Volume 1 of 2

Olalla Landfill Remedial Investigation/Feasibility Study

Prepared for

Kitsap County Department of Public Works,
Solid Waste Division

May 2014

Prepared by

Parametrix

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The technical material and data contained in this document were prepared by and under the supervision and direction of the undersigned Washington State licensed hydrogeologist and professional engineer.

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES (WITHIN REPORT)

LIST OF TABLES (END OF REPORT)

TABLE OF CONTENTS (CONTINUED)

APPENDICES (INCLUDED IN VOLUME 2)

KEY TERMS

Air Toxics	Air Toxics Ltd.
ARARs	Applicable, Relevant and Appropriate Requirements
ARI	Aquatic Research, Inc.
bgs	below ground surface
CAO	Cleanup Action Objectives
CLARC	Cleanup Levels and Risk Calculations
cm/sec	centimeters per second
COCs	Constituent s of Concern
COD	Chemical oxygen demand
CPEO	Center for Public Environmental Oversight
CPOC	Conditional point of compliance
CSCS	Confirmed and Suspected Contaminated Sites
CUL	Cleanup levels
DCA	disproportionate cost analysis
DCE	dichloroethene
DO	dissolved oxygen
DOT	U.S. Department of Transportation
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
EPI	Environmental Partners, Inc.
FS	feasibility study
GPS	global positioning system
HEAST	Health Effects Assessment Summary Tables
HQ	Hazard quotient
HSA	hollow-stem-auger
IRIS	Integrated Risk Information System
KCPW	Kitsap County Department of Public Works
KPHD	Kitsap Public Health District
Landfill	Olalla Landfill
LEL	Lower Explosive Limit
MCL	Maximum contaminant level
MFS	Minimum Functional Standards
MNA	Monitored natural attenuation
MRC^{TM}	Metals Remediation Compound

KEY TERMS (CONTINUED)

MTCA	Model Toxics Control Act
NGVD 1929	National Geodetic Vertical Datum 1929
NPDES	National Pollutant Discharge Elimination System
NTUs	nephelometric turbidity units
O&M	operation and maintenance
ORP	oxidation-reduction potential
PAHs	polycyclic aromatic hydrocarbons
Parametrix	Parametix, Inc.
PCBs	polychlorinated biphenyls
PCE	perchloroethene
PID	photoionization detector
PLP	Potentially Liable Person
POC	Point of compliance
QA	Quality assurance
QAPP	Quality Assurance Project Plan
Qob	Olympia Beds
Qva	Advance Outwash Deposits
Qvi	Ice-Contact Deposits
Qvlc	Lawton clay
Qvr	Recessional Outwash Deposits
Qvt	Till
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RI	remedial investigation
RI/FS	Remedial Investigation/Feasibility Study
RTK	Real Time Kinematic
SAP	Sampling and Analysis Plan
SFV	Standard formula values
SHA	Site Hazard Assessment
SVOCs	Semivolatile Organic Compounds
SWD	Kitsap County Public Works Solid Waste Division
SWHP	Solid Waste Handling Permit
TCE	trichloroethene
TDS	Total Dissolved Solids

KEY TERMS (CONTINUED)

TOC	Total Organic Carbon
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VOCs	volatile organic compounds
WAC	Washington Administrative Code

1. INTRODUCTION

This document describes the results of the Remedial Investigation/Feasibility Study (RI/FS) conducted for the Olalla Landfill (Landfill). The RI/FS was designed to determine the nature and extent of hazardous substances related to the Landfill in groundwater, surface water, and landfill gas, to evaluate the potential presence of solid waste in the northern portion of the Landfill, develop cleanup standards, and to identify and evaluate applicable remedial alternatives.

The RI/FS included the following investigations and evaluations:

- Groundwater investigation.
- Surface water investigation.
- Solid waste investigation.
- Landfill gas investigation.
- Site-specific chemical screening.
- Identification and evaluation of applicable remedial alternatives.

The RI/FS was conducted as an Independent Remedial Action to meet the requirements of the Model Toxics Control Act (MTCA) Chapter 70.105D Revised Code of Washington (RCW) and the MTCA Regulations Chapter 173-340 Washington Administrative Code (WAC). Kitsap County Department of Public Works (KCPW) assembled a team to develop a Work Plan and conduct the RI/FS investigation, technical evaluations, and reporting of the findings. The KCPW team consists of KCPW Solid Waste Division (SWD) and their environmental consulting team, Parametrix, Inc. (Parametrix) and Environmental Partners, Inc. (EPI).

1.1 PURPOSE AND OBJECTIVES OF THE RI/FS

As stated in Chapter 173-340 WAC, the purpose of an RI/FS is to collect, develop, and evaluate information for a site that is sufficient to support an assessment of the need for and selection of an appropriate cleanup action under WAC 173-340-360. The purpose of this Remedial Investigation (RI) is to present the results of the investigations conducted to date at the Landfill as outlined in the RI/FS Work Plan (Parametrix, 2010). The Feasibility Study (FS) evaluates the necessity for additional site remedial actions to reduce human health or ecological risk based on the data and evaluations from the RI and other applicable site investigations.

The specific objectives of the RI/FS are summarized as follows:

- Characterize the physical features of the Landfill including, topography, surface water, geology, and hydrogeology.
- Characterize the nature and extent of chemicals in the groundwater beneath the Landfill that may be attributed to the Landfill.
- Characterize the nature and extent of chemicals in the surface water of the Landfill that may be attributed to the Landfill.
- Conduct a solid waste evaluation of the northern part (Phase II Area) of the Landfill.
- Evaluate landfill gas composition and generation at the Landfill.
- Identify the chemicals and environmental media to be addressed in the FS.
- Identify and evaluate applicable remedial alternatives.

The following work was completed to meet the RI/FS objectives:

- Installed two additional downgradient monitoring wells to further delineate groundwater impacts attributable to the Landfill.
- Further characterized site hydrogeology by incorporating geologic data from the new monitoring wells.
- Characterized the extent and concentrations of chemicals in the aquifer.
- Calculated the rates of groundwater movement at the site using site specific aquifer coefficients.
- Sampled off-site water supply wells to further delineate the contaminant plume and evaluate the potential for off-site impacts potentially related to the Landfill.
- Sampled surface water from the detention pond and two additional sample locations in the stormwater drainage system to evaluate the potential for surface water impacts.
- Conducted a solid waste investigation to evaluate the potential presence of solid waste in the northern part of the Landfill.
- Performed an evaluation of the Landfill gas system to assess potential impacts related to the generation of landfill gas.
- Collected and evaluated data necessary to identify and evaluate remedial action alternatives in the FS.
- Identified applicable, relevant and appropriate requirements (ARARs).
- Developed cleanup standards consisting of cleanup levels and a conditional point of compliance.
- Screened cleanup action technologies.
- Combined the cleanup action technologies into cleanup action alternatives.
- Compared and evaluated the cleanup action alternatives in accordance with MTCA.

1.2 LANDFILL BACKGROUND

The Landfill is located in southern Kitsap County, Washington, approximately 0.75 mile east of Highway 16 on SE Burley-Olalla Road in the northeast quarter of Section 1, T22N, R1E. The location of the Landfill is shown in Figure 1-1 (located at the end of this report).

KCPW owns the Landfill property and the current parcel number is 012201-1-029-2003. The original parcel consisted of approximately 75 acres, which contained an old gravel pit. In 1996, the original parcel was subdivided into two parcels, a 45-acre parcel to the north, and a 30-acre parcel to the south. The parcel to the south was not used as a landfill.

The north parcel contains the closed Landfill and a Drop Box facility, known as a Recycling and Garbage Facility in Kitsap County, which was established as a transfer station at the time the Landfill stopped accepting waste. The section of the north parcel containing the Recycling and Garbage Facility was never used as a landfill and is not considered to be part of the Landfill for this RI/FS. A fence and locked gate separate the Recycling and Garbage Facility from the Landfill.

The Landfill currently consists of an area capped by a low-permeability barrier and vegetated protective soil cap (Phase I Area) and an area covered with vegetated soil (Phase II Area). Both areas of the Landfill are surrounded by a gravel perimeter access road that encompasses approximately 12 acres. The Phase I area encompasses approximately 6.5 acres and the Phase II area encompasses approximately 4.5 acres. The perimeter access road can be entered through a locked gate at Bandix Road to the east side of the property. The Landfill is unlined and is situated in the old gravel pit. The Landfill area also contains a groundwater monitoring well network, a passive landfill gas collection system, a surface water conveyance system, a stormwater detention pond, public access controls, and a surrounding vegetation buffer. The Phase I and Phase II Areas, as well as other features of the Landfill, are shown in Figure 1-2.

1.3 LANDFILL HISTORY

Records indicate that waste disposal at the Landfill started in the late 1950s or early 1960s; however, the exact timeframe is unknown. During that time, the Landfill accepted solid waste from residential and light commercial self-haulers. The waste types disposed at the Landfill were mixed municipal solid waste, demolition and construction materials, and a small volume of septic sludge (Parametrix, 1988). The consulting team reviewed historical information regarding early waste handling operations at the Landfill including aerial photos of the property from 1963, 1971, 1977, 1985, and 1989 and paid particular attention to the earlier photos to look for evidence of disposal or waste handling activities. The consulting team determined that the historical aerial photos did not show evidence of disposal or waste handling activities in areas outside of the current Landfill footprint.

Initial Landfill operations reportedly consisted of burning the refuse and covering the waste with soil on monthly intervals. Open burning was stopped in the early 1970s. In late 1971, KCPW took over operation of the Landfill and operated the facility in accordance with the solid waste landfill practices at the time, which included compaction of the waste and daily soil cover of the compacted waste (Parametrix, 1988).

The earliest known operating permit for the Landfill is dated 1969 and was issued by the Bremerton Kitsap County Health District (now known as the Kitsap Public Health District [KPHD]). The 1969 permit was issued to a private operator, and the permit allowed the Landfill to accept waste from residential and light commercial self-haulers. Language in the 1969 permit letter indicates that the Landfill might have been permitted several years earlier than 1969.

In 1978, KPHD approved a request to dispose of 300,000 gallons of septic tank sludge at the Landfill. The actual volume of septic tank sludge that the Landfill accepted is unknown. According to estimates performed in 1982, the Landfill received approximately 2,000 cubic yards of mixed municipal solid waste per month (Parametrix, 1988). The transfer station began operations in the northern part of the property in the spring of 1985, and the Landfill no longer accepted waste after that time. The transfer station now operates as a drop box facility (known as a Recycling and Garbage Facility in Kitsap County).

After the Landfill stopped accepting waste in 1985, four groundwater monitoring wells, designated MW-1 through MW-4, were installed. The wells were installed prior to implementation of formal landfill closure activities, which are discussed in the following section.

1.4 SUMMARY OF CLOSURE ACTIVITIES

The Landfill was officially closed in 1989 in accordance with the Olalla Final Closure Plan (Parametrix, 1988). At the time of closure, the Landfill area within the perimeter road was divided into two areas; the Phase I Area to the south, and the Phase II Area to the north as shown in Figure 1-2. Closure activities were conducted, and a landfill gas collection system consisting of three passive Landfill gas flares connected by underground perforated piping was installed in the 6.5-acre Phase I Area of the Landfill.

As part of Landfill closure, both the Phase I and Phase II areas of the Landfill were graded and compacted to create adequate slopes to facilitate effective runoff and reduce the effects of settling before the final low permeability cap could be placed on the Phase I Area. Slopes in the Phase I Area of the Landfill were graded to approximately 3 percent per Landfill closure design requirements. The existing soil cover over the Phase II Area of the Landfill was installed while disposal activities were taking place at the active Landfill. As described within the final closure plan (Parametrix, 1988), the closure schedule for the Olalla Landfill was to take place in two phases. The Phase I closure would take place during the 1988 construction season and would consist of an engineered cap. The Phase II closure would be delayed by approximately 1 year in order for Ecology to make a determination based on groundwater monitoring of whether the engineered cap would need to be extended over Phase II. The Phase I closure was conducted in 1988. No record has been found of the subsequent Ecology determination regarding the need for an engineered cap in the Phase II area. As part of the Phase I closure, slopes in the Phase II Area of the Landfill were graded to approximately 2 percent.

Following grading, a final cap consisting of a 2-foot-thick compacted bentonite-amended low-permeability soil cap was installed over the Phase I Area. The final cap has a maximum design permeability of 1×10^{-6} centimeters per second (cm/sec) and is overlain with 6 inches of topsoil and a vegetative cover (Kitsap County, 2007). To ensure the cap's soil-bentonite composition met the permeability requirements of 1×10^{-6} cm/sec, a comprehensive quality assurance (QA) program was instituted during the course of the cap installation. The QA testing results are contained in Appendix A. The installation lifts were divided into a grid pattern for the purpose of testing the bentonite-amended soil. Pacific Testing Laboratories of Seattle, Washington analyzed soil samples collected from the Olalla Landfill from August through December 1988. Soil samples collected in October 1988 were analyzed to conduct permeability testing of various soil to bentonite combinations. After analysis and comparison of the various soil-bentonite mixes, a test control plot was established on-site. Based on the test mixes and sample results, installation of the first lift commenced in November 1988. Pacific Testing Laboratories collected and analyzed samples of the 6% bentonite-soil mix as part of the lift installations to ensure the 1×10^{-6} cm/sec criteria was being met. Samples consisted of in-place measurement and core samples for laboratory analysis. The second lift and third lift of the cap were sampled and analyzed in December 1988. General analyses for most samples included in-place moisture, in-place density, dry density, optimum moisture, percent compaction, hydraulic conductivity, and Atterberg limits. Hydraulic conductivity analyses were typically conducted on core samples. These sample results indicated that the hydraulic conductivity for the first lift ranged from 1.7×10^{-6} to 9.3×10^{-8} cm/sec. The hydraulic conductivity for the second lift ranged from 1.4×10^{-6} to 7.8×10^{-8} cm/sec. The hydraulic conductivity for the third lift ranged from 1.4×10^{-7} to 5.0×10^{-9} cm/sec. Based on the soil sample results, the final mean hydraulic conductivity of the cap was calculated to be 3.8×10^{-7} cm/sec.

The final cap was hydroseeded with a mixture of native grasses to establish a vegetative cover for erosion control of the final cover. KCPW routinely inspects and maintains the vegetative cover at the Landfill.

A surface water management and conveyance system consisting of engineered drainage channels and culverts to drain surface water runoff away from the Landfill and into the stormwater detention pond was also installed during closure activities. The drainage channels comprise a surface water handling system that surrounds the Landfill area. Engineered drainage channels also surround the outside edge of the perimeter road to prevent runoff from entering the Landfill area and potentially contributing to potential infiltration through the Landfill cap. Routing surface water flow to the detention pond located west of the Phase I area attenuates peak surface water flow at the Landfill. The surface water management system at the Landfill was designed to comply with the requirements of Chapter 173-304 WAC.

As previously noted, four groundwater monitoring wells, designated MW-1 through MW-4, were installed in 1985 prior to implementation of formal landfill closure activities. Two additional monitoring wells, MW-5 and MW-6, were installed in 1988 as part of the Landfill closure activities. MW-5A was installed in 1989 as a replacement well for MW-5, which is screened in a laterally discontinuous perched groundwater zone above the elevation of the refuse. Well MW-7 was installed in 1993 after closure activities were completed to provide an additional downgradient monitoring location at the southwest corner of the Landfill. Two additional downgradient monitoring wells, MW-8 and MW-10, were installed in 2010 as part of the RI/FS. Monitoring well locations at the Landfill are shown in Figure 1-2.

A passive Landfill gas collection system was installed within the Phase I Area of the Landfill during closure activities in accordance with the final closure plan (Parametrix, 1988). The passive gas collection system was installed under the low permeable cap to collect and vent Landfill gas. The gas system consists of three flares connected with 6-inch perforated polyethylene pipes. Flares 1 and 2 are located on the east side of the Landfill and Flare 3 is located on the southwest side of the Landfill (Figure 1-2). The collection system piping is installed approximately 6-feet beneath the surface of the final cap. The piping is bedded with 1 to 1.5-inches of drain rock. The flare spacing was determined in accordance with the closure plan (Parametrix, 1988), which accounted for Landfill and gas parameters including pressure, depth, permeability, density, specific weight, and gas production rate.

Post-closure activities have been ongoing since closure of the Landfill. Post-closure activities consist primarily of quarterly landfill monitoring and maintenance per WAC 173-304-407 (Minimum Functional Standards [MFS] for Solid Waste Handling), “General Closure and Post Closure Requirements,” Kitsap County Board of Health Ordinance 2004-2 and 2010-1, “Solid Waste Regulations,” and Post Closure Solid Waste Handling Permits (SWHP) issued annually by KPHD. The current SWHP is dated June 1, 2012 and is effective from January 1, 2012, through December 31, 2012 (Appendix B). Monitoring for the RI/FS was conducted under the 2010-2011 SWHP which is also contained in Appendix B.

1.5 SUMMARY OF LANDFILL MAINTENANCE

The Landfill cap and surface water drainage system requires regular maintenance in order for the Landfill to perform as designed during the post-closure period. KCPW inspects and maintains the cap and soil cover on a quarterly basis in accordance with the SWHP. Two repair episodes have occurred since closure of the Landfill.

1.5.1 Landfill Cap Settlement and Surface Water Drainage Repair

The Landfill cap and surface water drainage system was evaluated by Parametrix in 1997 (Parametrix, 1997a & 1997b). The evaluations included a topographical survey, field investigation, and water balance analysis. The topographic survey conducted as part of the evaluation was compared to the as-built survey of the Landfill completed after construction of the cap in 1988. The Phase II Area of the Landfill was not part of the evaluation.

The evaluation found that the final cover system on the Landfill is performing as designed, with only moderate levels of settlement (less than one foot) over most of the surface of the cap. Grass is well established and well maintained over the cap area and in surface water drainage ditches around the perimeter of the Landfill. Some potential problem areas were identified including about 400 feet of surface drainage swale in the westernmost portion of the Landfill that had inadequate slope to provide drainage, inadequate freeboard in some portions of the existing drainage swales, some slope erosion in the southwestern portion of the Landfill outside the capped area, an area of about 1 acre in the west central portion of the Landfill that has surface slopes of less than two percent and appears to have ponding water, and a small area (about 5,000 square feet) of differential settlement in the easternmost portion of the Landfill near the two easternmost flares.

Based on the results of the evaluation, the following recommendations were made for maintenance and improvements to the cover and drainage system:

- An area of about one acre in the western portion of the Landfill could be regraded to increase surface slopes to greater than two percent.
- Monitor the areas of greatest differential settlement to determine if additional inspection is warranted. If warranted, excavate the 5,000 square foot area of differential settlement and inspect the compacted soil liner for damage. If damage occurred, repair and regrade the area.
- Repair the drainage swale in the westernmost portion of the Landfill. This includes placing a geomembrane liner within the ditch, regrading the ditch and installing a catch basin and downslope drain. Provide additional embankment in areas of inadequate freeboard and seed the new embankment areas.

The drainage improvements recommended by Parametrix (Parametrix, 1997b) and summarized above were designed by Parametrix for implementation at the Landfill (Parametrix, 1998). The stormwater conveyance system improvements were performed by Kitsap County in 1998 and are documented in an appendix to the Olalla Landfill Annual Report for 1998 (CH2M HILL, 1999).

Kitsap County performed additional improvements to stormwater ditches in 2000. The work consisted of removing soil from southern and eastern stormwater ditches and clearing debris and brush from all stormwater ditches surrounding the Landfill. This work was documented in Appendix E of the Olalla Landfill Annual Report for 2000 (CH2M HILL, 2001).

1.5.2 Landfill Cap Damage Repair

On November 21, 2003, a maintenance truck became mired in the Landfill cover soil and was towed off of the cover. The towing operation created tire ruts along a limited portion of the cover, potentially reducing its effectiveness as an infiltration barrier. Golder Associates Inc. examined the damaged area on multiple site visits by visually examining the surface and also excavating a trench by hand across the damaged portion of the cap (Golder, 2004). Golder Associates found the topsoil in the area to be a soft, dark brown, loamy soil that was relatively easy to dig with a shovel. The soil was moist to wet, due to recent rainfall. The topsoil layer appeared to have a significant organic material content, and the upper few inches included the root mass and thatch of a well-established grass cover. The total thickness of the topsoil layer as exposed in the trench varied between about 8 and 12 inches.

Below the topsoil was a layer of tan to light gray, dense soil of the bentonite amended cap layer. The bentonite-amended soil was reportedly very difficult to dig with a shovel. Field classification of the soil was silty sand with some gravel (Unified Soil Classification System [USCS]). The bentonite-amended soil cap exhibited some cohesion and plasticity, probably due to the bentonite content. The interface between the topsoil and cap layer was quite distinct, both in color and in physical properties. There was no obvious difference in elevation of the soil/cap interface where the ruts crossed the trench, nor was there any evidence of cap displacement or mixing with the topsoil. Golder Associates concluded that the disturbance resulting from towing the truck off of the cover was confined to the relatively soft vegetative soil layer, and that the underlying highly compacted bentonite-amended soil layer was not affected. Golder Associates recommended the repair consist of surface regrading and reseeding. In 2005, Golder Associates conducted the repair of the cap including the regarding and hydroseeding along with additional regrading of drainage ditches. Two ditch segments required regrading to alleviate ponding of surface runoff and to re-establish a positive downstream flow in all locations. The work was documented in a letter to KPHD on December 2, 2005 (Kitsap County, 2005; Golder, 2005).

1.6 PREVIOUS ENVIRONMENTAL INVESTIGATIONS

Post-closure quarterly monitoring has been ongoing at the Landfill since March 1992. The monitoring is conducted under a SWHP issued to KCPW by KPHD (Appendix B). The 2010–2011 SWHP contained the following specific monitoring requirements:

- Landfill gas parameter measurements for methane, Lower Explosive Limit (LEL), oxygen, carbon dioxide, and gas pressure at each of the three on-site passive Landfill gas flares;
- Depth-to-water measurements at all Landfill monitoring wells, with the exception of MW-5, which is completed in a shallow perched groundwater zone;
- Purge and collect groundwater samples at upgradient monitoring well MW-1, downgradient monitoring wells MW-3, MW-6, and MW-7, and cross–gradient well MW-5A;
- Collect a surface water sample from surface water location SW-2 during a wet season sampling event, either between January and March or November and December;
- Perform data evaluations, statistical tests, and data reporting in accordance with methods described in the Unified Guidance (USEPA, 2004 [draft] and 2009 [final]) and developed with input and direction from KPHD; and
- Prepare quarterly and annual environmental monitoring reports.

In addition, the SWHP requires ongoing operation and maintenance (O&M) activities necessary to allow for continued facility maintenance. These O&M activities include, but are not limited to, the following:

- Stormwater quantity and quality control.
- Slope stability, erosion, and dust control.
- Maintenance of access roads and ditches.
- Maintenance of facility structures and systems (i.e., stormwater, Landfill cap, gas control, surface water, and groundwater monitoring, etc.).
- Control and minimization or elimination of threats to human health and environment.
- Unauthorized entry at the facility shall be controlled, at a minimum, by means of a lockable gate, barrier, fence, etc., at the property boundary.

Groundwater sample data from wells MW-3 and MW-6 show concentrations of the constituents iron, manganese, and arsenic that are greater than Washington State Groundwater Standards. However, arsenic concentrations are also consistently greater than the Washington State Groundwater Primary Standard in samples from upgradient well MW-1, cross gradient well MW-5A, and in nearby water supply wells, some of which are completed in a deeper aquifer (EPI, 2011).

Historical data demonstrate that vinyl chloride was consistently detected at concentrations greater than the Washington State Groundwater Primary Standard in samples from MW-3 and MW-6. However, recent vinyl chloride data from these two wells have been non-detect for five of the six most recent sampling events from the March 2010 through June 2011 quarterly events. Time-series plots of constituent concentrations over time demonstrate significant improvements in groundwater quality, particularly in vinyl chloride results from downgradient wells MW-3 and MW-6 (Appendix C).

Prior to this RI/FS, four downgradient privately owned water supply wells were sampled on April 25, 1995, and again on September 24, 1997, to evaluate potential impacts to groundwater users downgradient of the Landfill. Both data sets noted no measurable impacts to groundwater quality in samples from the water supply wells.

Historical data from quarterly MFS monitoring at the Landfill indicate that the three passive landfill gas flares rarely produce measurable concentrations of methane, and commonly have oxygen, carbon dioxide, and methane concentrations that are similar to ambient air.

In March 1994, a bar hole survey was performed to investigate potential landfill gas migration. Soil vapor was collected and measured at 34 approximately 3-foot-deep bar-hole locations around the perimeter of the Landfill. Methane was not detected in samples from any of the bar hole locations. Oxygen was measured at 21 percent (ambient conditions) in all but one of the bar holes. At bar-hole location GS-3, which is next to the northern perimeter road approximately 200 feet east of MW-3, oxygen was measured at 14 percent. The low oxygen measurement can be an indication of landfill gas; however, methane, which is a stronger indicator of the presence of landfill gas, was not detected in the sample from this location in 1994 (CH2M HILL, 1994).

Prior to the RI field activities, the greatest methane measurement was 50 percent by volume in Flare 1 in the May 1994 and in Flare 2 in the July 1994 monitoring events. In September 2000, measurements of 19.4 percent and 17.1 percent methane by volume in air were recorded in Flares 1 and 2, respectively. From December 2000 through June 2010, methane concentrations have been less than 10 percent by volume in air.

In January 2006, at the request of KPHD, KCPW reported a release at the Landfill to Ecology in accordance with requirements of WAC 173-340-300(2). In January 2007, Ecology notified Kitsap County that the Landfill was placed on the Confirmed and Suspected Contaminated Sites (CSCS) list as a site known to be contaminated with hazardous substances (Ecology, 2007). The Ecology Toxics Cleanup Program completed a Site Hazard Assessment (SHA) of the Landfill in February 2008 based on existing analytical data and information. Ecology ranked the Landfill as a “3,” with “1” being the highest risk and “5” being the lowest risk (Ecology, 2008). To date, Kitsap County has not been notified by Ecology as a Potentially Liable Person (PLP) for the Olalla Landfill. KCPW voluntarily completed this RI/FS as an Independent Remedial Action, which has been performed to follow the MTCA process and meet the criteria of MTCA.

1.7 RI/FS DATA GAPS

As part of the RI/FS process, KCPW and their environmental consulting team identified several data gaps that required additional RI tasks designed to provide data necessary for the FS. In addition, the KCPW team met with KPHD and Ecology to discuss additional data gaps that should be addressed during the RI process. Steps to fill these additional data gaps identified by the regulators were included in the RI planning documents. The identified data gaps, rationale for each identified data gap, RI section where the data gap is addressed, and additional comments are summarized in Table 1-1 (located at the end of the document).

2. RI FIELD INVESTIGATION METHODS

The following sections present summaries of field investigation elements that were performed during the RI. Field investigation methods are grouped by the environmental medium that was investigated. The environmental media investigated under the RI are: groundwater, surface water, solid waste, and landfill gas.

2.1 GROUNDWATER INVESTIGATION METHODS

Groundwater at the Landfill has been sampled in monitoring wells on a quarterly monitoring schedule since 1992; however, monthly monitoring was conducted in 1994. As a result, a large and comprehensive database of groundwater sample analytical data exists for the monitoring well network at the Landfill. Although groundwater at the Landfill has been extensively analyzed for 81 volatile organic compounds (VOCs), conventional parameters (cations and anions), total coliform, and five to eight metals common to landfill leachate, only four constituents are routinely detected at concentrations greater than current regulatory levels noted in the SWHP. The four constituents are vinyl chloride, arsenic, iron, and manganese. These four constituents comprised the pre-RI Constituents of Concern (COCs) for the Landfill. Additional COCs could be added to the COC list based on the results of an expanded groundwater sampling program performed specifically for the RI.

Groundwater sampling for the RI incorporated a total of nine monitoring wells. The monitoring well network consists of seven existing monitoring wells, including Landfill interior wells MW-2 and MW-4, and two new downgradient wells, MW-8 and MW-10.

