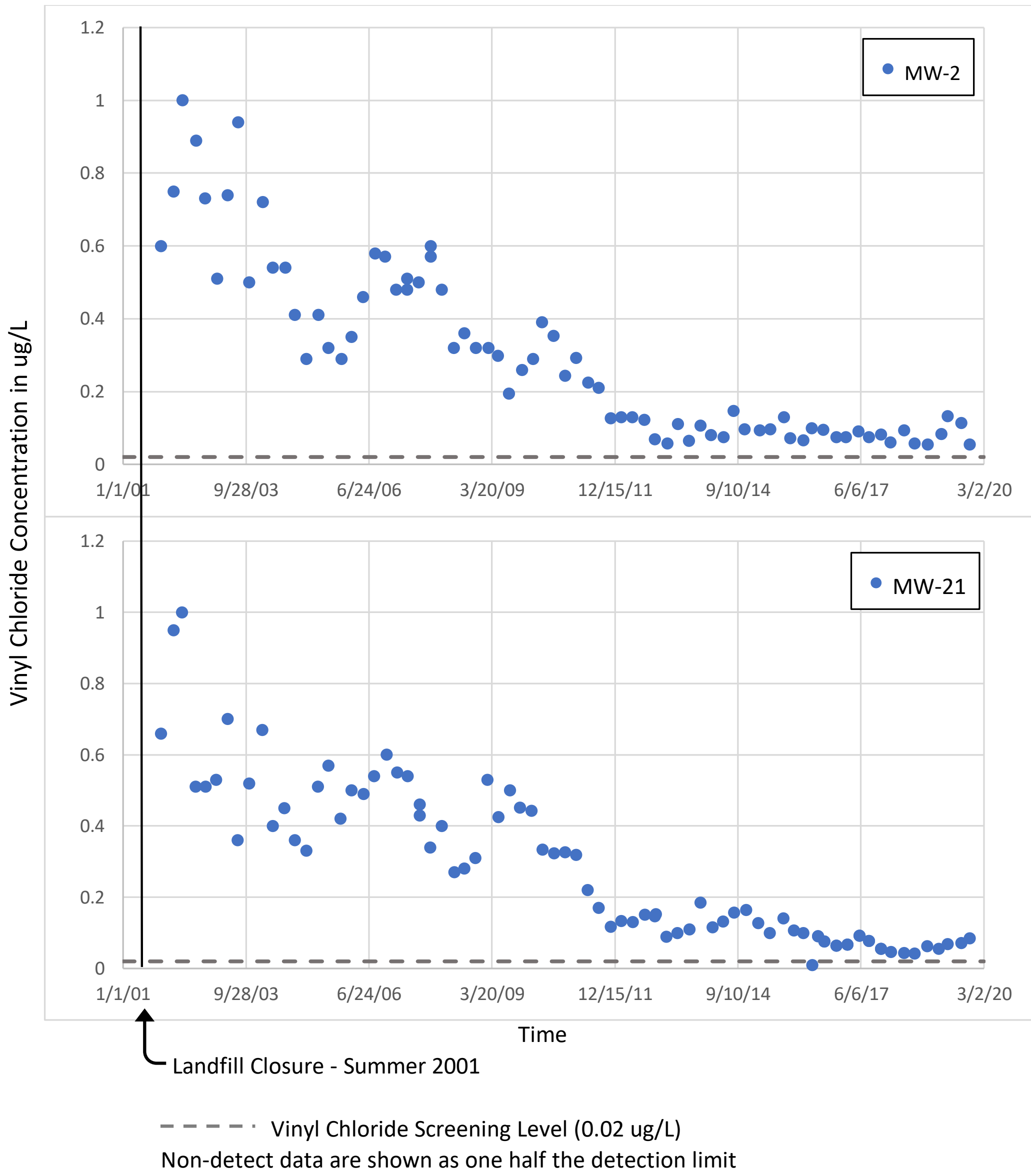


Figure 9.4

Vinyl Chloride in Groundwater, Time Series at MW-33, MW-5D/35, SW-W3

Remedial Investigation



Aspect Consulting
November 2020
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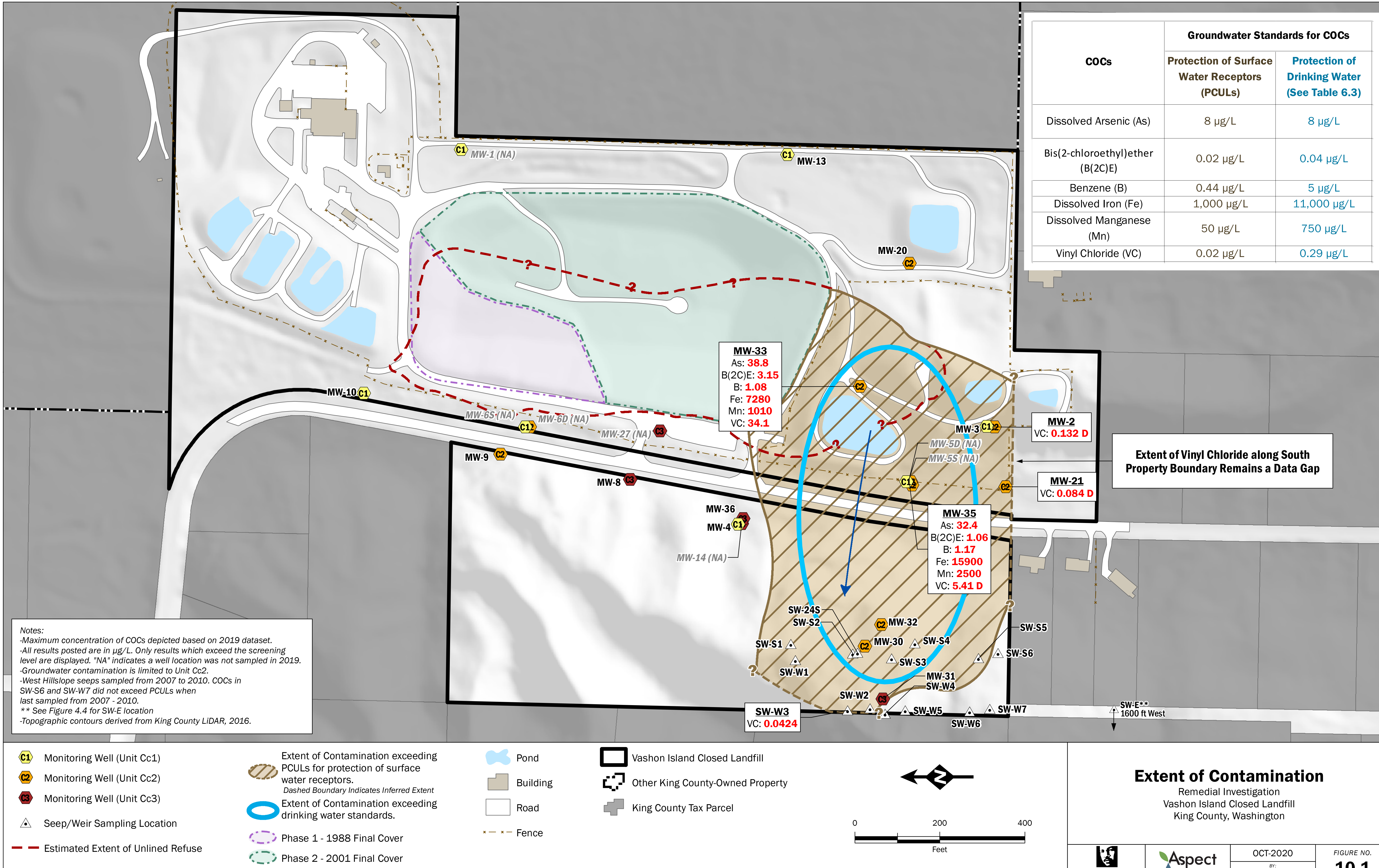
Figure 9.5
Vinyl Chloride in Groundwater, Time Series at MW-2 and MW-21
Remedial Investigation



COCs	Groundwater Standards for COCs	
	Protection of Surface Water Receptors (PCULs)	Protection of Drinking Water (See Table 6.3)
Dissolved Arsenic (As)	8 µg/L	8 µg/L
Bis(2-chloroethyl)ether (B(2C)E)	0.02 µg/L	0.04 µg/L
Benzene (B)	0.44 µg/L	5 µg/L
Dissolved Iron (Fe)	1,000 µg/L	11,000 µg/L
Dissolved Manganese (Mn)	50 µg/L	750 µg/L
Vinyl Chloride (VC)	0.02 µg/L	0.29 µg/L

Notes:
-Maximum concentration of COCs depicted based on 2019 dataset.
-All results posted are in µg/L. Only results which exceed the screening level are displayed. "NA" indicates a well location was not sampled in 2019.
-Groundwater contamination is limited to Unit Cc2.
-West Hillslope seeps sampled from 2007 to 2010. COCs in SW-S6 and SW-W7 did not exceed PCULs when last sampled from 2007 - 2010.
*** See Figure 4.4 for SW-E location*
-Topographic contours derived from King County LiDAR, 2016.

Extent of Contamination

Remedial Investigation
Vashon Island Closed Landfill
King County, Washington

King County | Aspect Consulting | OCT-2020 | BY: DAC / TDR | FIGURE NO. 10.1