Locations for new monitoring wells MW-8 and MW-10 were selected based on flow path evaluations using historical groundwater elevation contours and flow paths from quarterly monitoring reports relative to refuse in the Phase I area of the Landfill. The consulting team also evaluated the distances between existing downgradient wells and determined that one new monitoring well should be installed in the area between existing monitoring wells MW-7 and MW-6 and also one new monitoring well between monitoring wells MW-6 and MW-3. In addition, recharge and discharge zones for the Landfill were considered based on the location of the Landfill within the Burley Creek Watershed.

The recharge area for the Landfill extends east to the divide between the Burley Creek Watershed and the upgradient Purdy Creek Watershed, which is approximately 600 feet east of the eastern Landfill property boundary. The discharge areas for groundwater flowing beneath the Landfill include the minor springs and seasonal creeks reported to exist on the property to the west of the Landfill and the more significant discharge zone at Burley Creek, located approximately 2,900 feet west of the western property boundary of the Landfill.

RI groundwater sampling was performed at the new and existing monitoring wells in conjunction with the quarterly monitoring events for four consecutive quarters beginning in October 2010 and ending in June 2011. Two of the quarterly groundwater monitoring events performed during the RI included analyses for the comprehensive Appendix II and Appendix III constituent lists found in WAC 173-351-990. The remaining two quarterly RI groundwater monitoring events included analyses for the list of constituents in the 2010-2011 SWHP for the Landfill.

Groundwater investigation tasks performed during the RI are described in greater detail in the following sections.

2.1.1 Monitoring Well Installation

The KCPW consulting team performed groundwater flow path analysis and evaluations of site-specific geology to identify appropriate locations and screened intervals for two additional downgradient monitoring wells designated as MW-8 and MW-10. The identifier MW-9 has historically been used for field duplicate samples and, therefore, to coordinate with the existing monitoring well naming convention and avoid database issues, MW-9 was not used to identify either of the new monitoring wells.

MW-8 and MW-10 were installed downgradient of the Landfill with new well MW-8 located between existing wells MW-6 and MW-7 and new well MW-10 located between existing wells MW-3 and MW-6, as shown in Figure 2-1. Monitoring wells MW-8 and MW-10 were drilled as close to the downgradient property boundary as possible based on accessibility by a truck-mounted drilling rig.

2.1.1.1 Drilling, Soil Sampling, and Geologic Logging

The new wells were installed on October 7, 2010 using a standard truck-mounted hollow-stem-auger (HSA) drilling rig. All borings were logged and sampled by an on-site EPI geologist licensed in Washington State. Soils encountered were logged in accordance with the Unified Soil Classification System (USCS) Standard Practice Description and Identification of Soils (Visual Manual Procedure) (ASTM 2488D-09a). Samples for geologic logging were taken using decontaminated split-spoon samplers at 5-foot intervals and whenever a change in drilling rate, noise, or drill cuttings indicated a possible change in the geology, as directed by the EPI geologist. Observed geologic information at each borehole location was recorded on geologic logging forms. Geologic logs, as-built well diagrams, and photos of split-spoon samples are included in Appendix D.

A representative sample of aquifer material was collected from the screened interval at both new well locations. These soil samples were submitted to Aquatic Research Inc. for grain size analysis with hydrometer using ASTM Method D421/D422 (particle size distribution) to confirm visual soil classifications. No other borehole samples were collected for soil laboratory analysis.

Soil samples were field screened using visual and olfactory observations and by measuring vapor concentrations of each sample interval using a photoionization detector (PID). Immediately after opening the split-spoon sampler, the PID was slowly passed over the soil sample, and any detections of organic vapors were logged on the field data sheets. No PID detections greater than 10 parts per million were noted in any of the soil cores. The PID measurements below 10 ppm were attributed to moisture in the soil, which causes positive interference with the PID and, therefore, no soil samples were collected or submitted for laboratory analysis of VOCs by USEPA (United States Environmental Protection Agency) Method 8260C.

2.1.1.2 Monitoring Well Construction

The two new monitoring wells were drilled and installed to meet resource protection well construction standards found in WAC 173-160-420, Minimum Standards for Construction and Maintenance of Wells. The wells are constructed of 2-inch-diameter, flush-threaded, Schedule 40 PVC well casing and screen in conformance with WAC 173-160-430.

Well screens are constructed with 0.01-inch (10-slot) flush-threaded, machine-slotted, Schedule 40 PVC installed from approximately 25 to 35 feet below ground surface (bgs) at MW-8, and from 37 to 47 feet bgs at MW-10. The well design includes a 0.5-foot flush threaded Schedule 40 PVC sump with a flush-threaded end cap. Well screens are set in 2/12 Monterey silica sand filter pack, which extends from the bottom of the well screen assembly to at least 1 foot above the top of the screened interval. A minimum 2-foot-thick seal of hydrated bentonite chips is installed in the annular space immediately above the sand filter pack. The remainder of the annular space is sealed with bentonite chips, hydrated in place, to within approximately 1 foot of the ground surface. Flush-threaded, Schedule 40 PVC well casing extends from the top of the screened interval to approximately 2 feet above ground surface. A 2-inch-diameter, locking, watertight PVC well cap is installed to secure the well casing. Stainless steel centralizers were installed immediately above and below the screened interval to keep the well screen centered in the borehole and sand filter pack.

New monitoring wells MW-8 and MW-10 are secured in aboveground completion steel protective monuments set in concrete approximately 2 feet below ground with a 3-foot stickup height. The protective steel casing is further protected with three 3-inch-diameter steel bollards arranged in a triangular pattern and set in concrete. The bollards are 6 feet in length and are installed with 3 feet below ground and 3 feet above ground. Following installation, the bollards were filled with concrete for additional protection. Well construction diagrams for MW-8 and MW-10 are included in Appendix D. Total depths and screened intervals of the new wells are summarized in Table 2-1.

All down-hole well components were factory-decontaminated and in their original sealed packaging or decontaminated to the satisfaction of EPI's on-site geologist before installation. All down-hole drilling equipment was decontaminated as discussed in Section 3.0, and per the Quality Assurance Project Plan (QAPP).

2.1.1.3 Monitoring Well Development

New monitoring wells MW-8 and MW-10, and existing Landfill interior wells MW-2 and MW-4, were developed on October 8, 2010 by the drilling subcontractor under the oversight of the EPI geologist. Wells MW-2 and MW-4 were sampled prior to redevelopment to establish baseline conditions as requested by Ecology. Redevelopment was performed at MW-2 and MW-4 on October 13, 2010 because they had not been sampled since February 1990, and their sample-ready status was unknown.

Well development was performed using a combination of surging and over-pumping, generally following the guidance documented in Resource Conservation and Recovery Act (RCRA) Ground-Water Monitoring: Draft Technical Guidance (USEPA, 1992). Development was completed by continuous pumping at a steady rate using a submersible pump. Development equipment used inside a well was decontaminated to the satisfaction of the EPI geologist by pressure washing before use and between wells.

The field parameters pH, temperature, conductivity, and turbidity were measured and recorded during well development. In addition, color changes of water before, during, and after development were observed and recorded. Completed well development field data sheets are included in Appendix D.

Development water was retained in sealed U.S. Department of Transportation (DOT)-approved 55-gallon drums pending characterization and disposal. Characterization and disposal of well development water was completed by submitting representative samples to Aquatic Research, Inc. (ARI) in Seattle for metals and VOC analyses. Development water was disposed in a manner consistent with the analytical results as approved by KPHD.

2.1.1.4 Monitoring Well Surveying

After installation of MW-8 and MW-10 was completed, all new and existing monitoring well locations were surveyed for horizontal and vertical control using global positioning system (GPS) Real Time Kinematic (RTK) surveying equipment. Elevations were surveyed from the National Geodetic Vertical Datum 1929 (NGVD 1929) to an accuracy within 0.01 foot. Horizontal control accuracy was within 0.1 foot. Survey results are summarized in Table 2-2 and are presented in Appendix E.

2.1.2 Groundwater Level Measurements

Groundwater level measurements were obtained before sampling at each monitoring well at the Landfill. Groundwater levels were measured to the top of the well casing at a marked measuring point or to the north side of the casing if no measuring point was present. Depth to water measurements were performed using an electronic water level indicator and were measured to a precision of 0.01 foot. Depth to water measurements and measurement times were recorded in an RI field book. Depth to water measurements for the four quarterly monitoring events performed as part of the Olalla Landfill RI/FS are included in Appendix F.

2.1.3 Monitoring Well Sampling

Existing monitoring wells MW-1, MW-3, MW-5A, MW-6, and MW-7 and new RI/FS monitoring wells MW-8 and MW-10 are equipped with dedicated Grundfos Rediflow II submersible pumps that were used for both purging and sampling. Landfill interior wells MW-2 and MW-4 were purged and sampled using a Grundfos Rediflow II submersible pump, which was decontaminated before use and between each well location.

Wells were purged prior to sampling using low-flow (minimal drawdown) purging procedures. One exception to this procedure is that the initial sampling event for wells MW-2 and MW-4 was performed using no-purge sampling techniques as requested by Ecology. Low-flow purging procedures were used to minimize disturbance associated with turbidity and to provide quicker stabilization time for the measured field parameters pH, dissolved oxygen (DO), temperature, specific conductance, turbidity, and oxidation-reduction potential (ORP). The probes were housed in a flow-through cell to avoid entrainment of atmospheric gases during measurement, which can affect results. Procedures and guidance for low-flow purging and sampling can be found in the document titled Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures (USEPA, 1996).

Purge water field parameters were measured during low-flow purging and recorded on the field data sheets (Appendix F) approximately every 3 to 5 minutes. In addition, the appearance or odor of the water was described on the field data sheets if notable. The purge stabilization criteria are based on three successive readings of the field water quality parameters. The following are the stabilization criteria that were used for low-flow purging:

- pH: Plus or minus 0.1 pH units.
- Specific Conductance: Plus or minus 3 percent.
- ORP: Plus or minus 10 millivolts (optional).
- Turbidity: Plus or minus 10 percent (when turbidity is greater than 10 nephelometric turbidity units [NTUs]).
- Dissolved Oxygen (DO): Plus or minus 0.3 µg/L (optional).
- Temperature: Plus or minus 0.1°C.

Groundwater samples were collected following low-flow well sampling procedures when the above stabilization criteria were met. The appropriate use of field equipment and decontamination protocols was followed to minimize or eliminate the potential for cross contamination. Nitrile gloves, or equivalent, were changed, at a minimum, between wells and whenever a potential for cross-contamination was suspected.

The constituent groups for chemical laboratory analysis are the constituents listed in Appendix II and Appendix III of Criteria for Municipal Waste Landfills (WAC 173-351-990) (Appendix G) and the SWHP. Groundwater samples were collected into laboratory-cleaned, pre-labeled sample bottles and preserved as appropriate for the analytical parameters. Sample bottles were filled starting with the most sensitive sample aliquot and ending with the least sensitive aliquot as summarized below.

1. VOCs.
2. Semivolatile Organic Compounds (SVOCs).
3. Polychlorinated Biphenyls (PCBs) (reported as Aroclors).
4. Total Coliform.
5. Geochemical Indicator Parameters – Bicarbonate, Carbonate, Chloride, Sulfate, Alkalinity, Ammonia, Nitrate, and Nitrite.
6. Total Organic Carbon (TOC).
7. Total Dissolved Solids (TDS).
8. Cyanide.
9. Total Metals – Mercury and Nickel.
10. Dissolved Metals – Antimony, Arsenic, Barium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Potassium, Selenium, Silver, Sodium, Thallium, Tin, Vanadium, and Zinc.
11. Chemical Oxygen Demand (COD).

Groundwater samples collected for dissolved metals analyses were field-filtered prior to collection using single use disposable in-line 0.45-micron filters.

2.1.4 Water Supply Well Sampling

Groundwater elevation contour maps from the Landfill have shown a consistently northwestern to western groundwater flow direction. The adjacent areas northwest and west of the Landfill (downgradient of the Landfill) are developed with private residences served by private water supply wells. Most of the off-site water supply wells are completed in a deeper aquifer that is not directly hydraulically connected to the uppermost aquifer that has been impacted by the Landfill.

Four off-site wells located to the west and northwest of the Landfill were previously sampled in 1995 and 1997 for vinyl chloride and dissolved metals (arsenic, iron, and manganese). Analytical results for samples from these wells indicated no measurable impacts for these constituents associated with the Olalla Landfill. Vinyl chloride was not detected in samples from any of the off-site wells and dissolved metals concentrations were less than applicable drinking water criteria.

KCPW and their consulting team worked with KPHD to sample groundwater from six off-site water supply wells. The six off-site water supply wells were sampled for VOCs, vinyl chloride by SIM, and the dissolved metals arsenic, iron, and manganese. The six off-site water supply wells that were sampled during the RI/FS are shown on Figure 2-2 relative to the Landfill location.

Off-site well sampling included water level measurements, if possible, well purging and field parameter stabilization, and sample collection. The procedures for these sampling activities are described in the Sampling and Analysis Plan (SAP). The field parameters listed below were measured and documented at the time of sampling:

- Measured or estimated purge volume
- Temperature

- pH
- Specific Conductance
- DO
- ORP
- Turbidity

2.2 SURFACE WATER INVESTIGATION METHODS

As part of the ongoing quarterly monitoring program under Chapter 173-304 WAC, surface water at Olalla Landfill is sampled annually, when present, from location SW-2. SW-2 is located at the main culvert that discharges into the stormwater detention pond (Figure 2-3). During the RI, surface water samples were collected from SW-2 and from two additional surface water sampling locations. The new surface water sampling locations are designated SW-3 and SW-4 as shown in Figure 2-3. These locations were identified during a reconnaissance visit to the Landfill to provide representative samples of surface water runoff from the area outside of the Landfill (SW-3) and from the Landfill interior (SW-4).

2.2.1 Ditch and Detention Pond Sampling

To the extent possible, field staff scheduled the December 2010 and March 2011 quarterly monitoring events to coincide with periods of heavy precipitation when surface water runoff was expected to be present at the Landfill. Sufficient surface water for sampling was present during both the December 2010 and March 2011 site visits, and field samplers obtained surface water samples from SW-2, SW-3, and SW-4 in December 2010 and from SW-3 and SW-4 in March 2011.There was not adequate flow at SW-2 during the March 2011 sample event to collect a sample.

Field parameter measurements were performed and recorded prior to sampling surface water locations. However, unlike monitoring wells, there is no purging required prior to surface water sampling and only one set of field parameter measurements is required at each sample location. The field parameters listed below were measured and documented at the time of sampling and are included in the analytical data summary tables in Section 4 for each of the quarterly sampling events in which surface water was sampled:

- Measured or estimated flow rate (bottle and stopwatch method)
- Temperature
- pH
- Specific Conductance
- DO
- ORP
- Turbidity

Surface water samples collected in December 2010 were analyzed for the constituent groups in Section IV(D)(2) and (3) of the 2010–2011 SWHP (Appendix B). These analyses are summarized below:

- VOCs.
- Total and fecal coliform.

- Conventional parameters (alkalinity, ammonia, bicarbonate, carbonate, chloride, sulfate, nitrate, nitrite, and pH).
- TOC.
- Dissolved Metals (arsenic, barium, iron, manganese, and zinc).

2.2.2 Spring Sampling

Springs have historically been reported on the private property located west (downgradient) of the Landfill. However, KPHD, KCPW, and their consulting team were unable to obtain permission to access this property during the RI. Therefore, springs were not identified or sampled during the RI/FS.

2.3 SOLID WASTE INVESTIGATION METHODS

Solid waste data gaps identified for the Landfill are summarized in Table 1-1 and are described in the following paragraphs:

- Evaluate aerial photos and other historical data for Phase II area; determine if refuse was present in areas upgradient of MW-3 and MW-6.
- Prepare updated map of the Phase II area showing capped versus uncapped areas and areas with solid waste.
- Excavate test pits and trenches in Phase II area.
- If refuse is found in trenches, delineate the depths, thickness, and lateral extent of refuse.
- If refuse is found in Phase II area, evaluate potential costs and benefits of removing refuse.

Available historical records, including aerial photos, indicate that refuse was placed in areas inside and outside of the Phase I Area of the Landfill, including the area immediately north of the Phase I Area (known as the Phase II Area). Refuse found in the Phase II Area during Phase I closure activities was reportedly consolidated into the Phase I Area, which was later capped with an engineered low-permeability bentonite amended soil cap as part of the Landfill closure process.

During negotiations regarding the scope of work for the RI/FS, regulatory agencies required on-site confirmation that there is no refuse buried in the Phase II Area of the Landfill as part of the RI effort. On October 7, 2010, the KCPW consulting team excavated five exploratory trenches to evaluate if refuse is buried in the Phase II Area of the Landfill. The locations of the exploratory trenches that were performed at the Landfill are shown in Figure 2-4.

All trenches were backfilled using the excavated soil following evaluation and documentation of the material encountered. Backfilled soil was compacted to the extent possible using the bucket of the excavator. KCPW will monitor the backfilled exploratory trenches for settling and will add additional soil if needed. KCPW will also monitor the Phase II Area of the Landfill to confirm that the backfilled exploratory trenches are re-vegetated to their original condition.

2.4 LANDFILL GAS INVESTIGATION METHODS

A passive Landfill gas collection system and three Landfill gas flares were installed in the Phase I Area during Landfill closure. Since 1992, landfill gas has been monitored at these flares for the field-measured parameters: methane, LEL, carbon dioxide, oxygen, and gas pressure. The alignment of the perforated horizontal Landfill gas collection pipe and the locations of the three Landfill gas flares, designated Flares 1, 2, and 3, are shown in Figure 2-5.

Prior to performing this RI/FS, landfill gas at the three on-site flares was not sampled or analyzed for VOCs. This represented a data gap that was addressed in the RI/FS because VOCs potentially present in landfill gas can partition into groundwater causing VOC detections in groundwater at locations that are not necessarily logical given groundwater flow directions. Landfill gas can spread in all directions and can cause groundwater impacts in areas across and upgradient of the groundwater flow direction.

Prior to performing the RI/FS, historical groundwater flow direction data based on flawed measuring point elevation data indicated a generally east to west groundwater flow direction beneath the Landfill, and well MW-3 appeared to be cross gradient to the Phase I Area of the Landfill. The relatively consistent and low concentration detections of vinyl chloride in samples from well MW-3 indicated that there was a possibility of a soil vapor to groundwater contaminant transport pathway that would require further investigation. The first step of the landfill gas investigation process was to determine if landfill gas contains detectable concentrations of VOCs.

2.4.1 Landfill Flare Sampling Methods

Prior to initiating landfill gas sampling, field staff repaired or replaced the sampling ports on each of the three passive Landfill gas flares. Upon completion of sampling port repair work, field staff temporarily shut in all three flares using sewer balls to block the release of landfill gas and prevent the introduction of ambient air into the flares. The sewer balls were installed in the blank pipe section of the flare above the sampling port.

The three flares are connected by lateral piping as shown in Figure 2-5; therefore, all three flares were shut in concurrently to seal the entire flare system. After all three flares were sealed, field staff allowed landfill gas pressure in the flares to equilibrate. Field staff measured pressure, methane, oxygen, and carbon dioxide in all three flares to confirm equilibration prior to landfill gas sampling for laboratory analysis.

2.4.2 Landfill Flare Sample Analysis

On October 15, 2010, landfill gas samples were collected from sampling ports on Flares 1, 2, and 3 for VOC analysis. Samples were collected into laboratory-decontaminated, laboratory provided one-liter Summa canisters, which were slowly filled over a period of approximately 2 minutes using a laboratory-decontaminated and provided gas flow regulator. Filled Summa canisters were sent to Air Toxics Ltd. (Air Toxics) for analysis by USEPA Method TO-15. Summa canister samples require no preservation and were shipped to Air Toxics inside of appropriate cardboard shipping boxes under standard chain-of-custody procedures.

3. SCREENING LEVEL DEVELOPMENT

Screening levels for the project are defined as constituent concentrations above which the levels may pose a threat to human health or the environment. The regulatory levels chosen as screening levels for the relevant environmental media at the Landfill include:

- Washington State Groundwater Standards (WAC 173-200-040)
- Washington State Primary and Secondary Drinking Water Standards (WAC 246-290-310)
- Department of Ecology's Cleanup Levels and Risk Calculations (CLARC) Method A and Method B values from MTCA (Chapter 173-340 WAC).

3.1 GROUNDWATER SCREENING

As part of the RI/FS, the extensive historical record of groundwater data was evaluated, and this evaluation identified a small number of constituents that have been detected at concentrations greater than the screening levels listed above. Based on the historical groundwater data evaluations, the initial groundwater constituents of concern (COCs) for the Landfill are arsenic, iron, manganese, and vinyl chloride.

Two additional monitoring parameters, pH and total coliform, have sporadic results that are also outside of their screening levels. The rationale for not including pH and total coliform as COCs is presented below.

- **pH** – pH is measured in the field during well purging and is also analyzed in the laboratory as a check on the field measurements. Generally, field-measured pH values are lower than laboratory results, and in some cases, are slightly lower than the secondary Washington State Groundwater Standard range of 6.5 to 8.5. Low field-measured pH values (less than 6.5) are sporadically noted in purge water from all monitoring wells including upgradient well MW-1. Low laboratory-measured pH values are very uncommon, which indicates that the low pH measurements are likely a field instrument issue and are unrelated to the presence of the Landfill; therefore, pH was eliminated as an initial COC for the Landfill.
- **Total Coliform** – Total coliform has been sporadically detected in samples from all MFS monitoring wells, including upgradient well MW-1 and was also detected in the October 2010 sample from new RI/FS monitoring well MW-8. Based on the rare and sporadic nature of the total coliform detections, the presence of total coliform in some groundwater samples are likely related to cross-contamination by field staff or to transient conditions in the wells themselves, rather than a total coliform problem in the aquifer beneath the Landfill; therefore, total coliform was eliminated as an initial COC for the Landfill.

The groundwater data obtained during the remedial investigation conducted at the Landfill was also compared to the screening levels. A discussion of these results is contained in Section 4.

3.2 SURFACE WATER SCREENING

Surface water discharges from active and inactive landfills are regulated under the National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit for Stormwater Discharges Associated with Industrial Activities (i.e., Industrial Stormwater General Permit). Special Condition S1.C.10 of the Permit excludes "Closed landfills that are capped and stabilized, in compliance with Chapter 173-304 WAC, and in which no significant materials or industrial pollutants remain exposed to stormwater" from obtaining a permit. The only industrial pollutants from the Landfill that may be exposed to stormwater at the Landfill would be from potential intermittent seeps along the western portion of the Landfill, which have not been observed. Also, based on the final closure plan (Parametrix dated 1988), stormwater discharges from the detention pond may only occur during events larger than a 25-year, 24-hour storm event while the majority of stormwater will infiltrate into the bottom of the detention pond. Due to the exclusion granted by the Industrial Stormwater General Permit, the lack of impact on stormwater quality from potential seeps and the infiltration of the majority of stormwater from the Landfill, we used the groundwater screening levels for comparison to the surface water samples collected from the drainage ditches and the detention pond culvert. A discussion of these results is contained in Section 5.

4. GROUNDWATER INVESTIGATION RESULTS

Groundwater data obtained under the RI/FS investigation are presented and evaluated in the following sections. In addition, available historical Landfill monitoring data and information from off-site areas, including off-site water supply wells, are evaluated to provide a more comprehensive understanding of area-wide hydrogeology and groundwater quality.

4.1 GEOLOGY AND HYDROSTRATIGRAPHY

The Olalla Landfill RI/FS consulting team reviewed available regional geologic information to identify the geologic units that were encountered at the Landfill and surrounding area during drilling. The consulting team reviewed historical geologic logs for Landfill monitoring wells and also for water supply and other wells installed in the area surrounding the Landfill. New geologic logs were also generated during drilling for wells MW-8 and MW-10, which were installed in the area west and northwest of the Landfill and are provided in Appendix D. This information was used to update and expand hydrogeologic cross sections drawn through the Landfill and the surrounding area.

The geologic units observed in samples from boreholes for the new downgradient wells MW-8 and MW-10 are consistent with the geology observed in boreholes for the nearby downgradient wells MW-3, MW-6, and MW-7. The upper approximately 20 feet at each downgradient well location consists of dense, generally well-graded sand with gravel, which is identified as weathered glacial till. The weathered glacial till layer is underlain by poorly graded fine to medium sand with a trace of gravel and silt and is identified as advance outwash deposits. The uppermost aquifer at the Landfill is contained within these advance outwash deposits. Regional geologic descriptions for units underlying the Landfill are presented and described in a bullet list presented later in this section.

Geologic logs for all four downgradient monitoring wells confirm that there were no lenses or layers of perched groundwater in the geologic formations above the uppermost aquifer in which the monitoring wells are screened. In addition, geologic logs indicate that there were no low permeability layers encountered that could potentially form a perched groundwater layer at a depth above the uppermost aquifer.

A shallow perched groundwater zone has only been identified in the boreholes for three wells installed in the north part of the Landfill property; MW-5, which is screened in the perched zone, MW-5A, and the South Kitsap County Transfer Station Well. The boring log for Landfill interior well MW-4 indicates wet refuse containing paper and carpet scraps at 3 to 8 ft. bgs. The wet refuse does not appear to represent a perched groundwater zone because is not underlain by a low permeability layer that is capable of perching groundwater. In addition, the boring log for Landfill interior well MW-2, which was drilled at the same time as MW-4, indicates that the refuse encountered was moist, but was not wet and no low permeability layers or perched groundwater zones were encountered in the MW-2 borehole.

Landfill interior monitoring wells MW-4 and MW-2 were drilled in April 1985, several years before the Landfill was capped and the refuse was subject to much greater infiltration rates compared to the current infiltration rates through the engineered low permeability Landfill cap. Therefore, there is no evidence of perched groundwater zones in the geologic units beneath the Landfill and no reason to suspect their presence, especially under the current conditions of significantly limited infiltration through the Landfill cap.

The locations and alignments of four hydrogeologic cross sections through the Landfill are shown in Figure 4-1. Cross section A-A’ is presented in Figure 4-2a and runs from west to east through the Landfill. Cross section B-B’ is presented in Figure 4-2b and runs north to south through the Landfill. Cross sections C-C' and D-D' (Figure 4-2c and 4-2d, respectively) run north-south through the downgradient Landfill monitoring wells, and D-D' extends beyond the property boundary to include off-site well OW-3, which was one of the off-site water supply wells sampled during the off-site well sampling event performed during the RI/FS.

The hydrostratigraphy encountered beneath the Landfill is comprised of granular deposits emplaced during the Vashon glaciation as shown in the four cross sections presented in Figures 4-2a through 4-2d. The geologic formations underlying the Landfill contain three distinct occurrences of groundwater beneath the Landfill, from shallowest to deepest they are: the shallow perched groundwater zone, which is perched on top of the ice-contact deposits (Qvi) and is found only at MW-5, MW-5A, and the South Kitsap County Transfer Station Well, the uppermost unconfined aquifer, which occurs in the advance outwash deposits (Qva), and the deeper confined aquifer, which occurs in the Olympia Beds (Qob). These geologic formations are described in the Geologic Map of the Olalla 7.5′ Quadrangle King, Kitsap, and Pierce Counties, Washington (Booth and Troost, 2005) and summarized are below starting with the uppermost formation present at the Landfill:

- **Recessional Outwash Deposits (Qvr)** – Stratified sand and gravel, moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow. At the Landfill the Qvr formation occurs as light brown poorly-graded sand that is present in areas north, south, and east (upgradient) of the Landfill but is not present beneath the Landfill itself and is also not present in geologic logs at downgradient well locations. The Qvr deposit is approximately 35 feet thick to the south (cross gradient) of the Landfill and approximately 15 to 20 feet thick north (cross gradient) and east (upgradient) of the Landfill.
- **Ice-Contact Deposits (Qvi)** – Deposits similar in texture to unit Qvr but locally containing a much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till. This unit is present at MW-5, MW-5A, and the South Kitsap County Transfer Station Well locations, which are cross gradient to the Landfill. The Qvi unit does not extend to the area underlying the Landfill and was not indicated in geologic logs from upgradient, downgradient, and Landfill interior well locations. The Qvi formation ranges in thickness from approximately 30 feet at the South Kitsap County Transfer Station Well to 35 feet thick at MW-5A. A laterally discontinuous zone of perched groundwater occurs on top of the Qvi deposit as shown in Figure 4-2b.
- **Till (Qvt)** – Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms an undulating surface a few tens of meters thick. The Qvt unit is also found sporadically within areas mapped as unit Qvi. The Qvt unit was identified in geologic logs for wells throughout the Landfill property. The Qvt unit ranges in thickness from approximately 10 feet thick at MW-5A and MW-3 to approximately 20 feet thick at MW-6, MW-8, and MW-10. Groundwater levels in the uppermost unconfined aquifer extend to the bottom of the Qvt unit in the downgradient wells.
- **Advance Outwash Deposits (Qva)** – Well-bedded sand and gravel deposited by streams and rivers that issued from the leading edge of the advancing ice sheet. Formation is generally unoxidized almost devoid of silt or clay, except near the base of the unit. The Qva unit was identified in geologic logs for wells throughout the County's property. The Qva unit contains the uppermost unconfined aquifer and is the geologic unit in which all the monitoring wells are screened. The only well that fully penetrates Qva is the South Kitsap County Transfer Station water supply well (OW-1) and the geologic log for this well indicates that Qva is approximately 100 feet thick at this location.

The formations noted above are underlain by a thick sequence of blue clay identified as the Lawton Clay and described below. The top of the Lawton Clay is shown on all cross sections with the exception of cross-section C-C' (Figure 4-2c), which does not contain wells that were drilled deep enough to encounter the Lawton Clay. The full thickness of the underlying clay layer is shown in cross-section D-D' (Figure 4-2d), which indicates the clay layer is approximately 145 feet thick under the Landfill based on the geologic log from nearby off-site water supply well OW-3.

- **Lawton Clay (Qvlc)** – Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial lowland lakes. The full thickness of the underlying clay layer is shown in cross-section D-D' (Figure 4-2d), which indicates the clay layer is approximately 145 feet thick under the Landfill based on the geologic log from nearby off-site water supply well OW-3.

A water-bearing formation identified as the Olympia Beds underlies the Lawton Clay and is described below. This Olympia Beds water-bearing gravel formation is the aquifer that is commonly screened by water supply wells installed near the Landfill as shown in cross section D-D' (Figure 4-2d).

- **Olympia Beds (Qob)** – Pleistocene age sand and silt thinly interbedded with some gravel layers and, locally, with abundant organic material; deposited by lowland streams or in floodplain and (or) lacustrine environments. As noted above, many of the water supply wells installed near the Landfill are screened in the Qob formation, which contains the confined deeper aquifer beneath the Landfill.

4.2 GROUNDWATER LEVEL ELEVATIONS AND FLOW DIRECTIONS

During all four quarterly monitoring events performed for the RI/FS, field staff measured depth to groundwater at all monitoring wells at the Landfill, with the exception of well MW-5. All monitoring wells installed at the Landfill, with the exception of MW-5, are screened in a laterally continuous sand and gravel unit that has been interpreted as belonging to the same uppermost unconfined aquifer unit (Parametrix, 1988). Geologic logs for new wells MW-8 and MW-10 support that interpretation. Monitoring well MW-5 is screened in a shallow perched groundwater zone. Therefore, water level and water quality data are not collected from this well as part of the monitoring program for the Landfill. Monitoring well MW-5A was drilled adjacent to MW-5 and is screened in the uppermost unconfined aquifer, which is the same aquifer, in which the other monitoring wells at the Landfill are screened.

Landfill monitoring well locations and measuring point elevations were surveyed on November 19, 2010, as part of the RI/FS work at the Landfill. The RI/FS measuring point elevations are not consistent with historical measuring point elevation data for the Landfill. The historical survey data were compiled under separate surveying events over the course of several years as wells were installed at the Landfill. The well elevation data were based on data provided by multiple surveying companies, which might not have used the same methods or benchmarks. The RI/FS well elevation survey data are all from one surveying event, performed by one surveying team using modern, highly accurate GPS equipment; therefore, the RI/FS survey data are more consistent than historical surveying data. The measuring point elevations from the RI/FS surveying work were used to calculate groundwater elevations in this report. RI/FS survey data are provided in Appendix E.

Depth to groundwater data measured during the RI on October 28, 2010, December 28, 2010, March 23, 2011, and June 1, 2011, were used to calculate groundwater elevations and are summarized in Table 4-1. Groundwater elevation data from each of the Landfill monitoring wells was used to construct the groundwater elevation contour maps presented as Figures 4-3a through 4-3d. RI/FS groundwater elevation data were also added to a groundwater elevation hydrograph presented in Figure 4-4a. All of the historical groundwater elevation data used for the groundwater hydrograph were adjusted to use the RI/FS survey monitoring well measuring point elevations.

Figure 4-4b presents the most current 5 years (September 2006 to June 2011) of groundwater elevation data for Landfill monitoring wells compared to monthly precipitation totals for the weather station in Bremerton, Washington. Figure 4-4b demonstrates that seasonal peaks in precipitation do not cause corresponding peaks in groundwater elevations at the Landfill. Longer-term precipitation trends appear to correlate to groundwater elevation trends. The relatively warm dry summers the region experienced during 2007-2009 resulted in decreases in groundwater elevations over that period (approximately a 6.5 foot decrease based on data from MW-1). During 2010-2011 the region has experienced two consecutive wet and cool summers and groundwater elevations have correspondingly risen since the fall/winter of 2009 (approximately a 6.5 foot increase based on data from MW-1).

Based on the RI/FS measuring point elevations, the general groundwater flow direction beneath the Landfill is consistent throughout the year and is generally toward the northwest as depicted in Figures 4-3a through 4-3d. Recent (2010 and 2011) groundwater elevation data exhibit an upward trend, likely due in part to the wet winter and spring and the cool summers the region experienced in 2010–2011.

4.3 HYDRAULIC CONDUCTIVITY OF THE UPPERMOST AQUIFER

The hydraulic conductivity “K” of the aquifer has been estimated from the results of single well aquifer tests (slug tests) performed in monitoring wells MW-1, MW-2, MW-3, and MW-4. The range of hydraulic conductivity values obtained from these tests indicated that the hydraulic conductivity of the aquifer is approximately 7×10^{-3} to 3×10^{-2} cm/sec (approximately 20 to 85 feet/day), with an average value of 2.2×10^{-2} cm/sec (62.4 feet/day) (Parametrix, 1988).

During well drilling performed as part of the RI/FS, field staff collected soil samples from the planned screened intervals in the boreholes for new wells MW-8 and MW-10. These samples were sent to Aquatic Research Inc. for sieve analysis to determine grain size distribution of the aquifer material from which hydraulic conductivity was calculated using the empirical Hazen equation. Sieve analysis results for soil samples from MW-8 and MW-10 are presented in Appendix D.

Based on the Hazen equation using grain size data from samples of aquifer material obtained from MW-8 and MW-10, the calculated hydraulic conductivity of the uppermost aquifer is approximately 1.2 x 10-2 cm/sec (34 feet/day) for the sample from MW-8 and 1.4 x 10-2 cm/sec (40 feet/day) for the sample from MW-10. These calculated hydraulic conductivity values based on grain size analysis results are in general agreement with the single well aquifer test results.

4.4 CALCULATED GROUNDWATER FLOW VELOCITIES

Groundwater flow rates based on the RI/FS groundwater elevation contour maps have been calculated based on a modified form of Darcy’s Law:

$$V = KI/n$$

Where: V = average linear velocity (L/T)

K = hydraulic conductivity (L/T)

I = hydraulic gradient (L/L [dimensionless])

n = effective porosity (percent expressed as a decimal)

As noted in the previous section, the hydraulic conductivity "K" of the aquifer was estimated from the results of single well aquifer tests with an average value of 2.2 x 10^{-2} cm/sec (62.4 feet/day) (Parametrix, 1988).

The hydraulic gradient "I" of the aquifer is calculated from groundwater elevation contour maps presented in Figures 4-3a through 4-3d. Average hydraulic gradients across the Landfill range from 0.0098 (in December 2010) to 0.0139 (in June 2011).

The effective porosity "n" of the aquifer is assumed to be 0.40, which is a typical value for fine- to medium-grained sand as noted in the closure report (Parametrix, 1988).

The resulting groundwater flow velocities "V" calculated from RI/FS quarterly data range from 1.53 feet/day in December 2010 to 2.17 feet/day in June 2011. The calculated groundwater gradients and flow velocities are summarized in Table 4-2.

Groundwater velocity data average approximately 2 feet per day; therefore, groundwater passing under the Phase I Area of the Landfill will take approximately 250 days (0.7 year) to flow from the southeast corner to the northwest corner of the Phase I Area. Groundwater traveling from the area near upgradient well MW-1 will take approximately 550 days (1.5 years) to reach downgradient well MW-3.

4.5 SUMMARY OF GROUNDWATER MFS SAMPLING RESULTS

In accordance with the SWHP, groundwater at the Landfill has been sampled under WAC 173-304-407, MFS for Solid Waste Handling on a quarterly schedule since 1992; however, monthly sampling was conducted in 1994. As part of the MFS monitoring program, groundwater samples have been collected and analyzed for combinations of the following constituent groups:

- VOCs.
- Dissolved metals (arsenic, barium, cadmium, calcium, iron, lead, manganese, potassium, selenium, sodium, and zinc).
- Total coliform.
- Conventional constituents (carbonate, chloride, sulfate, bicarbonate, sodium, calcium, nitrate, nitrite, ammonia).
- TOC.
- COD.
- Field parameters (water level, specific conductance, pH, temperature).

As part of the RI/FS, the extensive historical record of groundwater data from the ongoing MFS sampling program was evaluated. This evaluation identified a small number of constituents that are routinely detected at concentrations greater than Washington State Groundwater Standards (WAC 173-200-040) or Washington State Drinking Water Standards (WAC 246-290-310). Screening level evaluations for the historical MFS data are summarized in Section 3.1. Based on this evaluation, the COCs for the Landfill are arsenic, iron, manganese, and vinyl chloride. Time series graphs of concentrations of the four COCs in samples from Landfill monitoring wells from 1992 to June 2011 and for recent 5 years of data (September 2006 to June 2011) are included in Appendix C. Time series graphs of the recent 5 years of data represent current groundwater conditions at the time the RI was performed. The full time series graphs from 1992 to 2011 are presented to provide a historical context.

The occurrence and nature of each of the four COCs in groundwater at the Landfill are summarized in the following bullets.

- **Arsenic** – Arsenic is a naturally occurring metal constituent that is present in native soil and in landfill leachate. Arsenic is more soluble in aquifers with geochemically reducing conditions, which are common in groundwater beneath landfills as a result of depleted oxygen through bacterial degradation of organics in the Landfill and in landfill leachate.

  Arsenic has been routinely detected at concentrations greater than the Washington State Groundwater Standard of 0.05 µg/L in samples from all Landfill monitoring wells, including upgradient well MW-1.

  Arsenic concentrations in samples from Landfill wells have not been greater than the current Washington State Drinking Water Standard of 10 µg/L since a single detection at 11 µg/L in the December 1992 sample from MW-6. Elevated arsenic concentrations in soil are an area-wide issue as discussed in Appendix H. The geochemically reducing conditions in the aquifer beneath the Landfill increases the solubility of the arsenic present in native soil, which increases arsenic concentrations in samples from downgradient monitoring wells relative to concentrations in samples from upgradient well MW-1 at the Landfill.

  Based on the recent time series graph, arsenic concentrations ranged from non-detect at a reporting limit of 0.05 µg/L for March and June 2008 samples from downgradient well MW-3, to 3.23 µg/L for the June 2008 sample from downgradient well MW-6. The time series graphs show that, with the exception of MW-3, arsenic concentrations are commonly greatest in samples from downgradient wells, particularly in samples from wells MW-6, MW-8, and MW-10, moderate in samples from interior and cross gradient wells, and lowest in samples from upgradient well MW-1.

- **Iron** – Iron is a naturally occurring metal constituent that is present in native soil and in landfill leachate. Like arsenic, iron is also more soluble in geochemically reducing conditions commonly found in groundwater at landfills. Iron is commonly detected at concentrations greater than its secondary Washington State Groundwater and Drinking Water Standard of 300 µg/L in samples from downgradient well MW-6.

  Based on the recent time series graph, iron concentrations ranged from non-detect at a reporting limit of 20 µg/L in most samples from wells MW-1, MW-3, MW-5A, and MW-7 to 2,150 µg/L for the October 2010 sample from downgradient well MW-6. The time series graphs show that iron is routinely detected only in samples from downgradient wells MW-6, MW-8, and MW-10. There are sporadic low concentration detections in historical samples from upgradient well MW-1, cross gradient well MW-5A, and downgradient wells MW-3 and MW-7.

- **Manganese** – Manganese is a naturally occurring metal constituent that is present in native soil and in landfill leachate. Like iron and arsenic, manganese is more soluble in geochemically reducing conditions commonly found in groundwater at landfills. Manganese is commonly detected at concentrations greater than its secondary Washington State Groundwater and Drinking Water Standard of 50 µg/L in samples from downgradient wells MW-3, MW-6, MW-8, and MW-10.

  Based on the recent time series graph, manganese concentrations ranged from non-detect in all samples from wells MW-1, MW-5A, and MW-7, to 6,240 µg/L for the June 2011 sample from downgradient well MW-10. The time series graphs show that manganese is only detected in samples from downgradient wells MW-3, MW-6, MW-8, and MW-10. During the last 5 years, manganese has not been detected in samples from upgradient well MW-1, cross gradient well MW-5A and downgradient well MW-7.

- **Vinyl Chloride** – Vinyl chloride is a breakdown product formed by the anaerobic degradation of chlorinated VOCs. The presence of chlorinated VOCs at the Landfill is likely from small quantities of household cleaning products containing chlorinated solvents that are contained in the refuse. Historically, vinyl chloride was routinely detected at concentrations greater than the Washington State Groundwater Primary Standard of 0.02 µg/L in samples from downgradient monitoring wells MW-3 and MW-6. In more recent data from sampling events performed in 2010 and 2011, vinyl chloride was sporadically detected in samples from some downgradient wells during dry season sampling events (i.e., June and October) but was not detected in samples from any wells during wet season sampling events (i.e., December and March). Vinyl chloride was never detected at a concentration greater than the Washington State Drinking Water Primary Standard of 2.0 µg/L in samples from any of the Landfill wells.

  Based on the recent time series graph, vinyl chloride concentrations ranged from non-detect in samples from upgradient well MW-1, cross gradient well MW-5A, and MW-7 to 0.17 µg/L for the December 2007 sample from MW-6. The time series graph for the recent 5 years of data show that vinyl chloride was detected in approximately half of the samples from downgradient wells MW-3, MW-8, and MW-10 and most of the samples from downgradient well MW-6. However, vinyl chloride was only detected in one of the four samples from MW-6 that were collected during the RI. During the past 5 years vinyl chloride was not detected in any samples from upgradient well MW-1, cross gradient well MW-5A, and downgradient well MW-7.

The parameters pH and total coliform have results that are sporadically outside of their regulatory levels. However, these sample results are likely attributable to factors other than releases from the Landfill as described in Section 3.1.

4.6 GROUNDWATER REMEDIAL INVESTIGATION SAMPLING RESULTS

Groundwater samples were obtained from nine monitoring wells at the Landfill during the four quarterly monitoring events comprising the RI/FS field investigation. The monitoring wells sampled during the RI/FS are: MW-1, MW-2, MW-3, MW-4, MW-5A, MW-6, MW-7, MW-8, and MW-10. In addition, interior Landfill wells MW-2 and MW-4 were sampled in October 2010, both prior to and after their redevelopment. The RI/FS groundwater samples were analyzed for a more comprehensive list of constituents for two of the four quarterly RI/FS monitoring events. During the October 2010 and March 2011 sampling events, representing dry seasons and wet season conditions, respectively, groundwater samples were analyzed for the full WAC 173-351-990 Appendix III constituent list, which is the list of hazardous inorganic and organic constituents under the Municipal Solid Waste Landfill regulations. The full Appendix III constituent list is included in Appendix G. Monitoring well sampling results are presented and evaluated for each quarterly RI/FS monitoring event in the following sections.

4.6.1 Summary and Discussion of October 2010 Results

The October 2010 monitoring event was the first groundwater monitoring event performed for the RI/FS. The consulting team performed three groundwater monitoring tasks in October 2010:

- Interior well MW-2 and MW-4 baseline (pre well development) sampling.
- Quarterly MFS groundwater sampling.
- RI/FS groundwater sampling, including post-well development samples from MW-2 and MW-4 (performed concurrently with MFS sampling).

Analytical results from the October 2010 groundwater monitoring tasks are summarized in the following paragraphs.

4.6.1.1 Interior Well MW-2 and MW-4 Baseline Sampling

As requested by Ecology, Landfill interior wells MW-2 and MW-4 were sampled on October 7, 2010, before the wells were redeveloped, which occurred on October 13, 2010, and without pre-purging to establish undisturbed “baseline” groundwater conditions in the aquifer immediately beneath the Landfill.

Baseline groundwater samples from MW-2 and MW-4 were analyzed for the Appendix III list of constituents under WAC 173-351-990 (Appendix G). Analytical data from the baseline MW-2 and MW-4 sampling are summarized in Table 4-4a. This data summary table does not include analytical results for the constituent groups SVOCs, PCBs, and cyanide, which had no detections.

The full set of laboratory data sheets, including the SVOCs, PCBs, and cyanide analytical results which are not summarized in Table 4-4a, are presented in Appendix I. These data demonstrate that, with the exception of arsenic, groundwater samples from MW-2 and MW-4 do not have any constituents detected at concentrations greater than screening levels.

Baseline samples from MW-2 and MW-4 had arsenic concentrations of 0.670 µg/L and 0.212 µg/L, respectively. These concentrations exceed the Washington State Groundwater Primary Standard of 0.05 µg/L, but are significantly less than the Washington State Drinking Water Primary Standard of 10 µg/L. Arsenic concentrations in samples from MW-2 and MW-4 are also within the arsenic concentration range typically exhibited by downgradient monitoring wells at the Landfill. During the last 5 years, arsenic concentrations in samples from downgradient wells ranged from non-detect at a reporting limit of 0.05 µg/L in two samples from MW-3 to detected at 3.23 µg/L in the June 2008 sample from MW-6.

4.6.1.2 Contaminant Transport Conceptual Model

Prior to baseline sampling, the KCPW consulting team anticipated that samples from Landfill interior wells MW-2 and MW-4 would likely have detectable concentrations of chlorinated VOCs, including vinyl chloride, at concentrations greater than those detected in downgradient wells. The finding that chlorinated VOCs were not detected in samples from interior wells MW-2 and MW-4 prompted a re-evaluation of the conceptual model for contaminant transport through the Landfill and into the uppermost aquifer. The revised contaminant transport model for the Landfill is presented as Figure 4-5.

The conceptual model for contaminant transport shows that limited infiltration of precipitation through the low permeability cap transports soluble constituents, including chlorinated VOCs such as vinyl chloride, from the underlying refuse directly downward under unsaturated groundwater flow conditions until the dissolved constituents reach the top of the water table. Upon reaching the water table, the dissolved constituents are transported horizontally toward downgradient wells MW-3, MW-6, MW-7, MW-8, and MW-10 through advective groundwater flow.

Interior wells MW-2 and MW-4 are screened several feet below the current top of the water table, and the dissolved constituents reaching the top of the water table under unsaturated flow are transported downgradient prior to reaching the top of the screened interval of those two wells. As shown in Figure 4-5, beneath the Landfill the impacted groundwater in the upper few feet of the aquifer has not undergone sufficient mixing through dispersion and diffusion to achieve detectable concentrations in groundwater at the screened interval of MW-2 and MW-4. The lack of detectable concentrations of the very common landfill constituents iron and manganese in samples from MW-2 and MW-4 is an indication that impacts from the limited infiltration through the Landfill cap and refuse have not reached the screened intervals of MW-

2 and MW-4. During long term drier conditions, such as during 1994 (see Figure 4-4a) groundwater elevations beneath the Landfill can decline to be within the screened interval of MW-2 and MW-4 and contaminants from the Landfill would potentially be detected in samples from these wells.

With continued downgradient groundwater flow and through the mechanisms of advection, dispersion, and diffusion the constituents leached from the refuse are spread to a greater depth in the upper part of the aquifer. The constituent plumes intersect the screened intervals of downgradient wells, where they are detected by groundwater monitoring as illustrated in Figure 4-5 where the contaminant plume reaches the screened interval of MW-6. Biodegradation of organic constituents is likely also occurring during contaminant transport to downgradient wells, which is indirectly demonstrated by measured reducing geochemical conditions (low DO) in purge water from downgradient wells (see DO data in Tables 4-4b through 4-4e).

4.6.1.3 October 2010 Quarterly MFS and RI/FS Sampling

The October 2010 quarterly sampling event was performed on October 28–29, 2010, and incorporated both the ongoing MFS monitoring and groundwater monitoring performed specifically for the RI/FS. The October 2010 sampling event represents the first dry season sampling event of the RI/FS.

Groundwater samples were analyzed for the Appendix III list of constituents (WAC 173-351-990). Analytical data from the October sampling event are summarized in Figure 4-6a and Table 4-4b. Three of the constituent groups analyzed, SVOCs, PCBs, and cyanide, did not have any detections and these constituent groups are not presented in Table 4-4b. The full set of laboratory data sheets, including non-detected constituent groups, is presented in Appendix I.

All of the Landfill COCs were detected at concentrations greater than their respective screening levels in samples from at least one well as shown in Figure 4-6a and described below.

Arsenic

- Arsenic was detected in samples from all nine wells sampled at concentrations ranging from 0.094 µg/L in the sample from upgradient well MW-1 to 2.77 µg/L in the sample from downgradient well MW-8.
- All arsenic concentrations are less than the Washington State Drinking Water Primary Standard of 10 µg/L, but are greater than the Washington State Groundwater Primary Standard of 0.05 µg/L.
- Arsenic concentrations have generally declined during the most recent 5 years, most notably in samples from downgradient wells MW-6 and MW-7 as shown in the arsenic time series graph in Appendix C.
- Elevated arsenic concentrations in groundwater at the Landfill are due in part to a regional issue that is described in Appendix H.

Iron

- Iron is a common landfill contaminant that was detected in samples from six wells at concentrations ranging from 16 µg/L in the sample from downgradient well MW-7 to 2,150 µg/L in the sample from downgradient well MW-6.
- The 2,150 µg/L iron concentration in the sample from MW-6 is the only detected concentration greater than the Washington State Groundwater and Drinking Water Secondary Standard of 300 µg/L. None of the detected iron concentrations are greater than the MTCA Method B cleanup level of 11,000 µg/L.

- Iron was not detected in samples from interior wells MW-2 and MW-4 and cross gradient well MW-5A.
- Iron concentrations have remained relatively stable during the most recent 5 years as shown in the iron time series graph in Appendix C.

Manganese

- Manganese is a common landfill contaminant that was detected in samples from four wells at concentrations ranging from 745 µg/L in the sample from downgradient well MW-6 to 5,310 µg/L in the sample from downgradient well MW-10.
- Manganese concentrations exceeded the Washington State Groundwater and Drinking Water Secondary Standard of 50 µg/L in samples from MW-3, MW-6, MW-8, and MW-10. Only the sample from downgradient well MW-10 exceeds the MTCA Method B cleanup level of 2,200 µg/L.
- Manganese was not detected in samples from upgradient well MW-1, cross gradient well MW-5A, interior wells MW-2 and MW-4, and downgradient well MW-7.
- Manganese concentrations have generally declined in samples from MW-3 and MW-6 during the most recent 5 years as shown in the time series graph presented in Appendix C.

Vinyl Chloride

- Vinyl chloride was detected in samples from four of the downgradient wells at concentrations ranging from 0.03 µg/L in the sample from downgradient well MW-3 to 0.16 µg/L in the sample from downgradient well MW-8.
- All four detections of vinyl chloride were at concentrations greater than the Washington State Groundwater Primary Standard of 0.02 µg/L and the MTCA Method B cleanup level of 0.029 µg/L. None of the vinyl chloride detections were at concentrations greater than the Washington State Drinking Water Primary Standard of 2.0 µg/L.
- Vinyl chloride was not detected in the sample from upgradient well MW-1, cross gradient well MW-5A, interior wells MW-2 and MW-4, and downgradient well MW-7.
- The time series graph for the most recent 5 years of vinyl chloride data (Appendix C) shows a general decline in vinyl chloride concentrations, particularly in samples from MW-6.

4.6.2 Summary and Discussion of December 2010 Results

The December 2010 quarterly sampling event was performed on December 28–29, 2010, and incorporated both the ongoing MFS monitoring and groundwater monitoring performed specifically for the RI/FS. The December 2010 monitoring event represents the first wet season sampling event of the RI/FS.

Samples were analyzed for MFS list of constituents found in the 2010-2011 SWHP (Appendix B). Analytical data from the December sampling event are summarized in Figure 4-6b and Table 4-4c. The full set of laboratory data sheets is presented in Appendix I.

Only two of the Landfill COCs, arsenic and manganese, were detected at concentrations greater than their respective screening levels in samples from at least one well as described below. Iron was not detected at concentrations greater than its Washington State Drinking Water and Groundwater Secondary Standard, and vinyl chloride was not detected in samples from any of the nine wells sampled in December 2010. Analytical results for COCs are presented in Figure 4-6b and are described below:

Arsenic

- Arsenic was detected in samples from all nine wells sampled at concentrations ranging from 0.098 µg/L in the sample from upgradient well MW-1 to 1.87 µg/L in the sample from downgradient well MW-8.
- Interior monitoring wells MW-2 and MW-4 had arsenic concentrations of 0.652 µg/L and 0.216 µg/L, respectively.
- All arsenic concentrations are less than the Washington State Drinking Water Primary Standard of 10 µg/L but are greater than the Washington State Groundwater Primary Standard of 0.05 µg/L.
- Elevated arsenic concentrations in groundwater are due in part to a regional issue that is described in Appendix H.

Iron

- Iron was detected in samples from downgradient wells MW-6 and MW-8 at concentrations of 298 µg/L and 180 µg/L, respectively. Iron was also detected in the field duplicate sample from MW-6 at a concentration of 268 µg/L. Iron was not detected in samples from other wells sampled during the December 2010 event.
- None of the detected iron concentrations is greater than the Washington State Groundwater and Drinking Water Secondary Standard of 300 µg/L or the MTCA Method B cleanup level of 11,000 µg/L.

Manganese

- Manganese was detected in samples from downgradient wells MW-3, MW-6, MW-8, and MW-10 at concentrations ranging from 631 µg/L in the sample from MW-8 to 3,340 µg/L in the sample from MW-10. Manganese was not detected in samples from other wells sampled during the December 2010 event.
- Manganese concentrations exceeded the Washington State Groundwater and Drinking Water Secondary Standard of 50 µg/L in samples from MW-3, MW-6, MW-8, and MW-10. Only the sample from MW-10 exceeded the MTCA Method B cleanup level of 2,200 µg/L.

Vinyl Chloride

- Vinyl chloride was not detected in samples from any of the nine RI/FS wells.

4.6.3 Summary and Discussion of March 2011 Results

The March 2011 quarterly sampling event was performed on March 23-24, 2011, and incorporated both the ongoing MFS quarterly monitoring and groundwater monitoring performed specifically for the RI/FS. The March 2011 sampling event represents the second wet season sampling event of the RI/FS.

Groundwater samples were analyzed for the Appendix III list of constituents (WAC 173-351-990). Analytical data from the March 2011 sampling event are summarized in Figure 4-6c and Table 4-4d. Three of the constituent groups analyzed, SVOCs, PCBs, and cyanide, did not have any detections in samples from any of the wells sampled. These constituent groups are not presented in Table 4-4d. The full set of laboratory data sheets, including non-detected constituent groups, is presented in Appendix I.

Three of the Landfill COCs, arsenic, iron, and manganese, were detected at concentrations greater than their respective screening levels in samples from at least one well. Vinyl chloride was not detected in samples from any of the nine RI/FS wells sampled in March 2011. Analytical results for COCs are presented in Figure 4-6c and described below:

Arsenic

- Arsenic was detected in samples from all nine wells sampled at concentrations that ranged from 0.082 µg/L in the sample from upgradient well MW-1 to 1.49 µg/L in the sample from downgradient well MW-8.
- All arsenic concentrations are less than the Washington State Drinking Water Primary Standard of 10 µg/L but are greater than the Washington State Groundwater Primary Standard of 0.05 µg/L.
- Elevated arsenic concentrations in groundwater are due in part to a regional issue that is described in Appendix H.

Iron

- Iron was detected in samples from downgradient wells MW-6 and MW-10 at concentrations of 316 µg/L and 84 µg/L; respectively, but was not detected in samples from other wells.
- The detection of 316 µg/L in the sample from MW-6 is the only detected iron concentration greater than the Washington State Groundwater and Drinking Water Secondary Standard of 300 µg/L. Neither of the detected iron concentrations was greater than the MTCA Method B cleanup level of 11,000 µg/L.

Manganese

- Manganese was detected in samples from downgradient wells MW-3, MW-6, MW-8, and MW-10 at concentrations ranging from 143 µg/L in the sample from MW-8 to 4,850 µg/L in the sample from MW-10.
- Manganese concentrations exceeded the Washington State Groundwater and Drinking Water Secondary Standard of 50 µg/L in samples from all four wells with detections. Only the sample from MW-10 exceeds the MTCA Method B cleanup level of 2,200 µg/L.

Vinyl Chloride

- Vinyl chloride was not detected in samples from any of the nine RI/FS wells sampled.

4.6.4 Summary and Discussion of June 2011 Results

The June 2011 quarterly sampling event was performed on June 1–2, 2011, and incorporated both the ongoing MFS monitoring and groundwater monitoring performed specifically for the RI/FS. The June 2011 monitoring event represents the second dry season sampling event of the RI/FS.

Samples were analyzed for MFS list of constituents found in the 2010-2011 SWHP. Analytical data from the June sampling event are summarized in Figure 4-6d and Table 4-4e. The full set of laboratory data sheets is presented in Appendix I.

Three of the Landfill COCs, arsenic, manganese, and vinyl chloride, were detected at concentrations greater than their respective screening levels in samples from at least one well. Iron was not detected at concentrations greater than Washington State Drinking Water or Groundwater Secondary Standards in samples from any of the nine wells sampled in June 2011.

Analytical results for COCs are presented in Figure 4-6d and summarized below:

Arsenic

- Arsenic was detected in samples from all nine wells sampled at concentrations that ranged from 0.057 µg/L in the sample from downgradient well MW-3 to 1.90 µg/L in the sample from downgradient well MW-10.
- All arsenic concentrations are less than the Washington State Drinking Water Primary Standard of 10 µg/L, but are greater than the Washington State Groundwater Primary Standard of 0.05 µg/L.
- Elevated arsenic concentrations in groundwater are due in part to a regional issue that is described in Appendix H.

Iron

- Iron was detected in samples from downgradient wells MW-6 and MW-8 at concentrations of 238 µg/L and 286 µg/L, respectively.
- Both detected iron concentrations are less than the Washington State Groundwater and Drinking Water Secondary Standard of 300 µg/L and the MTCA Method B cleanup level of 11,000 µg/L.

Manganese

- Manganese was detected in samples from downgradient wells MW-3, MW-6, MW-8, and MW-10 at concentrations ranging from 272 µg/L in the sample from MW-6 to 6,240 µg/L in the sample from MW-10.
- Manganese concentrations exceeded the Washington State Groundwater and Drinking Water Secondary Standard of 50 µg/L in samples from MW-3 (and its field duplicate MW-9), MW-6, MW-8, and MW-10. The samples from downgradient wells MW-8 and MW-10 also exceeded the MTCA Method B cleanup level of 2,200 µg/L.

Vinyl Chloride

- Vinyl chloride was detected in samples from downgradient wells MW-8 and MW-10 at concentrations of 0.08 µg/L and 0.02 µg/L, respectively.
- Both detections of vinyl chloride were at concentrations less than the Washington State Drinking Water Primary Standard of 2.0 µg/L. However, only the vinyl chloride detection in the sample from MW-8 was at a concentration greater than the Washington State Groundwater Primary Standard of 0.02 µg/L and the MTCA Method B cleanup level of 0.029 µg/L.

4.6.5 Distribution of Landfill Constituents of Concern

Analytical results for the Landfill COCs arsenic, iron, manganese, and vinyl chloride are presented at each monitoring well location by quarter in Figures 4-6a through 4-6d. These figures show that the COCs, with the notable exception of arsenic, are only detected at concentrations greater than screening levels in samples from downgradient wells. Arsenic is routinely detected at concentrations greater than screening levels in samples from all nine monitoring wells sampled. This consistent pattern of COC detections indicates that the well designations of MW-1 as the upgradient well, MW-5A as a cross gradient well, and the remaining wells as downgradient wells are accurate based on both groundwater elevation contour maps (Figure 4-3a through 4-3d) and the groundwater quality analytical results.

Groundwater data indicate that vinyl chloride was not detected in samples from any of the nine monitoring wells sampled during both RI/FS wet season sampling events (December 2010 and March 2011). However, vinyl chloride was detected in samples from one or more downgradient wells during both dry season events (October 2010 and June 2011). This finding is graphically demonstrated on the vinyl chloride time series graph for the most recent 5 years of data presented in Appendix C. The time series graph indicates a potential seasonal effect on groundwater quality in which vinyl chloride concentrations are generally greatest during the dry season, particularly late in the dry season when groundwater levels, and corresponding groundwater volumes, are at their lowest (September and October).

A weak seasonal effect is also possible in recent (2010-2011) manganese data for samples from downgradient wells, particularly MW-8 and MW-10 as shown in the manganese time series graph for the most recent 5 years of data presented in Appendix C. Samples from these wells had their greatest manganese concentrations during dry season sampling events and lower concentrations during wet season sampling events during the RI; however, the potential seasonal effects in historical data are not consistent with those observed during the RI.

Iron is commonly detected in samples from MW-6, MW-8, and MW-10. Evaluations of the time series graph for iron concentrations in the most recent 5 years of data, presented in Appendix C, indicates that seasonal effects on iron concentrations are not apparent.

Arsenic is commonly detected in samples from all Landfill monitoring wells and, therefore, is the COC that has the greatest potential for exhibiting seasonal variations. However, evaluations of data from the RI and from 1992 to the present do not demonstrate strong or consistent seasonal effects for arsenic. The lack of readily apparent seasonal variations in arsenic concentrations might be related to the area wide presence of naturally occurring arsenic in soil and groundwater, which represents a significantly different contaminant transport scenario compared to vinyl chloride, which is directly related to the presence of the Landfill.

4.7 WATER SUPPLY WELL SAMPLING RESULTS

The KCPW consulting team worked in coordination with KPHD to sample six off-site water supply wells in the area downgradient and cross gradient to the Landfill. KPHD and KCPW consultants sampled water supply wells designated OW-1, OW-2, and OW-9 on December 28 and 29, 2010, and water supply wells designated OW-2, OW-3, and OW-5 on January 27, 2011. Off-site well locations are shown in Figure 4-7. Three of the six water supply wells, OW-1, OW-2, and OW-9, are screened in the uppermost aquifer, which is the same aquifer in which the Landfill monitoring wells are screened. Two of the sampled water supply wells, OW-3 and OW-5, are screened in a deeper confined aquifer. One water supply well, OW-4, does not have an as-built diagram and geologic log available and was not constructed in a manner that allowed the sampling team to measure the total depth of the well. Well OW-4 is likely screened in the upper aquifer based on field parameter results, specifically DO, which is consistent with DO measurements made in purge water from other wells screened in the uppermost aquifer wells.

Field measurements presented in Table 4-5 indicate that the DO measurement from purge water from OW-4 is 3.83 mg/L. This value is similar to DO measurements in other water supply wells screened in the uppermost aquifer, which average 7.6 mg/L. Therefore, OW-4 is likely completed in the uppermost aquifer and is designed as an upper aquifer well in Figure 4-7. DO measurements from the two deeper confined aquifer wells are both very low at <0.1 mg/L. These low DO concentrations are expected in a deeper confined aquifer that is isolated from interaction with the atmosphere.

Groundwater samples from the six water supply wells sampled were analyzed for VOCs (including vinyl chloride by SIM) and for dissolved arsenic, iron, and manganese.

Analytical results for the water supply well sampling event are summarized below and in Figure 4-7 and Table 4-5:

Arsenic

- Arsenic was detected in samples from all water supply wells at concentrations ranging from 0.215 µg/L in the sample from OW-2 to 7.04 µg/L in the sample from OW-3.
- All arsenic concentrations are greater than the Washington State Groundwater Primary Standard of 0.05 µg/L, but are less than the Washington State Drinking Water Primary Standard of 10 µg/L.
- The greatest arsenic concentration was in the sample from well OW-3, which is screened in a deeper aquifer that is separated from the aquifer immediately underlying the Landfill by approximately 145 feet of dense low permeability clay. This concentration is significantly greater than in samples from downgradient monitoring wells at the Landfill, which have all been less than 3.0 µg/L since 2008.

Iron

- Iron was detected in samples from four of the six wells sampled at concentrations ranging from 54 µg/L in the sample from OW-5 to 572 µg/L in the sample from OW-3. During the same time period (December 2010) iron was detected in samples from two monitoring wells, MW-6 and MW-8, at concentrations of 298 µg/L and 180 µg/L, respectively.
- Iron was not detected in samples from OW-1 (South County Transfer Station Well) and OW-2.
- The 572 µg/L result in the sample from OW-3 is the only concentration that is greater than the Washington State Groundwater and Drinking Water Secondary Standard of 300 µg/L.
- None of the iron concentrations was greater than the MTCA Method B cleanup level of 11,000 µg/L.

Manganese

- Manganese was detected in samples from three of the six wells, OW-3, OW-4, and OW-5, at concentrations of 59 µg/L, 32 µg/L, and 38 µg/L, respectively. During the same time period (December 2010) manganese was detected in samples from four monitoring wells, MW-3, MW-6, MW-8, and MW-10, at concentrations of 1,100 µg/L, 713 µg/L, 631 µg/L, and 3,340 µg/L, respectively.
- The 59 µg/L manganese detection in the sample from OW-3 is the only concentration that is greater than the Washington State Groundwater and Drinking Water Secondary Standard of 50 µg/L. None of the manganese concentrations was greater than the MTCA Method B cleanup level of 2,200 µg/L.

Vinyl Chloride

- Vinyl chloride was not detected at a reporting limit of 0.02 µg/L in samples from any of the water supply wells. This finding is consistent with previous water supply well sampling events performed in May 1995 and September 1997. During the same time period (December 2010) vinyl chloride was not detected in samples from any of the Landfill monitoring wells.

Analytical results for groundwater samples from the water supply wells downgradient or cross gradient to the Landfill do not exhibit impacts from the Landfill. Among the off-site wells, the greatest arsenic, iron, and manganese concentrations were in the sample from OW-3, which is downgradient of the Landfill, but is screened in a deeper confined aquifer that is separated from the uppermost aquifer by approximately 145 feet of dense low permeability clay and could not be impacted by releases from the Landfill.

5. SURFACE WATER INVESTIGATION RESULTS

Surface water quality has been monitored annually, when present, at location SW-2 as part of the MFS monitoring program for the Landfill. The SW-2 sampling location is at the detention pond located immediately downgradient of the Landfill, which receives runoff from the Landfill cap. The detention pond could also receive seepage from the downgradient face of the Landfill, although no visible seeps have been identified.

Under the MFS monitoring program, samples from SW-2 are analyzed for field parameters (temperature, pH, and specific conductance), nitrate-nitrite, and fecal coliform. The limited list of MFS-required surface water constituents does not contain the groundwater COCs that have been identified for the Landfill. Therefore, as part of the RI/FS, KCPW elected to sample surface water for the full MFS list of groundwater constituents, which includes the four groundwater COCs for the Landfill.

In addition to sampling surface water at SW-2 for an expanded list of constituents, the KCPW consulting team identified two additional surface water sampling locations, SW-3 and SW-4, which are shown in Figure 5-1. SW-3 is located on the ditch outside of the perimeter road to the north of the Landfill and receives runoff from the area to the north and east of the Landfill. SW-4 is located at a stormwater vault that receives runoff from ditches draining the Phase I Area of the Landfill.

All three surface water locations were sampled for the full MFS groundwater constituent list during the December 2010 monitoring event. Locations SW-3 and SW-4 were sampled for the MFS surface water constituent list during the March 2011 monitoring event; however, SW-2 was not sampled in March because this location was dry at the time of sampling.

Observations regarding surface water sampling analytical results for the Landfill groundwater COCs are presented below, and the analytical data are summarized in Table 4-4c and Table 4-4d:

Arsenic

- Arsenic was detected at concentrations of 0.737 µg/L, 0.230 µg/L, and 0.566 µg/L in samples from SW-2, SW-3, and SW-4, respectively.
- These concentrations are greater than the Washington State Groundwater Primary Standard of 0.05 µg/L, but are less than the Washington State Drinking Water Primary Standard of 10 µg/L.
- Arsenic concentrations in surface water samples are in a similar range as the arsenic concentrations noted in groundwater samples from Landfill monitoring wells. This finding provides further evidence that arsenic concentrations in groundwater and surface water are related to area-wide natural concentrations of arsenic in soil.

Iron

- Iron was detected at concentrations of 87 µg/L, 91 µg/L, and 105 µg/L in samples from SW-2, SW-3, and SW-4, respectively.
- These concentrations are less than the Washington State Groundwater and Drinking Water Secondary Standard of 300 µg/L.
- Iron is commonly detected in samples from downgradient wells MW-8 and MW-10 at similar concentrations to those detected in the surface water samples. Iron is consistently detected in samples from MW-6 at concentrations greater than those detected in surface water samples. Iron is generally not detected in samples from other monitoring wells at the Landfill.

Manganese

- Manganese was detected at concentrations of 7 µg/L and 5 µg/L in samples from SW^{-}3 and SW-4, respectively but was not detected in the sample from SW-2.
- These concentrations are less than the Washington State Groundwater and Drinking Water Secondary Standard of 50 µg/L.
- Manganese is commonly detected in samples from downgradient wells MW-3, MW-6, MW-8, and MW-10 at concentrations generally greater than the secondary regulatory level and at concentrations greater than those detected in surface water samples. This finding provides further evidence that elevated manganese concentrations in groundwater samples from downgradient wells are caused by reducing geochemical conditions. These reducing geochemical conditions are noted in groundwater downgradient of the Landfill but are not noted in upgradient or cross gradient groundwater samples or in surface water samples.

Vinyl Chloride

- Vinyl chloride was not detected in any of the surface water samples collected during the RI/FS.

In addition to the regulatory exceedances for arsenic, all December 2010 surface water samples had field measured pH values that were less than the lower range of the Washington State Groundwater Secondary Standard of 6.5 to 8.5. These low pH values were expected in the surface water samples, because natural rainwater has a pH value of around 5.6 due to carbon dioxide found in the atmosphere, which reacts with water vapor to form a weak carbonic acid solution in rainwater.

6. SOLID WASTE INVESTIGATION RESULTS

The KCPW consulting team excavated five exploratory trenches in the Phase II portion of the Landfill to evaluate if refuse is present in the subsurface. Historical air photos and Landfill closure records were inadequate to indicate any specific parts of the Phase II Area of the Landfill that might have a higher probability of containing refuse. Therefore, trench locations and alignments were selected to provide representative coverage of the Phase II Area of the Landfill. Historical air photos also did not indicate the presence of refuse in the area between MW-3 and MW-5A.

As part of closure activities, test pits were also excavated within the Phase II Area of the Landfill on two occasions in 1988 in order to further delineate the area containing putrescible wastes (Parametrix, 1988). Figure 2-4 shows the location of the two test pits within the Phase II Area of the Landfill that were noted to contain putrescible wastes. The locations of these two test pits were not surveyed and their locations are approximated from Figure 3-1 of the closure report (Parametrix, 1988). The pits typically indicated from 4 to 5 feet of cover over 4 to 6 feet of refuse with one test pit containing 2 feet of cover over 8 feet of refuse.

6.1 EXPLORATORY TRENCH LOCATIONS AND DIMENSIONS

All five exploratory trenches were surveyed using GPS equipment to determine their length, alignment, and position in the Phase II Area. Exploratory trench locations are shown to scale on Figure 2-4. Figure 2-4 also shows the outlines of the capped Phase I Area and the uncapped but soil covered Phase II Area. GPS data for the exploratory trenches is presented in Appendix J.

Each exploratory trench was approximately 25 feet long, 8 feet deep, and at least as wide as the bucket of the excavator or as necessary based on soil stability characteristics. Trench 4 was extended to 47 feet in length, because a steel drum containing a small volume of a material resembling tar was noted at the north end of the original 25-foot trench.

6.2 EXPLORATORY TRENCH OBSERVATIONS

Construction debris, consisting primarily of wood and roofing material, was noted in all trenches with the exception of Trench TP-2, which contained no debris. This material was determined to primarily be inert waste and demolition waste; however, debris making up less than 10% of the total excavated material was found scattered among some of the inert demolition waste that may be considered refuse or could potentially produce gases or leachate during the decomposition process. Materials found that could be considered refuse not suitable for disposal in an inert waste or demolition waste landfill include plastic bags, a 55-gallon drum with residual tar-like material, plastic bottles, foam, tires, and netting. A photo-ionization detector (PID) was used to detect the presence of volatile organic compounds during the trench excavations and only a single detection of 2.3 parts per million was noted in material found in Trench TP-4. The single PID detection occurred when field personnel were evaluating the tar-like material within the drum. All material excavated from the trenches, including the 55-gallon drum, were backfilled within the trenches.

The inert waste and demolition waste is subject to different closure regulations than the municipal waste found in the Phase I Area of the Landfill. WAC 173-304-461 contains the regulations in effect for the closure of the Landfill for inert waste and demolition waste landfilling facility requirements. Descriptions of the materials encountered in each exploratory trench were logged on “Test Pit Designation” forms, which are presented in Appendix J.

Exploratory trenches were photographed to show representative views of the soil and inert waste and demolition waste that were encountered. The photos clearly show that the inert waste and demolition waste was scattered through the soil, and did not form a distinct layer. The photos also demonstrate that all inert waste and demolition waste was covered with a minimum of 1 foot of soil as required by WAC 173-304-461(6). Photographs of the exploratory trenches are presented in Appendix J.

6.3 SOLID WASTE INVESTIGATION CONCLUSIONS

Exploratory trenches installed in the Phase II Area of the Landfill demonstrated that minimal municipal refuse was found in the five trench locations and also that the area is capped with a minimum 1-foot-thick vegetated soil cover.

The soil cover comprising the surface of the Phase II Area is flat with no observed areas of subsidence or differential settling, which would indicate decomposition or compaction of large pockets of debris. This observation of surface conditions supports the subsurface observation that inert waste and demolition waste is scattered throughout the soil and does not occur in distinct layers or accumulations. In addition, all soil and inert waste and demolition waste was observed to be dry. Based on the conceptual site model, the inert waste and demolition waste is approximately 40 to 50 feet above the top surface of the uppermost aquifer. Based on this observation, there is no indication of waste in contact with groundwater or perched water zones in the Phase II Area of the Landfill.

Groundwater elevation contours and flow direction maps demonstrate that monitoring wells MW-3 and MW-10 are downgradient of both the Phase I and Phase II Areas of the Landfill. If the inert waste and demolition waste contained in the Phase II Area of the Landfill impacted groundwater, those impacts would be detected in samples from MW-3 and MW-10. Based on the observations documented during trench excavation (e.g. drum with tar-like material), expected constituents of concern from the Phase II Area of the Landfill would consist of petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAHs). Groundwater samples were analyzed for petroleum hydrocarbons and PAHs; and, petroleum hydrocarbons and PAHs were not detected. Furthermore, the constituents and concentrations detected in samples from MW-3 and MW-10 are similar to the constituents and concentrations in samples from MW-6 and MW-8, which are only downgradient of the Phase I Area of the Landfill. The constituents detected in groundwater samples from MW-3 and MW-10 are likely mainly attributable to releases from the Phase I Area of the Landfill without any measurable contribution from the Phase II Area of the Landfill.

Because the inert waste and demolition waste is already covered with a minimum 1-foot-thick vegetated soil cover as required and no settlement has been observed within the Phase II Area, no additional investigation work is warranted or recommended. In addition, monitoring wells MW-3 and MW-10 are downgradient of the Phase I and Phase II Areas of the Landfill and in the unlikely event of a release from the debris that is not considered inert waste and demolition waste, routine groundwater monitoring at these two downgradient locations would detect the release. These two wells will continue to be sampled as part of the MFS monitoring events under the SWHP.

7. LANDFILL GAS INVESTIGATION RESULTS

During the four RI/FS monitoring events, landfill gas was monitored for the field measured parameters methane, LEL, carbon dioxide, oxygen, and gas pressure. All three flares were temporarily shut in prior to the October 2010 monitoring event and remained shut in until September 2011. Field measured parameters measured in the flares are summarized in Table 7-1 and the following bullets:

- Methane was detected in all flares during all four quarterly events with the exception of the non-detect in Flare 1 in October 2010. Methane concentrations ranged from 0.4% to 39.1% by volume in Flare 3 in October 2010 and Flare 2 in June 2011, respectively.
- LEL values are calculated from the methane concentrations and range from 8% to 782% of the LEL in Flare 3 in October 2010 and Flare 2 in June 2011, respectively.
- Carbon dioxide was detected in all flares during all four quarterly events at concentrations ranging from 0.8% to 13.6% by volume in Flares 1 and 2, respectively; both during the October 2010 monitoring event.
- Oxygen was detected in all flares during all four quarterly events at concentrations ranging from 0.4% to 20.1% by volume in Flare 2 in December 2010 and Flare 1 in October 2010, respectively.
- Gas pressure was measurable in one or more of the flares during the December 2010, March 2011, and June 2011 monitoring events. Pressure measurements range from 0.1 to 10.5 inches of water in Flare 1 in June 2011and Flare 3 in March 2011, respectively.

Because the flares were temporarily plugged during all four quarters of RI monitoring the field measured parameters are significantly different than historical measurements under MFS monitoring. For example, historical methane measurements are generally non-detect or low single-digit percent by volumes when the flares are vented. This finding is consistent with the low gas production rates expected in a landfill that has been closed for more than 30 years. Temporarily plugging the flare system for RI sampling created conditions that allowed methane concentrations to accumulate to levels greater than 10%, which have not been measured since 2000.

In addition, during the October 2010 RI/FS monitoring event, landfill gas samples were collected and analyzed for VOCs to evaluate if VOCs detected in groundwater samples could be attributable, at least in part, to contaminant transport by landfill gas.

Analytical results for the Landfill gas samples from Flares 1, 2, and 3 are presented in Appendix K and are summarized in Table 7-2. In general:

- Chlorinated VOCs (perchloroethene [PCE], trichloroethene [TCE], dichloroethene [DCE], and vinyl chloride [VC]) were not detected in samples from the three flares.
- Landfill gas samples from the three flares contained detectable concentrations of the following compounds: Freon 11 (trichlorofluoromethane), Freon 12 (dichlorodifluoromethane), Freon 114 (1,2-dichloro-1,1,2,2-tetrafluoromethane), acetone, heptane, hexane, and toluene. The three detected Freon compounds were commonly used in aerosol products and refrigerants and their presence is likely attributable to aerosol cans and appliances containing Freon in the municipal waste disposed of within the Landfill.
- Groundwater has historically been analyzed for Freon 11, Freon 12, acetone, and toluene but was not analyzed for Freon 114, heptane, or hexane because these compounds are not in the SWHP constituent list.

- Freon 11 and Freon 12 have never been detected in groundwater samples from the Landfill monitoring wells.
- Acetone and toluene were sporadically detected at very low concentrations in samples from all wells, including upgradient well MW-1.
- Acetone is a common laboratory solvent that has historically been detected in groundwater samples during seven historical sampling events. Acetone has not been detected in groundwater samples from the Landfill since June 2004. During the June 2004 sampling event and the February 1994 sampling event, acetone was detected in samples from all wells, including upgradient well MW-1, indicating that the detections of acetone are likely a laboratory issue.
- Toluene is a component of gasoline and could have impacted samples due to the use of a gasoline-powered generator to power sampling pumps. Toluene has been detected in one or more groundwater samples, including samples from upgradient well MW-1, during five historical sampling events. Toluene has not been detected in groundwater samples from the Landfill since 2007.

In addition to the lack of detectable concentrations of chlorinated VOCs in landfill gas samples, revised monitoring well measuring point elevation data indicate that the groundwater flow direction beneath the Landfill is generally toward the northwest. The revision in groundwater flow direction means that MW-3 is downgradient of the Phase I Area of the Landfill and makes it likely that the VC detections in samples from MW-3 are from landfill leachate rather than impacts from landfill gas.

Based on the non-detections for chlorinated VOCs in all landfill gas samples, and the supporting groundwater flow direction revision demonstrating that MW-3 is downgradient of the Phase I Area of the Landfill, KCPW concludes that no further landfill gas investigations are warranted under the RI/FS. Quarterly landfill gas monitoring performed under the MFS monitoring program will continue in accordance with the SWHP.

8. CONSTITUENTS OF CONCERN

Evaluations of historical data and new data generated by investigations performed during the RI/FS have resulted in an enhanced understanding of site geology and hydrostratigraphy, groundwater quality, surface water quality, landfill gas constituent concentrations, and subsurface conditions in the Phase II Area of the Landfill. In addition, groundwater sampling at six water supply wells again confirmed that the Landfill has not impacted groundwater at downgradient water supply wells.

Based on our enhanced understanding of current conditions at the Landfill, the constituents of concern for the Landfill are summarized below by media:

- Groundwater – Arsenic, iron, manganese, and vinyl chloride.
- Surface Water – Arsenic.
- Soil – No chemicals of concern.
- Landfill Gas – No chemicals of concern.

The constituents of concern listed above are based on the following summary statements regarding their occurrence in the environmental media that were studied during the RI.

8.1 GROUNDWATER

Groundwater at the Landfill has been sampled quarterly since 1992 (monthly in 1994) and evaluation of the extensive analytical database yielded four potential COCs. During the RI, samples were analyzed twice for the full Appendix III list of constituents and no additional potential COCs were added as a result of the greatly expanded analyses. Therefore, groundwater cleanup levels for arsenic, iron, manganese, and vinyl chloride will be determined. The occurrence and nature of the groundwater COCs are summarized below:

- **Arsenic** – Arsenic is a naturally occurring metal constituent that is present in native soil. Arsenic is more soluble in geochemically reducing conditions, which are common in groundwater beneath landfills as a result of depleted oxygen through bacterial degradation of organics in the Landfill and landfill leachate. Arsenic is also a common constituent found within landfill leachate. Arsenic has been routinely detected at concentrations greater than the Washington State Groundwater Primary Standard of 0.05 µg/L in samples from all wells, including upgradient well MW-1. Arsenic concentrations in samples from Landfill wells have not been greater than the Washington State Drinking Water Primary Standard of 10 µg/L since a single detection of 11 µg/L in a sample from MW-6 in 1992. Elevated arsenic concentrations in groundwater are due in part to a regional issue that is discussed in Appendix H. However, some arsenic contribution within groundwater may be the result of the reducing conditions caused by the Landfill.
- **Iron** – Iron is a naturally occurring metal constituent that is present in native soil. Iron is also more soluble in geochemically reducing conditions commonly found in groundwater at landfills. Iron is also a common constituent found within landfill leachate. Iron is commonly detected at concentrations greater than its Washington State Groundwater and Drinking Water Secondary Standard of 300 µg/L in samples from downgradient wells MW-6 and MW-8. Some iron contribution within groundwater may be the result of the reducing conditions caused by the Landfill.

- **Manganese** – Manganese is a naturally occurring metal constituent that is present in native soil. Like iron, manganese is more soluble in geochemically reducing conditions commonly found in groundwater at landfills. Manganese is also a common constituent found within landfill leachate. Manganese is commonly detected at concentrations greater than its Washington State Groundwater and Drinking Water Secondary Standard of 50 µg/L in samples from downgradient wells MW-3, MW-6, MW-8, and MW-10. Some manganese contribution within groundwater may be the result of the reducing conditions caused by the Landfill.
- **Vinyl Chloride** – Vinyl chloride is a breakdown product formed by the anaerobic degradation of chlorinated VOCs. The presence of chlorinated VOCs at the Landfill is likely from small quantities of household cleaning products containing chlorinated solvents that are contained in the refuse in the Phase I area. Historically, vinyl chloride was routinely detected at concentrations greater than the Washington State Groundwater Primary Standard of 0.02 µg/L in samples from downgradient monitoring wells MW-3 and MW-6. In more recent data from sampling events performed in 2010 and 2011, vinyl chloride was sporadically detected in samples from some downgradient wells, including new downgradient wells MW-8 and MW-10, during dry season sampling events (i.e., October 2010 and June 2011) but was not detected in samples from any wells during wet season sampling events (i.e., December 2010 and March 2011). Vinyl chloride has never been detected at a concentration greater than the Washington State Drinking Water Primary Standard of 2.0 µg/L in samples from any of the Landfill wells.

8.2 SURFACE WATER

Surface water discharges from active and inactive landfills are regulated under NPDES and State Waste Discharge General Permit for Stormwater Discharges Associated with Industrial Activities (i.e., Industrial Stormwater General Permit). Special Condition S1.C.10 of the Permit excludes “Closed landfills that are capped and stabilized, in compliance with Chapter 173-304 WAC, and in which no significant materials or industrial pollutants remain exposed to stormwater” from obtaining a permit. The only industrial pollutants from the Landfill that may be exposed to stormwater at the Landfill would be from potential intermittent seeps along the western portion of the Landfill, which have not been observed. Also, based on the final closure plan (Parametrix, 1988), stormwater discharges from the detention pond may only occur during events larger than a 25-year, 24-hour storm event while the majority of stormwater will infiltrate into the bottom of the detention pond. Due to the exclusion granted by the Industrial Stormwater General Permit, the lack of impact on stormwater quality from potential seeps and the infiltration of the majority of stormwater from the Landfill, we used the groundwater screening levels for comparison to the surface water samples collected from the drainage ditches and the detention pond culvert.

Surface water samples from the Landfill were analyzed once during RI/FS field activities for the full MFS list of groundwater constituents. Arsenic was detected in all three surface water samples at concentrations greater than the Washington State Groundwater Primary Standard of 0.05 µg/L. No other constituents were detected above their respective screening levels. Arsenic concentrations in surface water samples are in a similar range as the arsenic concentrations noted in groundwater samples from Landfill monitoring wells. This finding provides evidence that arsenic concentrations in groundwater and surface water are related to area-wide natural concentrations of arsenic in soil; however, arsenic is considered a surface water COC due to its exceedance of the Washington State Groundwater Primary Standard.

9. APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Performance of cleanup actions under MTCA (WAC 173-340-710) requires identification of applicable, relevant and appropriate requirements (ARARs). Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal, state, or local environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site.

The potential ARARs for the Landfill include:

- Chemical-specific - typically health- or risk-based values that when applied to site-specific conditions represent cleanup standards.
- Location-specific - related to the geographical position and/or physical condition of the site and may affect the type of remedial action selected for the site.
- Action-specific – commonly technology-based or activity-based requirements or limitations on actions or conditions taken with respect to specific hazardous substances.

Action-specific requirements do not determine the selected remedial alternative, but indicate how or to what level a selected alternative must perform. Table 9-1 identifies ARARs for each medium of concern.

10. CLEANUP STANDARDS

Cleanup standards consist of two components:

- Cleanup Levels (CULs) – chemical concentrations.
- Points of Compliance – point at which the cleanup levels must be met.

Cleanup standards are established in accordance with WAC 173-340-700 through 173-340-760.

The cleanup standards proposed for the Landfill are determined based on exposures to human health and the environment. As documented within previous sections of this report, groundwater is the only medium impacted with COCs above screening levels; therefore, cleanup standards are only developed for groundwater. The cleanup standard selection process for the Landfill is described in the following sections.

10.1 CLEANUP LEVELS

MTCA defines CULs as the concentration of a hazardous substance in soil, water, air, or sediment that is determined to be protective of human health and the environment under specified exposure conditions. MTCA regulations require that the cleanup levels used to evaluate remediation alternatives for the Landfill be “at least as stringent as all applicable state and federal laws” (RCW 70.105D.030 [2][e]). State and federal laws described in WAC 173-340-710 may impose additional requirements at the discretion of Ecology.

Where applicable, the CULs were updated based on the most recent toxicity data in Ecology’s Cleanup Levels and Risk Calculation (CLARC) database, EPA’s Integrated Risk Information System (IRIS) database or EPA’s Health Effects Assessment Summary Tables (HEAST) database.

Standards applicable to groundwater COCs include federal and state drinking water standards (Maximum Contaminant Levels [MCLs]) and federal MCL Goals, which are Groundwater ARARs in the CLARC Database) and Equations 720-1 and 720-2 under WAC 173-340-720(4) (standard MTCA Method B equations, which were used to calculate MTCA Method B standard formula values [SFVs] in the CLARC Database). For those COCs with MCLs, the federal and state MCLs are identical.

Following is a summary of the CUL identification steps:

1. For each COC with a federal or state MCL:
    a) That MCL was selected as the initial standard (WAC 173-340-705[2][a]) and 720[4][b][i]).
    b) If substituting the MCL as the groundwater CUL and solving Equation 720-1 for hazard quotient (HQ) resulted in HQ greater than 1, the standard was revised to make the HQ less than or equal to 1 (WAC 173-340-705[5]).
    c) If substituting the MCL as the groundwater CUL and solving Equation 720-2 for risk resulted in excess cancer risk greater than $1x10^{-5}$, the standard was revised to make the risk less than or equal to $1x10^{-5}$ (WAC 173-340-705[5]).
2. If no MCL was available for a COC, then the MTCA Method B groundwater SFVs were used as the standard.

MCLs and MTCA Method B groundwater SFVs used in the CUL development process were available from the CLARC Database, which was updated in September 2012. For arsenic in groundwater, the CUL is based on Landfill background concentrations because the CUL falls below the background value calculated for arsenic (See Appendix H). Background values for iron and manganese were calculated similarly to the arsenic calculation as described in Appendix H. CULs for iron and manganese are based on MCLs since the background values fall below MCLs. The CULs for the COCs are summarized in Table 10-1.

Table 10-1. Preliminary Cleanup Levels

			MTCA B Groundwater		**Groundwater ARARs**				**Downward-adjusted ARARs**					
Chemical	**CAS #**	**Units**	**Non-Cancer SFV**	**Cancer SFV**	**Federal Primary MCL**	**Federal MCL Goal**	**State Primary MCL**	**State Secondary MCL**	**Adjusted Minimum MCL**	**Hazard Quotient**	**Excess Cancer Risk**	**Standard**	**Background**	**Preliminary Cleanup Level**
Arsenic, total	7440-38-2	µg/L	4.8	0.058	10	0	10	*NA*	0.58	0.121	1.00E-05	0.58	1.29	1.29
Iron, total	7439-89-6	µg/L	11,000	NR	NR	NR	NR	300	300	0.027	---	300	40	300
Manganese, total	7439-96-5	µg/L	2,200	NR	NR	NR	NR	50	50	0.023	---	50	10	50
Vinyl Chloride	75-01-4	µg/L	24	0.029	2	0	2	NA	0.29	0.012	1.00E-05	0.29	0	0.29

ARAR = Applicable or Relevant and Appropriate Requirement.

Downward-adjusted ARARs (WAC 173-340-705 (2)):

Hazard Quotient = Hazard quotient for Adjusted Minimum MCL based on applicable MTCA B Groundwater non-cancer SFV. If HQ > 1 for the MCL, then the MCL was adjusted downward so that HQ ≤ 1.

Excess Cancer Risk = Cancer risk for Adjusted Minimum MCL based on applicable MTCA B Groundwater cancer SFV. If greater than 1x10^{-5} for the MCL, then MCL was adjusted downward so that CR ≤ 1x10^{-5}.

MCL downward-adjusted so that Hazard Quotient ≤ 1 and Excess Cancer Risk ≤ 1x10^{-5}.

Standard = Downward-adjusted ARAR or, if no ARARs, minimum of MTCA B groundwater cancer and non-cancer SFVs.

MCL = Maximum Contaminant Level.

NR = Not Researched (CLARC Database).

SFV = Standard Formula Value (CLARC Database).

NA = Not Applicable.

10.2 POINT OF COMPLIANCE

WAC 173-340-200 defines "Point of Compliance" (POC) as the point or points where cleanup levels established in accordance with WAC 173-340-720 through 173-340-760 shall be attained. WAC 173-340-720(8) defines the standard groundwater POC for all sites as the groundwater throughout the site from the uppermost level of the saturated zone extending vertically to the lowest most depth which could potentially be affected by the site. However, WAC 173-340-720(8)(c) allows for a conditional point of compliance (CPOC) where it is not practicable to meet the cleanup level throughout the site within a reasonable restoration timeframe. The regulation requires that the CPOC shall be as close as practicable to the source of hazardous substances and shall not exceed the property boundary.

The Landfill property meets the conditions for a CPOC because leachate will continue to be generated within the Landfill for years thereby creating an ongoing source of contaminants and maintaining reducing geochemical conditions that are anticipated to impact groundwater under the capped or covered refuse. Since the source will not be completely mitigated without complete removal of all refuse at the Landfill, it will not be practicable to meet the cleanup levels throughout the Landfill within a reasonable restoration timeframe. The County property boundaries would be appropriate as the Landfill’s CPOC (Figure 1-2). Based on the west-northwest regional groundwater flow direction as documented in Figures 4-3a through 4-3d, the western property boundary is a downgradient boundary, the north and south boundaries are roughly parallel to regional groundwater flow, and the eastern boundary is upgradient. The County property boundary is also within the 1,000-ft minimum distance required for water supply wells located near solid waste landfills (WAC 173-160-171). The wells located along the western property boundary (MW-3, MW-6, MW-7, MW-8, and MW-10) are close to the refuse limits and would serve as the monitoring point for the CPOC.

Current concentrations of COCs in groundwater can be used to determine that the extent of contamination has been sufficiently characterized at the CPOC boundary if the groundwater data represents a fully-developed groundwater plume (i.e. not growing or changing with time). The concentration of COCs, based on monitoring since 1992, is steady or trending downward at all locations suggesting a stable or declining plume. Thus, new COCs are unlikely to be identified in the future as a result of increasing concentrations at the CPOC.

10.3 LANDFILL CLEANUP STANDARD ANALYSIS

COC concentrations in groundwater at the CPOC from the past 3 years were compared to the CULs developed for the Landfill. Table 10-2 provides a summary of COC concentrations detected during the RI period. A discussion of each COC and the relationship to the CUL are discussed below:

- Arsenic detections were noted in samples from all Landfill monitoring wells (i.e., MW-1, MW-2, MW-3, MW-4, MW-5A, MW-6, MW-7, MW-8, and MW-10) since 2009. The arsenic detections have ranged from 0.057 µg/L in sample from well MW-3 in June 2011 to 3.44 µg/L in well MW-10 in September 2012. The detections of arsenic have exceeded the cleanup level of 1.29 µg/L in a sample from well MW-6 once in the past 3 years (December 2009) at a value of 1.38 µg/L. The detections of arsenic have exceeded the cleanup level in samples from well MW-8 six of nine sampling events in the past 3 years with a range of 1.32 µg/L (March 2012) to 2.77 µg/L (October 2010). The detections of arsenic have exceeded the cleanup level in samples from well MW-10 seven of nine sampling events in the past 3 years with a range of 1.9 µg/L (June 2011) to 3.44 µg/L (September 2012).

- Iron detections were noted in samples from wells MW-1, MW-3, MW-5A, MW-6, MW-7, MW-8, and MW-10 since 2009. The iron detections have ranged from 16 µg/L in the sample from well MW-7 in October 2010 to 2,150 µg/L in the sample from well MW-6 in October 2010. The detections of iron have exceeded the cleanup level of 300 µg/L in samples from well MW-6 eight of 15 sampling events in the past 3 years with a range of 316 µg/L (March 2011) to 2,150 µg/L (October 2010). The detections of iron have exceeded the cleanup level in a sample from well MW-8 one of nine sampling events in the past 3 years with a value of 1,310 µg/L (March 2012).
- Manganese detections were noted in samples from wells MW-3, MW-6, MW-8, and MW-10 since 2009. The manganese detections have ranged from 143 µg/L in a sample from well MW-8 in March 2011 to 7,130 µg/L in a sample from well MW-8 in March 2012. The detections of manganese have exceeded the cleanup level of 50 µg/L in samples from wells MW-3, MW-6, MW-8, and MW-10 in each of the sampling events conducted within the past 3 years.
- Vinyl Chloride detections were noted in samples from wells MW-3, MW-6, MW-8, and MW-10 since 2009. The vinyl chloride detections have ranged from 0.02 µg/L in samples from various wells during each sample event to 0.18 µg/l in well MW-8 in December 2011. The detections of vinyl chloride have not exceeded the cleanup level of 0.29 µg/L at the Landfill within the past 3 years.

Table 10-2. Summary of Remedial Investigation COC Data

		COC Concentrations in µg/L			
Well	**Sample Date**	**Arsenic**	**Iron**	**Manganese**	**Vinyl Chloride**
Preliminary Cleanup Levels		**1.29**	**300**	**50**	**0.29**
MW-1	October 28, 2010	0.094	25	10 U	0.02 U
	December 28, 2010	0.098	20 U	5 U	0.02 U
	March 23, 2011	0.082	20 U	10 U	0.02 U
	June 1, 2011	0.113	20 U	5 U	0.02 U
MW-2	October 28, 2010	0.687	10 U	10 U	0.02 U
	December 28, 2010	0.652	20 U	5 U	0.02 U
	March 23, 2011	0.517	20 U	10 U	0.02 U
	June 1, 2011	0.749	20 U	5 U	0.02 U
MW-3	October 28, 2010	0.184	23	1,300	0.03
	December 28, 2010	0.107	20 U	1,100	0.02 U
	March 23, 2011	0.087	20 U	1,330	0.02 U
	June 1, 2011	0.057	20 U	532	0.02 U
MW-4	October 28, 2010	0.226	10 U	10 U	0.02 U
	December 28, 2010	0.216	20 U	5 U	0.02 U
	March 23, 2011	0.188	20U	10 U	0.02 U
	June 1, 2011	0.326	20 U	5 U	0.02 U
MW-5A	October 28, 2010	0.153	10 U	10 U	0.02 U
	December 28, 2010	0.160	20 U	5 U	0.02 U
	March 23, 2011	0.113	20 U	10 U	0.02 U
	June 1, 2011	0.259	20 U	5 U	0.02 U

(Table Continues)

Table 10-2. Summary of Remedial Investigation COC Data (Continued)

		COC Concentrations in µg/L			
Well	**Sample Date**	**Arsenic**	**Iron**	**Manganese**	**Vinyl Chloride**
Preliminary Cleanup Levels		**1.29**	**300**	**50**	**0.29**
MW-6	October 28, 2010	1.17	2,150	745	0.04
	December 28, 2010	0.983	298	713	0.02 U
	March 23, 2011	0.689	316	412	0.02 U
	June 1, 2011	0.829	238	272	0.02 U
MW-7	October 28, 2010	0.345	16	10 U	0.02 U
	December 28, 2010	0.318	20 U	5 U	0.02 U
	March 23, 2011	0.327	20 U	10 U	0.02 U
	June 1, 2011	0.652	20 U	5 U	0.02 U
MW-8	October 28, 2010	2.77	215	2,160	0.16
	December 28, 2010	1.87	180	631	0.02 U
	March 23, 2011	1.49	20 U	143	0.02 U
	June 1, 2011	1.53	286	4,470	0.08
MW-10	October 28, 2010	2.37	37	5,310	0.06
	December 28, 2010	1.05	20 U	3,340	0.02 U
	March 23, 2011	1.03	84	4,850	0.02 U
	June 1, 2011	1.90	20 U	6,240	0.02

Notes: U = Indicates compound was analyzed for, but not detected at the specified detection limit.
COC = Constituents of Concern

Arsenic, the only COC for surface water, was noted to have a concentration ranging from 0.230 µg/L in a sample from station SW-3 to 0.737 µg/L in a sample from station SW-2 during the December 2010 sampling event. The detections of arsenic in surface water did not exceed the groundwater cleanup level of 1.29 µg/L.

Based on the analysis above, arsenic, iron, and manganese are the COCs with concentrations at the CPOC that have exceeded the cleanup levels for the Landfill within the past 3 years. Therefore, the feasibility study will address the occurrence of arsenic, iron, and manganese concentrations greater than CULs in groundwater. Vinyl chloride was not detected at concentrations that exceeded the cleanup level within the past 3 years; therefore, vinyl chloride is not a COC nor will it be addressed in the feasibility study.

11. FEASIBILITY STUDY

In this section, cleanup action alternatives are developed from cleanup action technologies to meet the goals of the cleanup in accordance with MTCA requirements and guidelines. The process of developing appropriate cleanup action alternatives begins with a broad overview of all types of cleanup technologies. A comprehensive list of relevant technologies was developed using professional knowledge and judgment, experience, and screening information prepared by the U.S. Environmental Protection Agency (EPA), Center for Public Environmental Oversight (CPEO), and other organizations for sites across the United States.

The list of technologies is given a cursory screening to eliminate any technologies that do not apply to the COCs or site-specific conditions. The technologies retained are then given a more comprehensive screening before being accepted or rejected. The accepted technologies are then combined to create a range of alternatives that represent various approaches to achieving the cleanup action objectives (CAOs).

11.1 CLEANUP ACTION OBJECTIVES

The following CAOs have been established for the cleanup action alternatives:

- Achieve the MTCA Method B groundwater cleanup levels for arsenic, iron, and manganese at the CPOC.
- Use permanent solutions to the maximum extent practicable (which includes consideration of cost-effectiveness).

11.2 CLEANUP ACTION TECHNOLOGIES

A list of relevant cleanup action technologies (see Table 11-1) was developed using screening information prepared by the EPA, CPEO (see References), and other organizations for sites across the United States. Furthermore, the cleanup action technologies categorized in Table 11-1 were compiled based on the nature of the COCs at the Landfill, the environmental medium affected at concentrations greater than CULs (groundwater), and the types of exposures that need to be addressed.

The potentially applicable cleanup action technologies were screened using the criteria in WAC 173-340-350(8)(b) to determine a list of technologies applicable to the Landfill (e.g., retained technologies). The following screening criteria were used to evaluate technologies:

- **Technical Feasibility/Effectiveness**—the ability of the technology to function effectively and achieve meaningful progress toward the cleanup action objectives, based on site-specific characteristics, including the nature and extent of COCs, waste/source type and locations, Landfill hydrogeology, and time required to achieve CULs.
- **Implementability**—administrative issues related to the technology, including required government regulatory approvals, construction schedule, constructability, access, monitoring, operation and maintenance, and community concerns.
- **Relative Cost**—the relative cost of the technology, including initial capital and future annual operating, maintenance, and monitoring costs, compared to other technologies.

In addition, land use planning and controls can also be considered cleanup action components. The roles of land use planning and controls as supplements to retained technologies are further evaluated within each cleanup action alternative.

11.2.1 Retained Technologies

The retained technologies shown in Table 11-1 result from several factors including, but not limited to, qualitatively evaluating the potential remediation technologies based on screening information prepared by EPA, CPEO, and other organizations for sites across the United States and using the screening criteria listed above in Section 11.2. The selections of the retained technologies are based on the experiences gained at similar sites as well as professional knowledge and judgment. More complete descriptions of the retained technologies and their applicability to the Landfill are provided below. Long-term groundwater monitoring will be conducted in conjunction with all cleanup action alternatives.

Land Use Controls

Land use controls provide protection from exposure through the use of non-engineered or legal controls that limit land or resource use, such as access controls and property restrictions. Although land use controls provide no reduction of toxicity, volume, or mobility of contaminants, they can reduce or eliminate direct exposure pathways and resultant risk. Land use controls are commonly most effective when used in combination with other measures, such as source removal, containment, and monitored natural attenuation (MNA).

For Landfill groundwater, land use controls could potentially include groundwater use controls. Land use controls for off-site groundwater could potentially include restricting well installation in contaminated aquifers, implementing proper well construction/seal, and preventing cross-contamination during installation of drinking water wells. These controls could require restricting the property’s use and providing programs to educate residents who are affected or potentially affected by contaminated groundwater. Current regulations restrict installation of water wells within 1,000 feet of a landfill (WAC 173-160-171(3)(b)(vi)).

Containment: Low Permeability Cap

Landfill capping with a low permeability cap is a containment technology that forms a barrier between the contaminated media and the surface, thereby shielding humans and the environment from the harmful effects of its contents and limiting the dissolution and migration of the contaminants in the refuse. A low permeability cap must restrict infiltration of surface water and precipitation into the contaminated subsurface to reduce the potential for contaminants to leach into groundwater and be transported off-site by groundwater flow. If water is allowed to seep through a landfill, it can saturate the refuse and form leachate, which commonly contains high concentrations of contaminants. The leachate can seep out of the bottom or sides of the landfill and can enter and impact groundwater.

Landfill caps do not lessen the toxicity, mobility, or volume of wastes, but they do limit migration of contaminants. Landfill caps are most effective where all or most of the underlying waste is above the water table. Landfill cap integrity must not be compromised by present and/or future land use activities. Institutional controls are commonly required to protect the landfill cap.

In accordance with Chapter 173-304 WAC, the Landfill currently consists of an area capped by a low-permeability native soil/bentonite barrier (Phase I Area) and an area covered with soil (Phase II Area). Leachate generation rates for the existing conditions for the Phase I Area of the Landfill have been calculated within various documents and range from 610,000 gallons (Parametrix, 1997a) to 4.5 million gallons per year (Parametrix, 1988). For landfills regulated under Chapter 173-351 WAC, a composite liner system composed of a combination of a geomembrane (typically HDPE or PVC) and a protective barrier vegetated soil layer are required. These cap systems typically reduce leachate generation to a fraction of one percent of the pre-closure leachate generation for landfills. Based on modeling performed by Ecology (Ecology, 2005), leachate generation at the Phase I Area could be reduced to approximately 17,000 gallons per year if a geomembrane liner was installed.

In Situ Biological Treatment: Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) could be applied as a remedy for groundwater. The natural attenuation processes include a variety of physical, chemical, and biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These in situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, and destruction of contaminants. Periodic monitoring is necessary to demonstrate that contaminant concentrations continue to decrease at a rate sufficient to ensure that they do not become a threat to human health or the environment.

MNA may, under certain conditions (e.g., through sorption or oxidation-reduction [redox] reactions), effectively reduce the dissolved concentrations and/or toxic forms of inorganic contaminants in groundwater and soil. Metals may be attenuated by sorption reactions such as precipitation, adsorption on the surfaces of soil minerals, absorption into the matrix of soil minerals, or partitioning into organic matter. Redox reactions can transform the valence states of some inorganic contaminants to less soluble and thus less mobile forms and/or to less toxic forms. Sorption and redox reactions are the dominant mechanisms responsible for the reduction of mobility, toxicity, or bioavailability of inorganic contaminants. It is necessary to know what specific mechanism (type of sorption or redox reaction) is responsible for the attenuation of inorganics so that the stability of the mechanism can be evaluated.

Inorganic contaminants persist in the subsurface because, except for radioactive decay, they are not degraded by the other natural attenuation processes. Often, however, they may exist in forms that have low mobility, toxicity, or bioavailability such that they pose a relatively low level of risk. Therefore, natural attenuation of inorganic contaminants is most applicable to sites where immobilization or radioactive decay is demonstrated to be in effect and the process/mechanism is irreversible.

According to MTCA as described under WAC 173-340-370(7), MNA as a remediation alternative is most appropriate for sites with the following characteristics:

- Source control has been conducted to the maximum extent practicable;
- Leaving contaminants on site during the restoration timeframe does not pose an unacceptable threat to human health or the environment;
- There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site; and
- Appropriate monitoring is conducted to ensure that contaminant concentrations continue to decrease, the natural attenuation processes continue to occur, and human health and the environment are protected.

For Landfill groundwater, this technology would be applicable because:

- Various source control activities (e.g., waste consolidation, low permeability capping, surface water controls, etc.) have been completed.
- Residual contamination does not pose a threat because potential receptors do not have direct contact with the contaminants remaining on site and the contamination does not pose a risk to human health or the environment because there is no complete exposure pathway.

- There is evidence at the Landfill that natural attenuation is occurring and has significantly decreased contaminant concentrations, particularly for organic contaminants.

In-Situ Physical/Chemical Treatment: Air Sparging

Air sparging is the process of injecting air directly into groundwater. Air sparging remediates groundwater by volatilizing contaminants, enhancing aerobic biodegradation of some VOCs, and can change reducing geochemical conditions to oxidative conditions by providing oxygen to groundwater. It is akin to blowing bubbles from a straw into a bowl of water. As the bubbles rise, the volatile contaminants are removed from the groundwater by physical contact with the air (i.e., stripping) and are carried upward into the unsaturated zone (i.e., soil) as soil vapor. The addition of oxygen to contaminated groundwater and soils also enhances biodegradation of some contaminants in and above the water table, as it serves as an oxygen source for aerobic bacteria. Finally, the addition of oxygen increases the concentration of dissolved oxygen in groundwater and would potentially create aerobic geochemical conditions that would decrease the solubility of arsenic, iron, and manganese which would reduce their concentrations dissolved in groundwater.

For Landfill groundwater, this technology would be applicable because:

- Manganese and iron solubility is increased as a result of the reducing geochemical conditions within the groundwater below and downgradient of the Landfill.
- Providing oxygen would provide an oxidant to oxidize manganese and iron and cause the less soluble oxidized metals to precipitate and adhere to the soil matrix, thereby reducing their mobility.

In-Situ Physical/Chemical Treatment: Complexation

Metals Remediation Compound (MRC™) is a proprietary compound produced by Regenesis. MRC™ directly affects geochemical processes to remove metals from groundwater quickly, effectively, and at a relatively low cost.

MRC™ is a non-toxic formulation that, upon injection into the contaminated subsurface, removes dissolved metals from groundwater under reducing conditions.

The active compound in MRC™ is a benign organosulfur compound that is environmentally safe. Once MRC™ becomes hydrated and subject to microbial biodegradation, it slowly releases the organosulfur compound. Upon contact with metal ions, the organosulfur compound irreversibly reacts to produce a metal-organosulfur complex (complexation). This metal-organosulfur complex sorbs strongly to soil and is immobile in the subsurface. Over time, the immobilized metals may be incorporated into the soil matrix as sulfide solids. The immobilized metals are stable under low redox potential (reducing conditions) and may be stable under oxidizing conditions.

Based on vendor documentation and bench-scale testing, MRC™ is applicable to treat arsenic within the groundwater; however, our understanding of the chemical processes involved with complexation of arsenic would preclude the use of MRC™ under oxidizing conditions; therefore, the use of MRC™ upgradient to air sparging would be required. Full-scale implementation of MRC™ has only been used to remediate hexavalent chromium.

12. CLEANUP ACTION ALTERNATIVES

Considering the nature and extent of contamination, MTCA requirements for selection of cleanup actions (WAC 173-340-360) and the cleanup action technologies retained after screening, the following cleanup action alternatives have been assembled for the groundwater contamination present at the Landfill:

1. Monitored Natural Attenuation (MNA) and Land Use Controls. This alternative is a continuation of the activities currently being conducted at the Landfill including monitoring and Landfill post closure maintenance in accordance with the SWHP. Land use controls include continued provision and maintenance of fencing, locked gates, and signs. These aspects of this alternative will continue regardless of the selected remedial action.
2. Low Permeability Cap with Monitored Natural Attenuation and Land Use Controls. The low permeability cap would consist of a geomembrane installed over the Phase I landfill area.
3. In-Situ Treatment using air sparging and complexation, Monitored Natural Attenuation, and Land Use Controls.

12.1 ALTERNATIVE 1 – MNA AND LAND USE CONTROLS

This alternative would consist of:

- MNA of groundwater; and
- Continued application of Land Use Controls to reduce the potential for exposure to contaminated groundwater.

12.1.1 Description of Alternative 1

MNA would consist of continuing the post closure monitoring and maintenance activities as specified in the Landfill Final Closure Plan and the SWHP. Activities would include:

- Continued quarterly monitoring of five (5) groundwater monitoring wells (MW-1, MW-3, MW-6, MW-8, and MW-10) and annual monitoring of two (2) wells (MW-5A and MW-7) and one (1) surface water location (SW-2) with quarterly reporting.
- Continued inspection, maintenance, and repair of Landfill closure systems, including the cap, drainage ditches, and the Landfill gas system.
- Continued quarterly monitoring, maintenance, and operation of the Landfill gas system.
- Preparation of a Restrictive Covenant, Land Use Control Implementation Plan, and Notice of Conveyance or Other Transfer of an Interest in the Property upon property transfer.

12.1.1.1 Groundwater MNA

Groundwater MNA relies upon natural attenuation processes (within the context of controlled and monitored site conditions) to achieve the Cleanup Action Objectives. Natural attenuation is the process by which concentrations of chemicals introduced into the environment are reduced over time by natural physical, biological, and chemical processes. Natural attenuation has been shown to effectively reduce the concentrations of inorganic and organic contaminants in groundwater.

WAC 173-340-370(7) identifies that monitored natural attenuation may be appropriate at sites that have the following characteristics:

Characteristic	Conditions at Olalla Landfill
Source control, including removal and/or treatment of hazardous substances, has been conducted to the maximum extent practicable.	The Olalla Landfill Phase I Area was closed with a low permeability bentonite-amended soil cap in accordance with Chapter 173-304 WAC. The cap is monitored and maintained in accordance with the Landfill closure plan and the SWHP. The Phase II area does not have an engineered cap; however, the facility is covered by a minimum of 1 foot of soil, and wastes remain dry and are separated from the uppermost aquifer by 40 to 50 feet, indicating no contact between waste and groundwater.
Leaving contaminants on-site during the restoration timeframe does not pose an unacceptable threat to human health or the environment.	Groundwater at the Olalla Landfill exceeds CULs at the CPOC; however, no direct contact exposure route for groundwater ingestion or contact is identified. Continued post closure operation and land use controls will reduce the potential for future changes to groundwater exposure scenarios.
There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site.	Based on typical trends observed with other similar closed Chapter 173-304 WAC landfills, declining leachate releases and landfill gas production over time lead to long-term declining trends in groundwater contaminant concentrations. Groundwater concentrations of COCs at the Landfill have been steady or declining during the monitoring period and would be expected to continue to decline and ultimately achieve CULs.
Appropriate monitoring requirements are conducted to evaluate if conditions favorable for natural attenuation processes are maintained and that human health and the environment are protected.	Quarterly groundwater monitoring is required at the Landfill as part of the SWHP and will continue in accordance with the SWHP. Monitored parameters include parameters used to evaluate if natural attenuation processes are taking place including specific conductance, pH, dissolved oxygen, and oxidation-reduction potential. Land use restrictions currently in place and permit limitations on developing adjacent properties within 1,000 feet of the Landfill will continue to protect potential exposure through direct contact or ingestion of groundwater that exceeds CULs.

Natural attenuation processes at the Landfill that may reduce the COC concentrations in groundwater during transport downgradient are dispersion, dilution, chemical stabilization, and sorption. Dispersion and dilution appear to be the current dominant attenuation processes at the Landfill; however, as the leachate generation and anaerobic conditions beneath the Landfill dissipate over time, the geochemistry within the subsurface will change and chemical stabilization and sorption will become the dominant attenuation processes. Supporting information for this statement includes:

- pH is neutral or slightly acidic in samples collected from all Landfill wells which allows for the mobilization of metals in reducing conditions or the precipitation or re-adsorption of metals to the aquifer matrix in oxidizing conditions;
- Dissolved oxygen and ORP levels are generally low in samples collected from Landfill wells that demonstrate elevated metals concentrations. This demonstrates that anaerobic (reducing) conditions are occurring.; and,
- Dissolved oxygen and ORP levels are generally high (>100 millivolts [mV]) in samples collected from Landfill wells where metals concentrations are low indicating

oxidizing conditions and the ability to decrease metals concentrations where oxidizing conditions exist.

12.1.1.2 Groundwater Monitoring

MNA requires a robust groundwater monitoring program to ensure the Cleanup Action Objectives are being achieved in a reasonable timeframe. The long-term groundwater monitoring program for the facility will consist of specific wells, specific constituents, and monitoring frequency to ensure achievement of the Cleanup Action Objectives and support the Post Closure care requirements.

Depth-to-water measurements would be measured at wells MW-1, MW-2, MW-3, MW-4, MW-5, MW-5A, MW-6, MW-7, MW-8, and MW-10. These wells were selected because they provide appropriate upgradient, cross gradient, and down-gradient coverage of groundwater elevations at the Landfill. Wells MW-1, MW-3, MW-5A, MW-6, MW-7, MW-8, and MW-10 will be sampled for laboratory analyses. Of the wells sampled, MW-3, MW-6, MW-7, MW-8, and MW-10, also represent locations for monitoring the CPOC. KCPW has also elected to measure depth to water at well MW-5 to track changes in the water level of the shallow perched groundwater north of the Landfill.

The constituents to be analyzed would include field parameters (i.e., pH, specific conductance, DO, temperature, and ORP), dissolved metals (i.e., iron, manganese, and arsenic) and conventional constituents (e.g., ammonia, chloride, total organic carbon, bicarbonate, carbonate, nitrate, nitrite, sulfate, alkalinity). The field parameters, specifically DO and ORP, will provide an indication of the aquifer’s geochemical characteristics. These parameters will be evaluated over time to determine if, and to what extent, natural attenuation is occurring. Natural attenuation will be indicated by geochemical conditions becoming more aerobic as evidenced primarily by increasing DO concentrations and higher ORP values. As the geochemical conditions become more aerobic, the dissolved metals should show a downward trend over time. Other constituents may be included in the monitoring program as required by the SWHP.

Monitoring would continue to meet the requirements specified in the SWHP. Adjustments to the monitoring frequency should occur based on approval from the KPHD, but are expected to continue quarterly for 5 years. The County may consider performing a technical analysis demonstrating the effectiveness of semi-annual sampling after collecting 5 years of quarterly data from the current monitoring well network, including new wells MW-8 and MW-10.

The groundwater monitoring program discussed for the FS is based on the current SWHP and will continue in accordance with the SWHP. Implementation of quarterly groundwater monitoring is assumed for cost estimating purposes in the FS for a duration of 30 years; however, KCPW anticipates groundwater monitoring frequency, constituents, and duration will be modified and reduced in coordination with KPHD.

12.1.1.3 Land Use Controls

Land Use Controls are currently in place in the form of requirements established in the SWHP and Kitsap County Board of Health Solid Waste Ordinance 2010-01. These controls will continue until CULs are achieved and other Landfill post-closure criteria are achieved. Controls include fencing, locked gates, and signage to limit access to the Landfill. The Landfill property is also listed in County and State records as a landfill and water well installation and residential development is restricted within 1,000 feet of the property boundary. The Landfill is regulated under Washington State Minimum Functional Standards for Solid Waste Handling (Chapter 173-304 WAC). Existing deed restrictions for the Landfill property are in place and will be maintained. A Restrictive Covenant will be prepared and executed for the Landfill.

12.1.2 Cost

The cost for this alternative includes routine inspections and maintenance of the closure system and environmental monitoring as specified in the 2012 SWHP and the Post Closure Maintenance Plan. The post-closure program will be in accordance with the SWHP; however, for estimating purposes we have included costs for the following:

- Inspection of final cap to identify settlement and erosion effects and correct deficiencies.
- Inspection, cleaning and repair of drainage ditches.
- Inspection and regrading of access roads.
- Inspection and repair of groundwater monitoring wells and dedicated sampling devices.
- Landfill gas monitoring and flare operation and maintenance.
- Quarterly monitoring of groundwater for:
    - Dissolved metals (iron, arsenic, manganese, zinc, barium).
    - Total metals (sodium, calcium, potassium).
    - Total Coliform.
    - Conventionals (carbonate, bicarbonate, chloride, sulfate, nitrate, nitrite – nitrogen, ammonium nitrogen).
    - Chemical Oxygen Demand (COD).
    - Total Organic Carbon (TOC).
    - Volatile Organic Compounds (VOC) by EPA Method 8260C.
    - Vinyl Chloride by SIM.
    - Field Parameters (temperature, pH, oxidation-reduction potential, dissolved oxygen, and specific conductance).
    - Field measurements – depth to water.
- Quarterly and annual reporting of Landfill monitoring and maintenance activities. The groundwater monitoring program will be in accordance with the SWHP; however, for estimating purposes, a 30 year monitoring period was assumed.
- Annual Solid Waste Handling Permit fees.

Based on the items above, the total estimated net present value for Alternative 1 is $2,725,393. Appendix L contains a detailed breakdown of the estimated costs associated with each alternative including Alternative 1.

The cost estimates contained in Appendix L include capital, long-term operation and maintenance (O&M), monitoring, and institutional costs. Costs are available from five sources: the professional opinion of Parametrix design engineers, quotes requested from remediation firms, published literature, known costs for O&M at the Olalla Landfill, and similar projects. All costs are order of magnitude preliminary estimates used to compare the alternatives.

12.2 ALTERNATIVE 2 – LOW PERMEABILITY CAP WITH MNA AND LAND USE CONTROLS

Implementation of this alternative would consist of:

- Installation of a low permeability geomembrane cap over the Phase I area of the Landfill.
- MNA of groundwater as described in Alternative 1.
- Continued application of Land Use Controls to reduce the potential for exposure to contaminated groundwater.
- Preparation of an Environmental Covenant, Land Use Control Implementation Plan, and Notice of Conveyance or Other Transfer of an Interest in the Property upon property transfer.

12.2.1 Description of Alternative 2 Low Permeability Geomembrane Cap

Alternative 2 would consist of installation of an engineered geomembrane cap over the existing low permeability soil cap on the Phase I Area. Generally, this requires excavation/embankment, minor grading and compacting subgrade, construction of a geomembrane landfill cap system on top of the existing low permeability soil cap, road construction and grading, and stormwater perimeter ditches. Although the Olalla Landfill was closed in accordance with Chapter 173-304 WAC, the low permeability geomembrane cap would be constructed using Chapter 173-351 WAC, Criteria for Municipal Solid Waste Landfills, as a guide. The top liner consists of a compacted bedding layer and an overlying 30 mil PVC geomembrane. The cap system consists of a 24-inch soil layer on top of the Landfill, and an 18-inch side slope layer overlaid with an 8-inch rock armor layer for the side slope areas. All road access will consist of embankment material and crushed surfacing. The installation of a geomembrane would require reconstruction of the passive Landfill gas system including installation of new gas collection piping, new flares, and four new soil gas wells for landfill gas migration monitoring. Depending on methane concentrations measured in the new Landfill gas system, active gas collection and treatment might be necessary.

12.2.1.1 Groundwater MNA

Groundwater MNA for Alternative 2 would be identical to Alternative 1 with the exception that monitoring frequency has been reduced from quarterly to semi-annually in years 20 through 30. This reduction is based on the assumption that groundwater concentrations will reach CULs at year 20 and that confirmation monitoring will be required from year 20 through year 30 to ensure that the geomembrane cap maintains its functionality. The following updates the natural attenuation evaluation compared to Alternative 1.

Characteristic	Conditions at Olalla Landfill
Source control, including removal and/or treatment of hazardous substances, has been conducted to the maximum extent practicable	The Phase I Area would be closed with a low permeability geomembrane cap system using Chapter 173-351 WAC as a guide. The cap system would be monitored and maintained in accordance with the Landfill closure plan and the SWHP.
Leaving contaminants on-site during the restoration timeframe does not pose an unacceptable threat to human health or the environment	Identical to Alternative 1.

Characteristic	Conditions at Olalla Landfill
There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the site	Identical to Alternative 1.
Appropriate monitoring requirements are conducted to evaluate if conditions favorable for natural attenuation processes are maintained and that human health and the environment are protected.	Identical to Alternative 1.

12.2.1.2 Groundwater Monitoring

Groundwater monitoring would be identical to Alternative 1 with the exception that monitoring frequency has been reduced from quarterly to semi-annually in years 20 through 30.

12.2.1.3 Land Use Controls

Land Use Controls would be similar except the Phase I Area would be covered with a low permeability geomembrane cap system, which would require on-going monitoring and maintenance.

12.2.1.4 Cost Alternative 2

The cost for Alternative 2 would include all cost components described in Alternative 1, plus the following:

- Design and construction of a low permeable geomembrane cap over the existing low permeability soil cap within the 6.5 acres encompassed by the Phase I area (Figure 12-1).
- Monitoring and routine maintenance of the low permeable geomembrane cap system. It is assumed that maintenance improvements would be required every 5 years. Monitoring and maintenance would be conducted in accordance with the SWHP; however, for estimating purposes we have assumed a 30-year monitoring and maintenance period with a reduction in monitoring frequency from year 20 to year 30. Maintenance requirements would be greater than Alternative 1 because of the use of a geomembrane, which may require periodic repair.
- Reconstruction of the existing Landfill passive gas recovery system.
- Installation of four soil gas probes.

Based on the items above, the total estimated net present value for Alternative 2 is $4,478,585. Appendix L contains a detailed breakdown of the estimated costs associated with Alternative 2.

12.3 IN-SITU PHYSICAL/CHEMICAL TREATMENT: AIR SPARGING AND COMPLEXATION

This alternative would consist of:

- All elements of Alternative 1.
- Air sparging to remediate arsenic, iron, and manganese in groundwater.

- Complexation as an initial added step to remediate arsenic in groundwater.
- Additional groundwater monitoring.

12.3.1 Description of Alternative 3

Alternative 3 consists of installation of an air sparging system to add oxygen to the subsurface in order to create an aerobic subsurface environment at the CPOC and a remediation substrate injection system to provide remediation products designed for metals complexation. Alternative 3 also includes MNA of groundwater and Land Use Controls similar to Alternative 1.

12.3.1.1 Air Sparging

Alternative 3 would install an air sparging system consisting of up to 10 air injection wells installed in intervals of approximately 50 feet along the western boundary of the Landfill property, hydraulically upgradient from MW-3, MW-6, MW-8, and MW-10. The wells would be constructed using a hollow-stem auger drill and extend to approximately 225 National Geodetic Vertical Datum 1929 (NGVD 29) or between 40 and 50 feet bgs. Wells would be designed with 5 feet of machine-slotted well screen set in a sand filter pack at the base to allow for air injection to increase dissolved oxygen concentrations in groundwater. The air injection wells would be connected to a piping manifold at the surface that would allow compressed air to be equally distributed between the wells.

The air sparging system would be operated for approximately 25-day intervals (monthly), followed by 5-day shutdown periods to allow for aquifer stabilization, which is necessary for static water level measurements and groundwater sampling to occur. The 5-day shutdown would allow for maintenance to the blower, wells, and ancillary equipment. After sampling, the sparging wells would be treated to control iron-fixing bacteria that are common in oxidized environments. The air sparging system would be operated in cycles of approximately 25 days on with 5 days off for the first year as described above. After the first year of operation, the air sparging system would be operated for approximately 3-month intervals (quarterly) followed by 5-day shutdown periods to allow for aquifer stabilization, water level measurements, groundwater sampling, and maintenance. For this feasibility study, the air sparging system is assumed to operate for 30 years. The operating duration is an estimate based on professional judgment and because refuse (source area) will be left in place with no active remediation. The air sparging system is intended as a treatment zone that will be necessary to modify geochemical conditions until the source area degrades to a point where downgradient COC concentrations are not elevated by reducing geochemical conditions.

A single well pilot test would be conducted to refine the full-scale treatment approach for air sparging. The pilot test would help refine the air flow requirements and range of influence of each air injection point. The pilot test would involve the installation of one air injection well. Air would be injected into the well for a 30 day period and dissolved oxygen and ORP would be monitored daily in the adjacent monitoring wells.

12.3.1.2 Complexation

Alternative 3 also includes installation of up to 21 injection points in intervals of approximately 25 feet along the eastern edge of the eastern perimeter road as shown in Figure 12-2. The injection points would extend approximately 60 to 70 feet bgs and extend 20 feet below the seasonal low groundwater level. The bottom of the injection points would be fitted with 20 feet of slotted well screen set in a sand filter pack that would allow for the injection of MRC™. MRC™ would be injected at a rate of approximately 100 pounds per injection point. We assume that a total of five annual treatments would be necessary to reduce groundwater metals concentrations to near cleanup levels. After 5 years of MRC treatment, we assume that air sparging alone would be sufficient to maintain the reduced metals concentrations. Metals concentrations would be measured during ongoing MFS groundwater sampling at monitoring wells MW-3, MW-6, MW-8, and MW-10.

Bench-scale treatability and pilot tests would be conducted to help refine the full-scale treatment approach for Alternative 3. Results of the treatability and pilot tests would be used to refine the full-scale treatment approach for groundwater. If the results of the bench and/or pilot scale treatability tests indicated that MRC was not effective in complexing the site COCs, full scale complexation would be eliminated from the alternative.

In addition to the air and MRC™ injection points, Alternative 3 would install an approximate 20-by-20-foot maintenance building to house a pad-mounted compressor and provide for chemical handling and storage and for maintenance equipment and supplies.

12.3.1.3 Additional Groundwater Monitoring

Groundwater monitoring, in addition to the requirements presented in Alternative 1, would involve monthly performance sampling of air sparging wells during the first year, followed by quarterly performance sampling until levels of iron and manganese were reduced below CULs. The air injection wells would also be sampled for arsenic to assess the effectiveness of complexation efforts. However, ongoing MFS groundwater monitoring is sufficient to evaluate and demonstrate permanence of remediation efforts.

12.3.1.4 Cost

The cost for Alternative 3 would include the following elements:

- Plan, conduct, and report on a pilot test to refine full scale treatment approaches.
- Installation of an air sparging system including the construction of up to 10, 2-inch diameter air injection wells to an average depth of 45 feet bgs. The air sparging system would also include the procurement and installation of an air compressor and associated piping, instrumentation and power.
- Construction of a 20 feet x 20 feet building.
- Plan, conduct, and report of bench-scale treatability testing of MRC™ technology.
- Installation of the MRC™ injection network including the construction of up to 21, 2-inch diameter injection points to an average depth of 65 feet bgs. This would involve contracting construction services, site improvements to facilitate construction, drilling and well materials, and oversight and reporting.
- Purchase of the MRC™ chemicals.
- Five rounds of chemical injection.
- 48 rounds of additional groundwater monitoring of 10 air sparge wells.
- Decommissioning of the remediation systems, including decommissioning of the injection points and site restoration.
- Annual and close out reporting.

Based on the items above, the total estimated net present value for Alternative 3 is $5,659,031. Appendix L contains a detailed breakdown of the estimated costs associated with Alternative 3.

13. EVALUATION OF CLEANUP ACTION ALTERNATIVES

MTCA established minimum requirements and procedures for selecting cleanup actions in WAC 173-340-360. The minimum requirements include threshold requirements and other requirements discussed below.

13.1 THRESHOLD REQUIREMENTS

MTCA requires that all cleanup actions meet the threshold requirements that are part of the minimum requirements. This section uses the threshold requirements to evaluate the list of three remedial alternatives developed. Under MTCA, cleanup action alternatives must meet the following threshold requirements as defined in WAC 173-340-360(2)(a):

- Protection of human health and the environment.
- Compliance with cleanup standards.
- Compliance with ARARs.
- Provision for compliance monitoring.

Each alternative is evaluated individually against the threshold criteria in the following sections.

13.1.1 Protection of Human Health and the Environment

As a threshold criterion, protection of human health and the environment addresses whether a cleanup action alternative would result in sufficiently low residual risk to human and ecological receptors after completion of the alternative.

Protection of human health and the environment would be unchanged from present conditions for Alternative 1 because no active remediation technologies would be implemented. However, Alternative 1 is protective of human health and the environment because the existing cap and soil cover reduces the leaching potential through the wastes and eliminates exposures to contaminants above CULs by human and ecological receptors.

Alternative 2 would be protective of human health and the environment because capping of the Landfill Phase I Area would reduce the leaching potential through the wastes and potentially decrease the rate of future releases of COCs to groundwater. However, residual concentrations of the COCs in the Landfill areas beneath the low permeability caps would remain unchanged.

Alternative 3 would be protective of human health and the environment because COCs in groundwater may be transformed to insoluble oxides that would adsorb onto soil particles and ultimately reduce COC concentrations in groundwater. As with Alternative 2, residual concentrations of the COCs in the Landfill areas beneath the low permeability caps would remain unchanged.

13.1.2 Compliance with Cleanup Standards

Compliance with cleanup standards is defined by meeting the requirements of WAC 173-340-700 through WAC 173-340-760.

All Alternatives comply with cleanup standards by attaining cleanup levels at the point(s) of compliance within a reasonable period of time and in accordance with WAC 173-340-720(8)(c). Alternatives 1 and 2 rely on natural attenuation, which potentially requires decades to achieve applicable cleanup levels. Alternative 3 would likely achieve applicable cleanup levels more quickly; estimated to be less than 10 years. However, maintenance of the cleanup levels after the 10 years will still be required due to the source area remaining.

13.1.3 Compliance with ARARs

Compliance with ARARs for all alternatives requires, in addition to meeting cleanup standards, that the actions also meet location-specific and action-specific state and federal requirements. All three alternatives leave waste materials at the Landfill beneath either the existing landfill cap or a new geomembrane cap in accordance with MTCA. All three alternatives comply with the ARARs identified for the site (Table 9-1).

13.1.4 Provide for Compliance Monitoring

Compliance monitoring requirements are defined in WAC 173-340-410. Compliance monitoring includes: 1) "protection monitoring" to evaluate if human health and the environment are adequately protected during implementation of an alternative; 2) "performance monitoring" to evaluate if cleanup standards or other performance goals have been attained; and 3) "confirmation monitoring" to monitor the long-term effectiveness of the remedy after completion of the alternative.

All three alternatives provide for compliance monitoring and long-term groundwater monitoring.

13.2 OTHER REQUIREMENTS

In addition to the threshold requirements, WAC 173-340-360(2)(b) requires cleanup actions to meet "other requirements" or "additional requirements" that are part of the minimum requirements for the alternatives. These other requirements include the following:

- Use permanent solutions to the maximum extent practicable including consideration for public concerns.
- Provide for a reasonable restoration timeframe.
- Consider additional performance criteria.

13.2.1 Permanent Solutions

This section describes the permanent solutions criteria and compares each of the alternatives regarding the criteria.

13.2.2 Permanent Solutions Criteria

WAC 173-340-360(2)(b)(i) requires selected cleanup actions to use permanent solutions to the maximum extent practicable. To determine if the selected cleanup action meets this test, a disproportionate cost analysis (DCA) is performed. The DCA involves ranking the cleanup action alternatives from most to least permanent based on the benefits provided by each alternative. Alternatives are then compared on the basis of cost. Costs are considered disproportionate to benefits if the incremental cost of an alternative over that of a lower cost alternative exceeds the incremental degree of benefits achieved (WAC 173-340-360[3][e][i]). The six benefit criteria and single cost criteria cited in WAC 173-340-360(3)(f) to be used for the DCA are described below.

- **Protectiveness—**addresses overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, the time required to reduce the risk and attain cleanup standards, the on-site and off-site risks resulting from implementation, and improvement of the overall environmental quality.
- **Permanence—**addresses the degree to which a cleanup action alternative reduces the inherent toxicity, the ability of contaminants to migrate to potential human or environmental receptors, or the quantity of contaminated material.
- **Cost—**used to consider the costs of performing the alternative, including capital, long-term operation and maintenance (O&M), monitoring, and institutional costs. Alternative costs are compared on a net present value basis.
- **Effectiveness Over the Long-Term—**based on the degree of certainty that the alternative will be a success, the long-term reliability, the magnitude of residual risk, and the effectiveness of controls required to manage treatment of residual or remaining waste.
- **Management of Short-Term Risks—**addresses short-term effects on human health and the environment while the alternative is being implemented. The evaluation includes consideration of the following factors:
  - Risk to Landfill workers.
  - Risk to the community.
  - Risk to the environment (short-term ecological risk).
- **Technical and Administrative Implementability—**addresses the degree of difficulty in implementing the alternative. Implementability issues are important because they address the potential for delays, cost overruns, and failure. Implementability is evaluated by considering the following:
  - Technical Feasibility: Technical feasibility addresses the potential for problems during implementation of the alternative and related uncertainties. The evaluation includes the likelihood of delays due to technical problems and the ease of modifying the alternative, if required.
  - Availability of Services and Materials: The availability of experienced contractors and personnel, equipment, and materials needed to implement the alternative.
  - Administrative Feasibility: The degree of difficulty anticipated due to regulatory constraints and the degree of coordination required among various agencies.
  - Scheduling: The time required until cleanup action would be complete, and any difficulties associated with scheduling.
  - Complexity and Size: The more complex or larger a cleanup action, the more difficult it is to construct or implement. Sufficient space must be available at the Landfill to enable efficient implementation of the alternative in a manner that achieves the specific time constraints.
  - Other Considerations: Monitoring requirements, access for construction, operation and maintenance, integration with existing operations, current or potential cleanup action, and other factors were considered in accordance with WAC 173-340-410.

- **Consideration of Public Concerns—**public participation is an integral part of MTCA. Ecology's goal is to provide the public with timely information and meaningful opportunities for participation. This goal is met through a public participation program that may include:
  - Early planning and development of a site-specific public participation plan.
  - Provision of public notices.
  - Public meetings or hearings.
  - Participation of regional citizen's advisory committees.

13.2.2.1 Permanent Solutions Evaluation and Ranking of Alternatives

Each alternative is evaluated and ranked against the permanent solutions criteria in the following subsections. A DCA performed using the ranking provided in this subsection is provided in Section 13.3.

Protectiveness

Alternatives 1 and 2 meet the goal of protectiveness because they provide a permanent method of containment and over time reduce COC concentrations in groundwater through natural attenuation. Alternatives 1 and 2 also provide containment of wastes and rely on land use controls to reduce or eliminate exposure pathways. Alternative 3 meets the protectiveness goal by reducing COC concentrations to below CULs on a faster timeframe than the other alternatives. All proposed alternatives leave the solid waste in place within the permitted Landfill in accordance with MTCA; and, all the alternatives eliminate exposures to contaminants above CULs by human and ecological receptors. Alternative 3 is considered the most protective due to the faster estimated timeframe to reach CULs (10 years) followed by Alternative 2 (20 years), then Alternative 1 (30 years).

Permanent Reduction in Toxicity, Mobility, and Volume

Alternative 1 provides permanent reduction in the toxicity and mass of contaminants through natural attenuation. Alternative 2 provides permanent reduction in the mobility of contaminants in the environment with the installation of the geomembrane cap; however, note that the alternative is only permanent if the geomembrane cap is maintained in near perpetuity. If the geomembrane is allowed to degrade, infiltrating groundwater could reach the encapsulated solid waste and cause groundwater concentrations to rebound. These alternatives only reduce water infiltration into the subsurface and have no effect on toxicity, mobility, or volume of the residual COCs already in groundwater. Alternative 3 provides a permanent reduction in the toxicity and mobility of some contaminants by transforming the metal COCs to insoluble oxides that adsorb to the aquifer matrix. This reduction in toxicity and mobility includes contaminants already in groundwater beneath the Landfill. Alternative 3 is considered to provide the most benefit under this criterion followed by Alternative 2, then Alternative 1.

Long-Term Effectiveness

All alternatives exhibit long-term effectiveness because contaminant concentrations would be reduced over time for all of the proposed alternatives. Alternative 2 provides enhanced containment that would effectively reduce the risks to human health and the environment associated with the contaminants left in place. Alternative 3 would be effective because metal COCs would be removed from groundwater media and bound to the aquifer matrix in their less soluble forms. Land use controls would be in place for all alternatives to increase the effectiveness of the cleanup action and to reduce potential exposure scenarios. Alternative 3 is considered to provide the most benefit under this criterion followed by Alternative 2, then Alternative 1.

Management of Short-Term Risks

Short-term risks for implementation of Alternative 1 are very low. This alternative is currently being implemented and has been in effect since 1992. Groundwater monitoring data demonstrate significant decreases in COC concentrations under this alternative. This decrease is demonstrated in the time series plots provided in Appendix C.

Short-term risks for Alternative 2 are similar and relatively low. Standard construction safety and traffic controls will be needed to provide safe operations. The primary risk to Landfill workers would be construction accidents during construction activities. Direct exposure to contaminated groundwater would not occur. Exposure to solid waste would be limited because the quantity of waste and method of excavation do not typically require direct worker contact. Any solid waste disturbed during construction activities would be replaced under the Landfill cap.

Short term risks for Alternative 3 would be the greatest. Construction activities would involve potential contact with contaminated groundwater and complexation would require chemical handling during injections. A hazard communication program and personal protective equipment would help to protect workers. Wastes generated during construction and operation of Alternative 3 would be contained and disposed in accordance with state and local regulations.

The increased risk to the community for the alternatives would primarily result from the increased traffic and construction resulting from the cleanup actions. This risk can be controlled through increased traffic control and site security during cleanup action activities.

Short-term risks to the environment would be reduced by acquiring and maintaining compliance with required construction permits.

Alternative 1 is considered to present the lowest short-term risk followed by Alternative 2, then Alternative 3.

Implementability (Technical and Administrative)

Implementation of construction activities at the Landfill would be relatively straightforward with no technical or administrative concerns. A number of construction activities have been implemented at the Landfill and there is sufficient area available for equipment and material storage.

Alternative 1 is currently being implemented with no additional technical or administrative issues.

Alternative 2 is technically and administratively implementable. An existing low permeability soil cap is present on the Phase I Area and many low-permeability caps (both soil and geomembrane) have been constructed at solid waste facilities in Kitsap County. Due to the complexity of the construction compared to Alternative 1, Alternative 2 is less readily implementable than Alternative 1.

Alternative 3 is administratively implementable. Technical implementability would be evaluated based on bench-scale and pilot studies to demonstrate feasibility; however, significant technical difficulties regarding the dosing of the aquifer, complexation of unknown species of metals, and changing the oxidation state of the aquifer are present. Construction would be complex and the delivery of chemicals and air to the aquifer could be difficult. Operation and maintenance of the air sparging and injection wells systems would also be more intensive as many more technical variables influence system performance.

Alternative 1 is the most technically and administratively implementable alternative and provides the most benefit under this criterion, followed by Alternative 2, then Alternative 3.

Consideration of Public Concerns

A public participation program using WAC 173-340-410 as a guide will be in place for the Landfill. KCPW and Ecology will take into consideration reasonable public comments with respect to the final cleanup action for the groundwater contamination at the Landfill. Consideration of public concerns considers local agencies and local governments as well as the general public. Alternative 2 is considered to provide the most benefit considering perceived public concern followed by Alternative 1, then Alternative 3.

13.2.3 Reasonable Restoration Timeframe

This section describes the reasonable restoration timeframe criteria and compares each of the alternatives regarding the criteria. The estimated restoration timeframes are 30 years for Alternative 1, 20 years for Alternative 2, and 10 years for Alternative 3.

13.2.3.1 Reasonable Restoration Timeframe Criteria and Evaluation

Specific requirements and procedures for determining whether a cleanup action provides for a reasonable restoration timeframe, as required under WAC 173-340-360(2)(b)(i), are provided in WAC 173-340-360(4). Factors to be considered when determining whether a cleanup action provides for a reasonable restoration timeframe and a discussion regarding the alternatives are provided below:

- **Potential risk posed by the Site to human health and the environment**—Currently, the only risks posed by the Landfill are from direct exposure to contaminated groundwater exceeding CULs or exposure to solid waste. These risks are extremely low for all three alternatives due to the lack of exposure pathways. Alternative 1 poses the greatest potential risk since groundwater COCs will attenuate over a period of decades, extending exposure potential. Alternative 2 reduces the exposure potential for solid waste, but is similar to Alternative 1 for groundwater exposure. Alternative 3 potentially reduces COC concentrations in groundwater on a faster timeframe and is the most protective.

- **Practicability of achieving a shorter restoration timeframe**—The cleanup timeframe is assumed to be 30 years for Alternative 1 and 20 years for Alternative 2. The time to reach cleanup levels at the CPOC for Alternative 3 is probably less than 10 years; however, the ultimate cleanup time is likely similar to Alternatives 1 and 2 since groundwater concentrations will rebound if the air sparging system is shut off before the end of the 30 year treatment period.

- **Current and future use of the Site, surrounding area, and associated resources that are or may be affected by releases from the Site—**The current use of the Landfill, surrounding area, and associated resources are not anticipated to change within the foreseeable future. New receptors will not be introduced and further impacts to resources are not anticipated.

- **Availability of alternative water supply**—An alternative water supply is not necessary for the Landfill because water supply wells downgradient of the Landfill are generally completed in the deeper confined aquifer that is not hydraulically connected to the uppermost aquifer. The South Kitsap County Transfer Station Well is cross gradient to the Landfill. In addition, samples from off-site water supply wells have never demonstrated impacts from the Landfill. New wells within 1,000 feet of the Landfill property boundary are not permitted.

- **Likely effectiveness and reliability of institutional controls**—Land use controls, will be effective and reliable in preventing contact with the contaminated groundwater under all Alternatives. The Landfill is currently operated under a post closure SWHP that requires regular groundwater, surface water, and landfill gas monitoring and maintenance of land use controls and engineering controls.
- **Ability to control and monitor migration of hazardous substances**—All three alternatives effectively monitor the migration of COCs in groundwater. Alternative 1 is the least effective in controlling the migration of COCs; however Remedial Investigation findings demonstrate that groundwater COC concentrations are stable or decreasing and are not migrating beyond their current extent of impact. Alternative 2 would be slightly more effective in controlling the migration by reducing the infiltration rate and leaching potential through the solid wastes. Alternative 3 would be most effective in controlling the migration of COCs as it reduces their mobility in the environment.
- **Toxicity of hazardous substances at the Site**—The concentrations of the COCs in samples from some downgradient monitoring wells at the Landfill are several times greater than their applicable cleanup levels. However, groundwater samples from off-site water supply wells sampled in 1995, 1997, and as part of the RI in late 2010 early 2011, have consistently demonstrated no measurable impacts from the Landfill. Therefore, the presence of COCs at concentrations greater than cleanup levels in samples from downgradient monitoring wells does not warrant a short restoration timeframe. Direct exposure to the COCs is unlikely due to the current and future use of the Landfill and the demonstrated lack of measurable impacts to offsite water supply wells.

Based on consideration of all the sub-criteria associated with the evaluation of the reasonable restoration timeframe, as well as the various scenarios associated with the Landfill, all of the proposed alternatives provide a reasonable restoration timeframe.

13.2.4 Additional Performance Criteria

In addition to meeting the minimum requirements, MTCA provides direction regarding the requirements of alternatives on a number of other performance criteria. These criteria and the performance of the alternatives based on the criteria are described below.

13.2.4.1 Institutional Controls and Financial Assurances

WAC 173-340-360(2)(e) requires cleanup actions to use institutional controls and financial assurances where required under WAC 173-340-440. All alternatives will require engineering and institutional controls to reduce the potential for exposures. All alternatives will require financial assurances.

13.2.4.2 Release and Migration

Cleanup actions under MTCA (WAC 173-340-360(2)(f)) are required to prevent or minimize present and future releases and migration of hazardous substances in the environment. All alternatives reduce the migration of hazardous substances through the use of low permeability caps and containment.

13.2.4.3 Remediation Levels

Cleanup actions under MTCA (WAC 173-340-360(2)(h) that use remediation levels shall meet each of the minimum requirements specified above. Cleanup actions that use a remediation level are required, in part, to conduct a determination that a more permanent cleanup action is not practicable, based on a disproportionate cost analysis and a demonstration that the action is protective of human health and the environment. Remediation levels are not included as part of the implementation of the cleanup action alternatives for the Olalla Landfill.

13.3 DCA AND PREFERRED ALTERNATIVE

Table 13-1 provides a permanent solutions scoring matrix for a qualitative comparison of alternatives. Each alternative was scored relative to the other alternatives with a “3” signifying that the alternative provided the most benefit under the criterion and a “1” signifying that the alternative provided the least benefit. The scoring provided reflects the ranking discussions provided in Section 13.2.2.1.

Table 13-1. Alternative Scoring Matrix

	Alternative		
Permanent Solutions Criteria	**1**	**2**	**3**
Protectiveness	1	2	3
Reduction of toxicity, mobility, and volume	1	2	3
Long-term effectiveness	1	2	3
Short term risks	3	2	1
Implementability	3	2	1
Public concerns	2	3	1
Permanent Solutions Criteria Score:	**11**	**13**	**12**

Alternative 2 scored highest and as such provides the most benefit under the evaluation criteria. The DCA procedure identifies the cleanup action that provides the most benefit as most permanent. Thus Alternative 2 is ranked as the most permanent cleanup action followed by Alternative 3, then Alternative 1. As the most permanent alternative, Alternative 2 is the baseline cleanup action alternative against which the other alternatives are compared.

Costs for each alternative are summarized in Table 13-2. Because Alternative 3 is more costly than the baseline alternative, while providing less benefit, no further comparison will be made. A benefit versus cost comparison for Alternatives 1 and 2 is provided below.

The assumed benefit under Alternative 2 is that groundwater CULs are attained at the CPOC sooner than under Alternative 1, which may result in a reduction in human health risk. However, this benefit has value only if human health risks under Alternative 1 are unacceptable, which may not be supported by the data. Dissolved arsenic, iron, and manganese are expected to undergo attenuation within a relatively short distance downgradient of the landfill. This occurs as oxygen-depleted groundwater mixes with fresh groundwater, geochemical conditions become less reducing, and the dissolved metals become less soluble and less mobile (see next paragraph for supporting reference). The current horizontal extent of the dissolved arsenic, iron, and manganese plume may be approximated by the location of off-site downgradient and cross gradient water supply wells sampled during the RI. These wells, which represent neighboring water supply wells, were not found to be impacted by the landfill. The wells range in distance from approximately 930 to 1,660 feet to the nearest edge of solid waste in the landfill. The offsite well data, specifically for OW-2, OW-4 and OW-9 that are screened in the uppermost aquifer beneath the landfill, indicate that water supply wells located greater than approximately 1,000 feet from the edge of the solid waste are not currently impacted, and are not expected to be impacted, by dissolved metals associated with the Landfill in the future. The risk of new water supply wells being installed closer than 1,000 feet from the Landfill is eliminated by the prohibition against installation of water supply wells within 1,000 feet of the Landfill boundary in accordance with WAC 173-160-171.

The above observations are supported by available information from Fort Lewis Landfill No. 5. This landfill, located on Fort Lewis, Washington, is similar to the Olalla Landfill in that it is an unlined landfill that accepted mixed municipal and demolition waste from 1962 to 1990, when it was closed. Data from the RI/FS performed for the landfill indicated that, at the time of closure, dissolved iron and manganese concentrations decreased to near background levels at a distance of approximately 2,000 feet downgradient of the landfill boundary (USEPA 1992b; Woodward Clyde 1991). In this instance, the solid wastes were relatively fresh and manganese concentrations at the edge of the landfill were over 10,000 μg/L, much higher than concentrations detected at the edge of the Olalla Landfill during the RI.

Risks to human health from drinking Landfill impacted groundwater appear to be nonexistent at the current time and minimal under potential future exposure scenarios. The apparent increase in benefits regarding reductions in human health risk under Alternative 2 are not significant and do not justify the additional $1,753,192 in total costs for Alternative 2 over Alternative 1. Based on this DCA, it is recommended that Alternative 1 is the preferred alternative.

Table 13-2. Summary of Remedial Alternatives Estimated Costs

	Remedial Alternatives		
	1. MNA and Land Use Controls	**2. Low Permeability Geomembrane Cap with MNA and Land Use Controls**	**3. In-Situ Physical/Chemical Treatment: Air Sparging and Complexation**
Capital Costs	$0	$1,912,456	$986,475
O&M Costs	$2,725,393	$2,566,129	$4,672,556
Total Costs:	**$2,725,393**	**$4,478,585**	**$5,659,031**

13.4 PREFERRED ALTERNATIVE IMPLEMENTATION

Based on the data and analyses presented in this RI/FS, Kitsap County intends to initially implement Alternative 1 (Monitored Natural Attenuation) as the preferred alternative for this independent remedial action. This includes ongoing quarterly monitoring to be conducted in accordance with regulatory requirements. These quarterly reports will be used to evaluate effectiveness of this alternative on an ongoing basis. Given some uncertainty with the timeframe for monitored natural attenuation results, Kitsap County intends to leave remedial options open and evaluate available data and overall effectiveness of the alternative at 5-year intervals as part of the periodic review process.

The 5-year review process will include an evaluation of human exposure to impacted drinking water similar to the evaluation conducted during the RI. All six off-site drinking water wells sampled during the RI will be sampled concurrently with the final quarterly monitoring round at the end of the 5-year periodic review interval. A 5-year sampling interval was selected partly based on an analysis of groundwater flow velocities, which indicates that groundwater migrating from beneath the landfill reaches the downgradient drinking water wells in approximately 1 to 2 years. Groundwater flow velocity is estimated at 2.3 feet per day; therefore, the estimated time to travel the 930 to 1,660 feet to the off-site wells is 1.1 to 2 years. As the landfill was closed in 1989, the leading edge of any potential groundwater plume has long since reached the vicinity of the wells. The RI sampling results for the wells should represent worst case conditions and conditions are expected to improve with time.

Additionally, the 5-year off-site well sampling interval provides the opportunity to incorporate off-site groundwater data into the MTCA-required periodic review.

Prior to sampling, a review of the Ecology Well Log database will be conducted to evaluate if new drinking water wells have been installed that could be potentially impacted by the Landfill. If Kitsap County determines that new wells exist that could be potentially impacted, the wells will be sampled along with the other six drinking water wells. All drinking water well samples will be analyzed for dissolved arsenic, iron, and manganese. Sampling of the drinking water wells will be conducted by Kitsap County in partnership with KPHD under an inter-agency agreement.

No later than 10 years after commencing the implementation of Alternative 1, Kitsap County will thoroughly re-evaluate all available performance data and reconsider viable alternatives versus monitored natural attenuation, including Alternative 2 (Geomembrane cap over Phase 1), for the remedial action of the landfill.

14. REFERENCES

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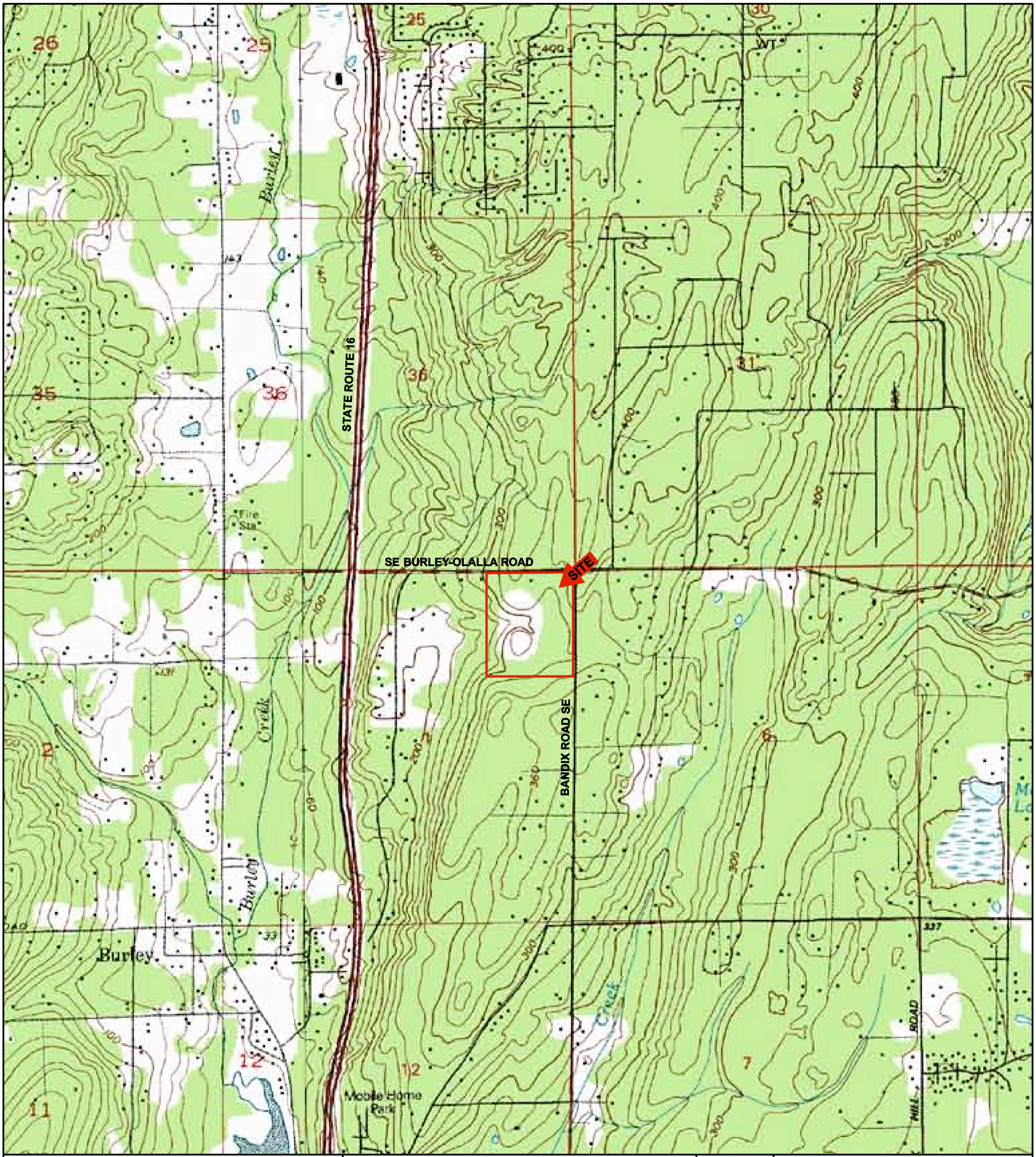
Figures



KEY:

SOURCE: USGS 7.5 MINUTE QUADRANGLE
(TOPOGRAPHIC)

BURLEY, WA
1953; REVISED 1994

OLALLA, WA
1953; REVISED 1994

SCALE = 1:24,000

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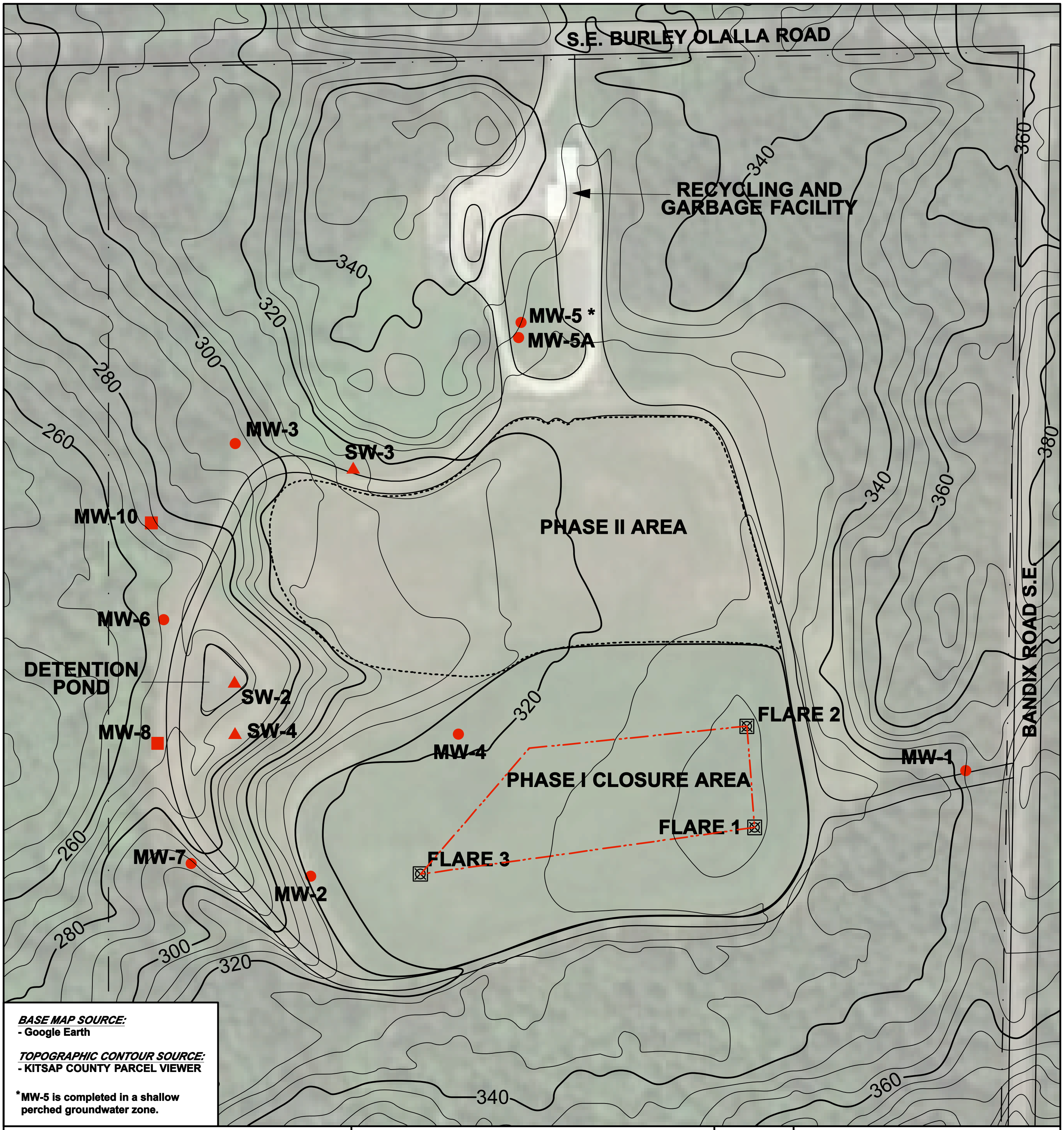
FIGURE 1-1

OLALLA LANDFILL LOCATION MAP

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	2850 SE BURLEY-OLALLA ROAD OLALLA, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ARM*	*DCK*	*02/14/12*



BASE MAP SOURCE:
- Google Earth

TOPOGRAPHIC CONTOUR SOURCE:
- KITSAP COUNTY PARCEL VIEWER

*MW-5 is completed in a shallow perched groundwater zone.

KEY:

- — — : APPROXIMATE PROPERTY BOUNDARY
- ≈ : PERIMETER ACCESS ROAD
- MW-2 ● : EXISTING MONITORING WELL
- MW-8 ■ : NEW MONITORING WELL
- SW-2 ▲ : SURFACE WATER SAMPLING LOCATION
- 300 : TOPOGRAPHIC ELEVATION CONTOURS
- ☒ : LANDFILL GAS FLARE
- -·-·- : APPROXIMATE ALIGNMENT OF UNDERGROUND PIPING SYSTEM

N

0 50 100 200

SCALE: 1" = 200'

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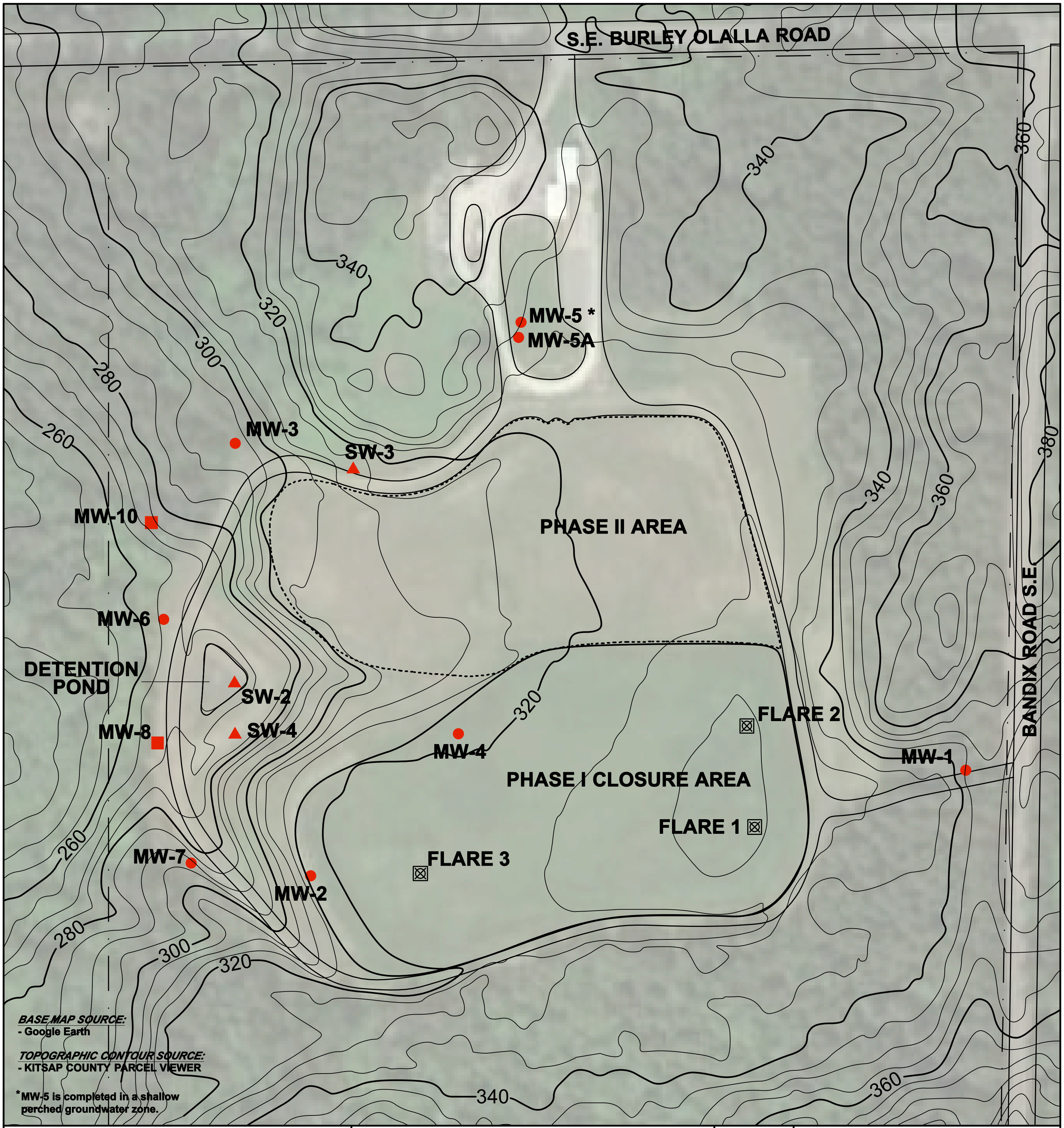
FIGURE 1-2

OLALLA LANDFILL
SITE MAP AND FEATURES
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	DRAWN BY	REVIEWED BY	DATE
1 of 1	ARM	DCK	02/14/12



BASE MAP SOURCE:
- Google Earth

TOPOGRAPHIC CONTOUR SOURCE:
- KITSAP COUNTY PARCEL VIEWER

*MW-5 is completed in a shallow perched groundwater zone.

KEY:

— · — : APPROXIMATE PROPERTY BOUNDARY
═ : PERIMETER ACCESS ROAD
MW-2 ● : EXISTING MONITORING WELL
MW-8 ■ : NEW MONITORING WELL
SW-2 ▲ : SURFACE WATER SAMPLING LOCATION
—300— : TOPOGRAPHIC ELEVATION CONTOURS
☒ : LANDFILL GAS FLARE

N

0 50 100 200

SCALE: 1" = 200'

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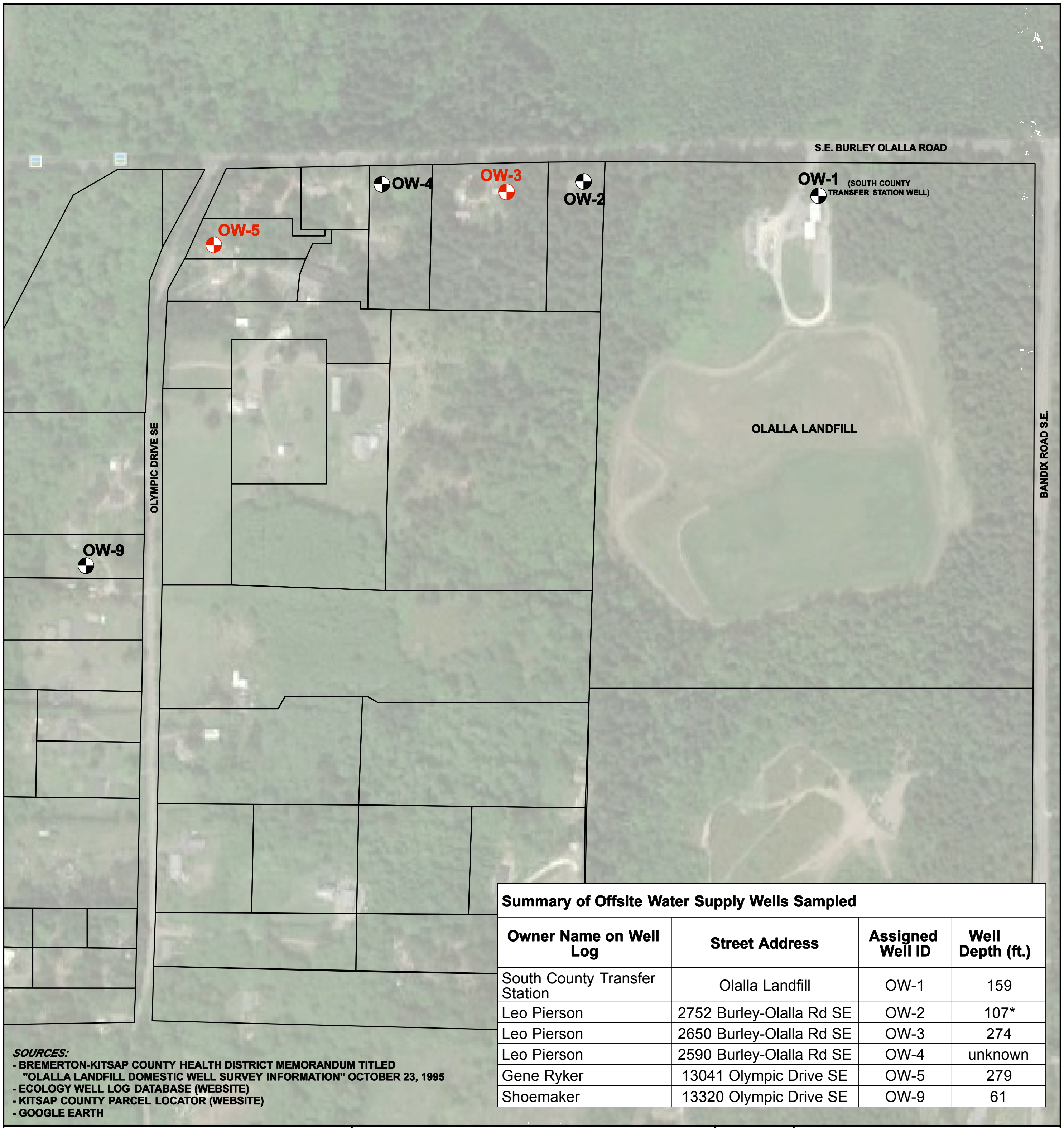
FIGURE 2-1

OLALLA LANDFILL
EXISTING AND NEW
MONITORING WELL LOCATIONS
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ARM*	*DCK*	*02/14/12*



Summary of Offsite Water Supply Wells Sampled

Owner Name on Well Log	Street Address	Assigned Well ID	Well Depth (ft.)
South County Transfer Station	Olalla Landfill	OW-1	159
Leo Pierson	2752 Burley-Olalla Rd SE	OW-2	107*
Leo Pierson	2650 Burley-Olalla Rd SE	OW-3	274
Leo Pierson	2590 Burley-Olalla Rd SE	OW-4	unknown
Gene Ryker	13041 Olympic Drive SE	OW-5	279
Shoemaker	13320 Olympic Drive SE	OW-9	61

SOURCES:
- BREMERTON-KITSAP COUNTY HEALTH DISTRICT MEMORANDUM TITLED "OLALLA LANDFILL DOMESTIC WELL SURVEY INFORMATION" OCTOBER 23, 1995
- ECOLOGY WELL LOG DATABASE (WEBSITE)
- KITSAP COUNTY PARCEL LOCATOR (WEBSITE)
- GOOGLE EARTH

KEY:

* **Well information provided by owner. Well log not available in KCHD records or Ecology Well Log database.**

◐ **: OFFSITE WELL LOCATION (UPPER AQUIFER)**

◐ **: OFFSITE WELL LOCATION (DEEPER AQUIFER)**

——— **: PARCEL BOUNDARY**

N

0 100 200 400

SCALE: 1" = 400'

E N V I R O N M E N T A L
P A R T N E R S I N C

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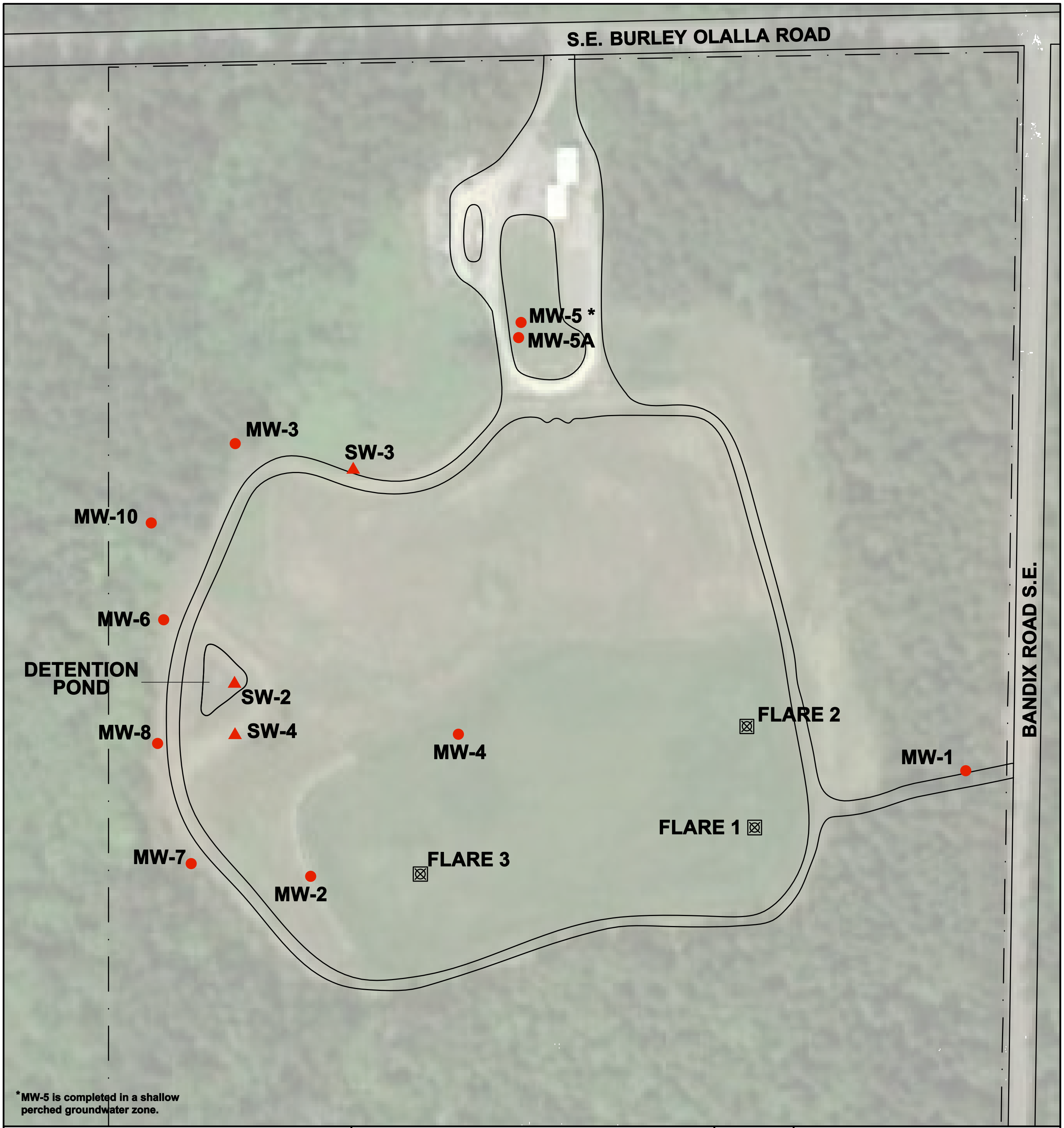
FIGURE 2-2

OFFSITE WATER SUPPLY WELL
SAMPLING LOCATIONS
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL RI/FS KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ALW*	*DCK*	*12/13/12*



*MW-5 is completed in a shallow perched groundwater zone.

KEY:

— · —: APPROXIMATE PROPERTY BOUNDARY
〰: PERIMETER ACCESS ROAD
MW-2 ●: MONITORING WELL
SW-2 ▲: SURFACE WATER SAMPLING LOCATION
☒: LANDFILL GAS FLARE

N

0 50 100 200

SCALE: 1" = 200'

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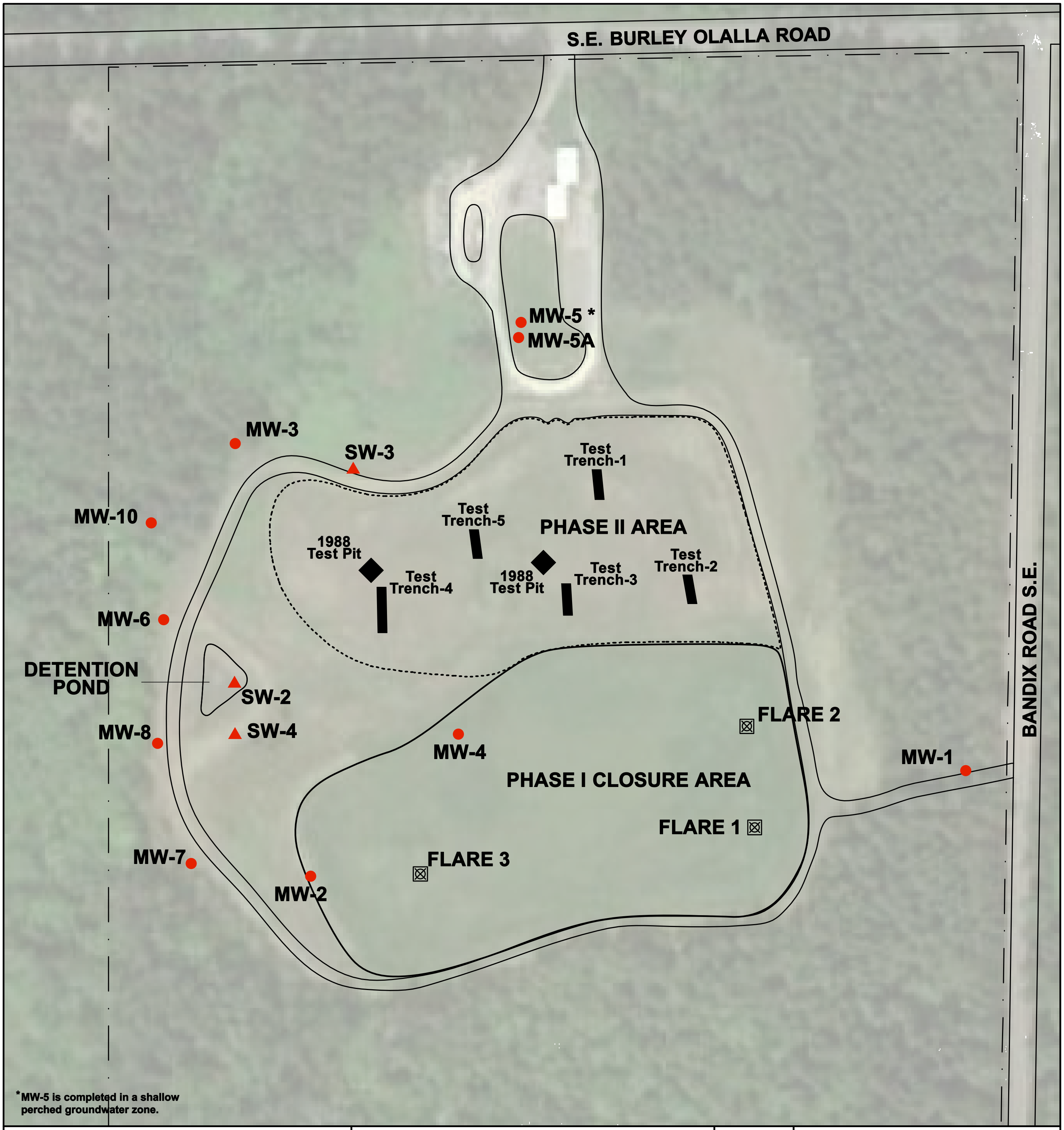
FIGURE 2-3

SURFACE WATER SAMPLING LOCATIONS
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ALW*	*DCK*	*12/10/12*



*MW-5 is completed in a shallow perched groundwater zone.

KEY:

— · —: APPROXIMATE PROPERTY BOUNDARY

: PERIMETER ACCESS ROAD

MW-2 ●: MONITORING WELL

SW-2 ▲: SURFACE WATER SAMPLING LOCATION

☒: LANDFILL GAS FLARE

▬: EXPLORATORY TEST TRENCH

◆: MAY 3, 1988 TEST PITS

N

0 50 100 200

SCALE: 1" = 200'

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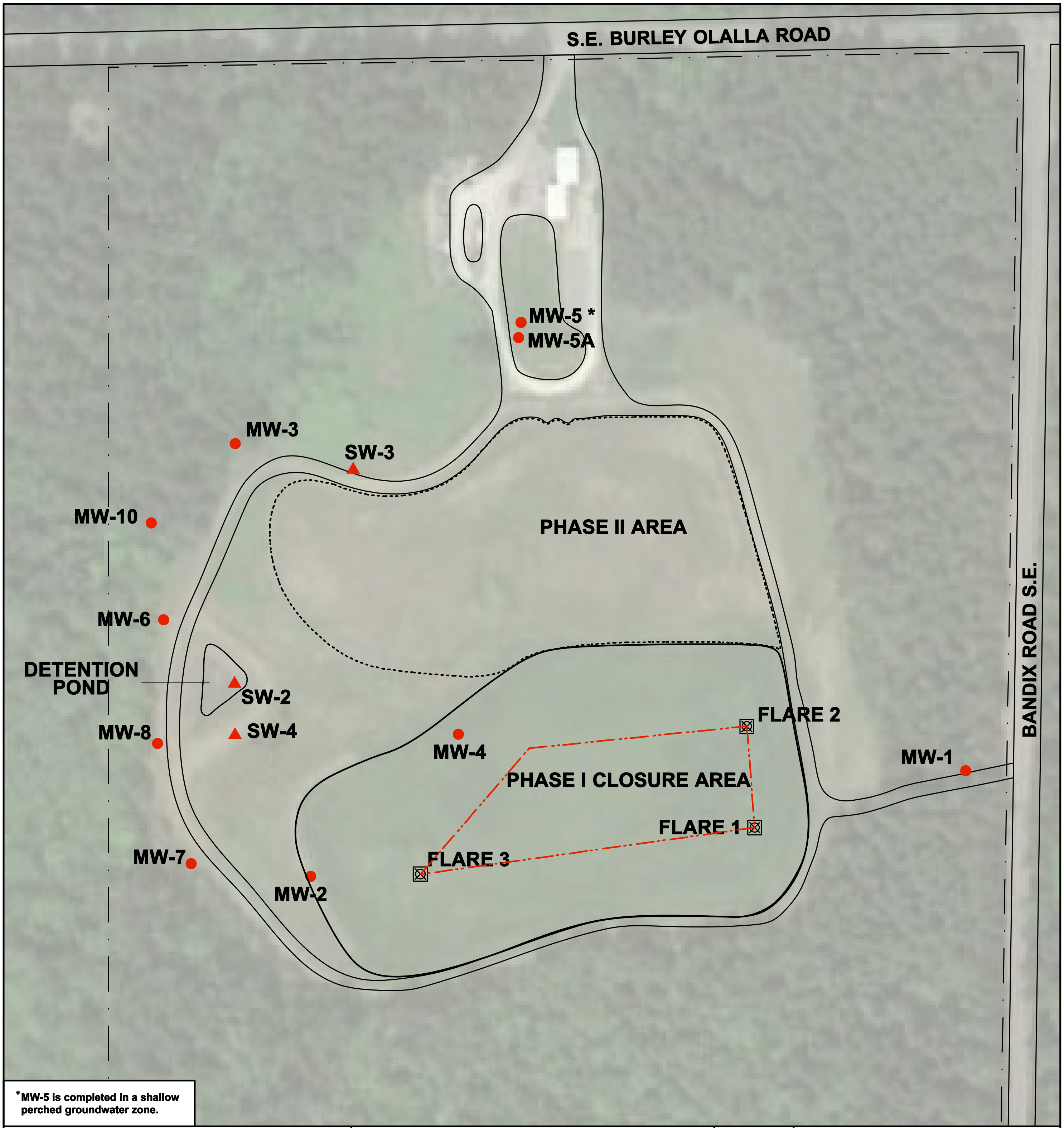
FIGURE 2-4

EXPLORATORY TEST TRENCH LOCATIONS
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ALW*	*DCK*	*12/14/12*



*MW-5 is completed in a shallow perched groundwater zone.

KEY:

— · —: APPROXIMATE PROPERTY BOUNDARY
═: PERIMETER ACCESS ROAD
MW-2 ●: MONITORING WELL
SW-2 ▲: SURFACE WATER SAMPLING LOCATION
☒: LANDFILL GAS FLARE
— · —: APPROXIMATE ALIGNMENT OF UNDERGROUND LANDFILL GAS PIPING SYSTEM

N

0 50 100 200

SCALE: 1" = 200'

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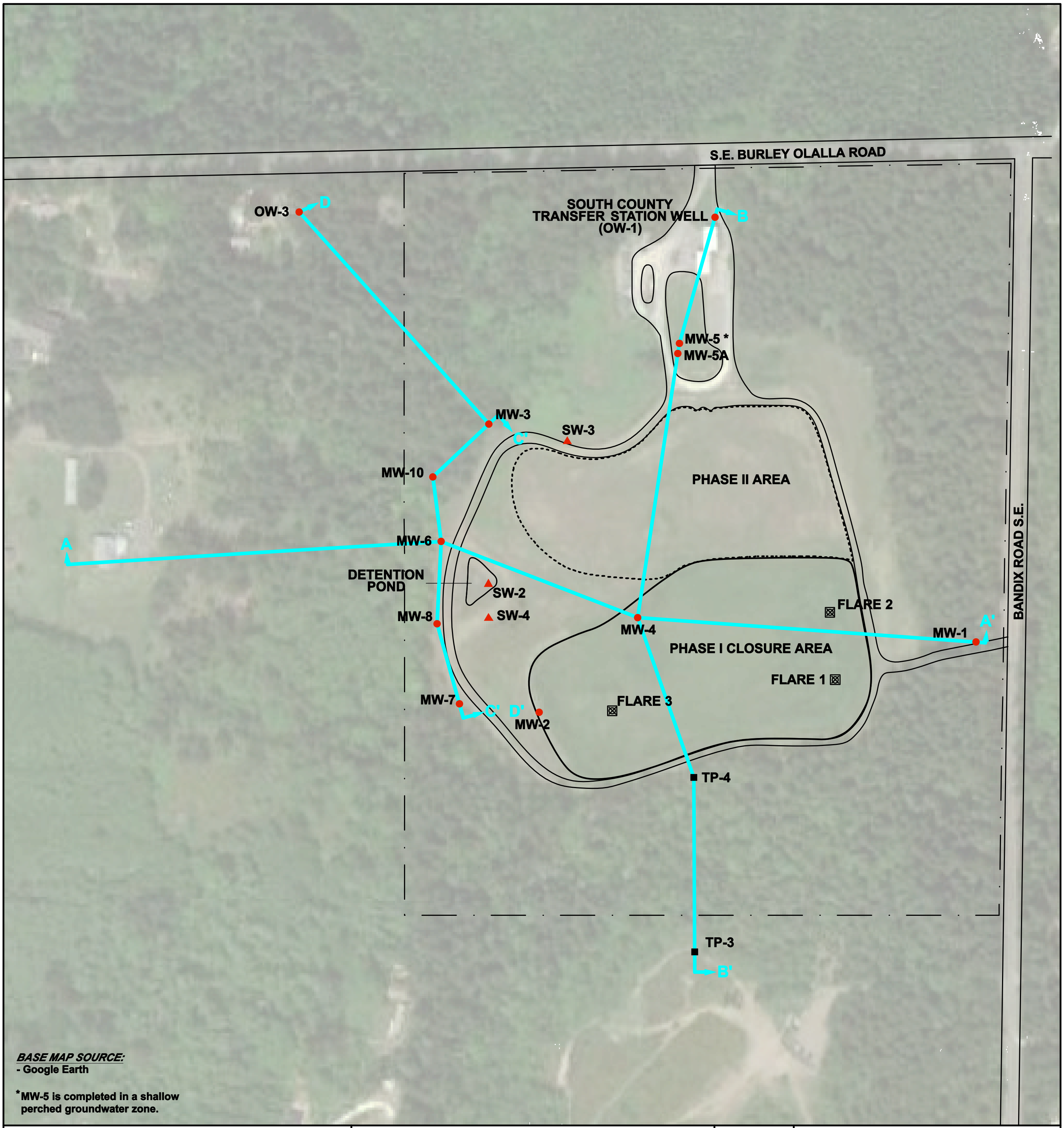
FIGURE 2-5

LANDFILL GAS FLARE LOCATIONS AND
UNDERGROUND PIPING SYSTEM
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ARM*	*DCK*	*02/14/12*



BASE MAP SOURCE:
- Google Earth

***MW-5 is completed in a shallow perched groundwater zone.**

KEY:

— · — : APPROXIMATE PROPERTY BOUNDARY
═ : PERIMETER ACCESS ROAD
MW-2 ● : WELL LOCATION
SW-2 ▲ : SURFACE WATER SAMPLING LOCATION
■ : TEST PIT LOCATION
⊠ : LANDFILL GAS FLARE
A ⌐ A' : CROSS SECTION ALIGNMENT

N

0 75 150 300

SCALE: 1" = 300'

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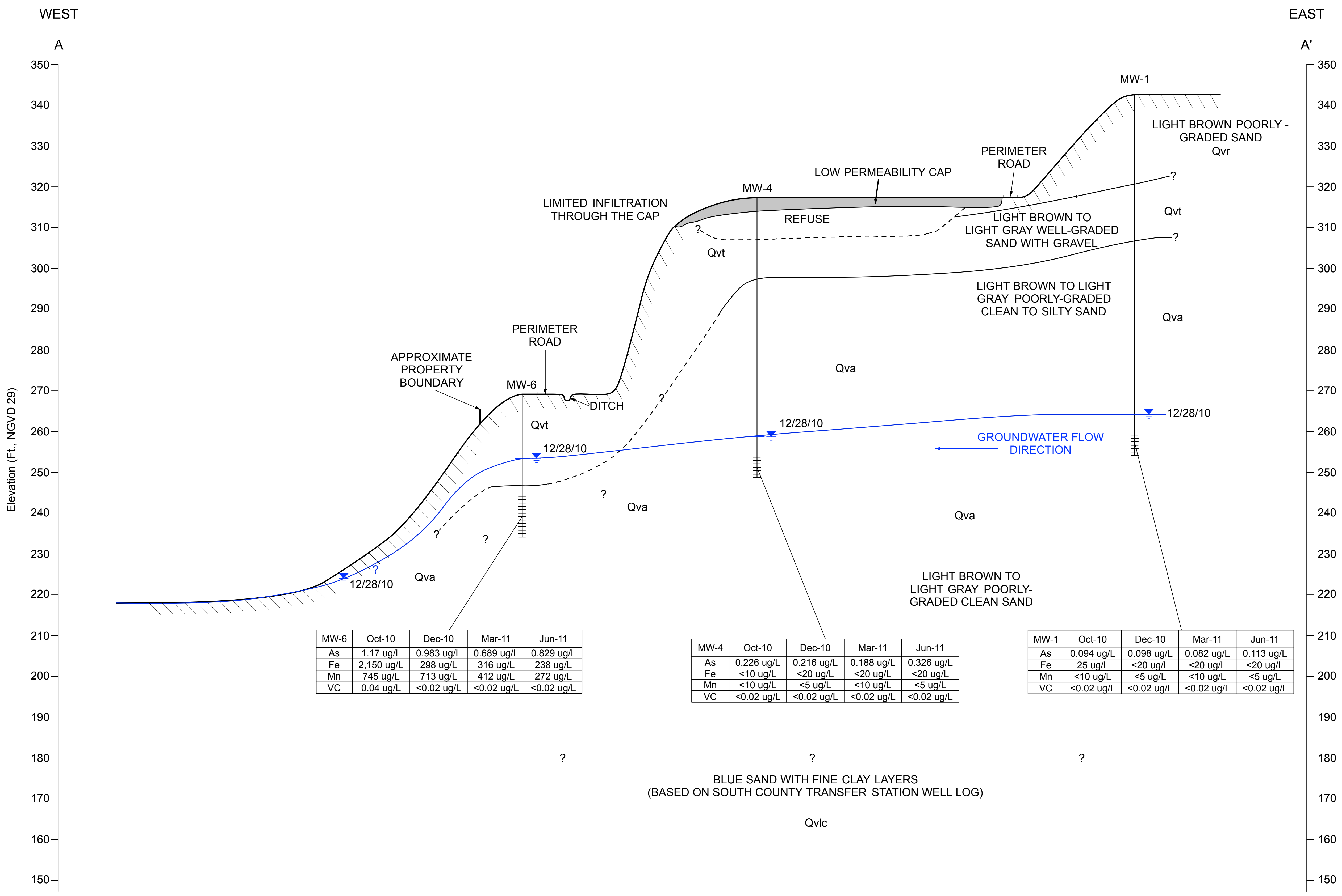
FIGURE 4-1

HYDROGEOLOGIC CROSS SECTION ALIGNMENTS
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ALW*	*DCK*	*12/13/12*



MW-6	Oct-10	Dec-10	Mar-11	Jun-11
As	1.17 ug/L	0.983 ug/L	0.689 ug/L	0.829 ug/L
Fe	2,150 ug/L	298 ug/L	316 ug/L	238 ug/L
Mn	745 ug/L	713 ug/L	412 ug/L	272 ug/L
VC	0.04 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-4	Oct-10	Dec-10	Mar-11	Jun-11
As	0.226 ug/L	0.216 ug/L	0.188 ug/L	0.326 ug/L
Fe	<10 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	<10 ug/L	<5 ug/L	<10 ug/L	<5 ug/L
VC	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-1	Oct-10	Dec-10	Mar-11	Jun-11
As	0.094 ug/L	0.098 ug/L	0.082 ug/L	0.113 ug/L
Fe	25 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	<10 ug/L	<5 ug/L	<10 ug/L	<5 ug/L
VC	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

KEY:

⧹⧹⧹⧹	GROUND SURFACE
∼	LITHOLOGIC CONTACT, DASHED WHERE INFERRED.
╪	MONITORING WELL AND SCREENED INTERVAL
▼	WATER LEVEL ON 12/28/10

0 50 100 200

SCALE: 1" = 200'

Qvr	**Recessional Outwash Deposits -** Stratified sand and gravel moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow.
Qvi	**Ice-Contact Deposits -** Deposits similar in texture to unit Qvr but locally containing much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till.
Qvt	**Till -** Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms undulating surface a few tens of meters thick. Also found sporadically within areas mapped as unit Qvi.
Qva	**Advance Outwash Deposits -** Well-bedded sand and gravel; deposited by streams and rivers that issued from front of advancing ice sheet. Generally unoxidized; almost devoid of silt or clay, except near base of unit.
Qvlc	**Lawton Clay -** Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial or lowland lakes.

Source: Geologic map of the Olalla 7.5' Quadrangle, King, Kitsap and Pierce Counties, WA. By Derek B. Booth and Kathy Goetz Troost 2005.

PROJECT	60101.0 OLALLA, WASHINGTON		
PREPARED FOR	KITSAP COUNTY		
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON		
SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*KLA*	*DCK*	*02/08/12*

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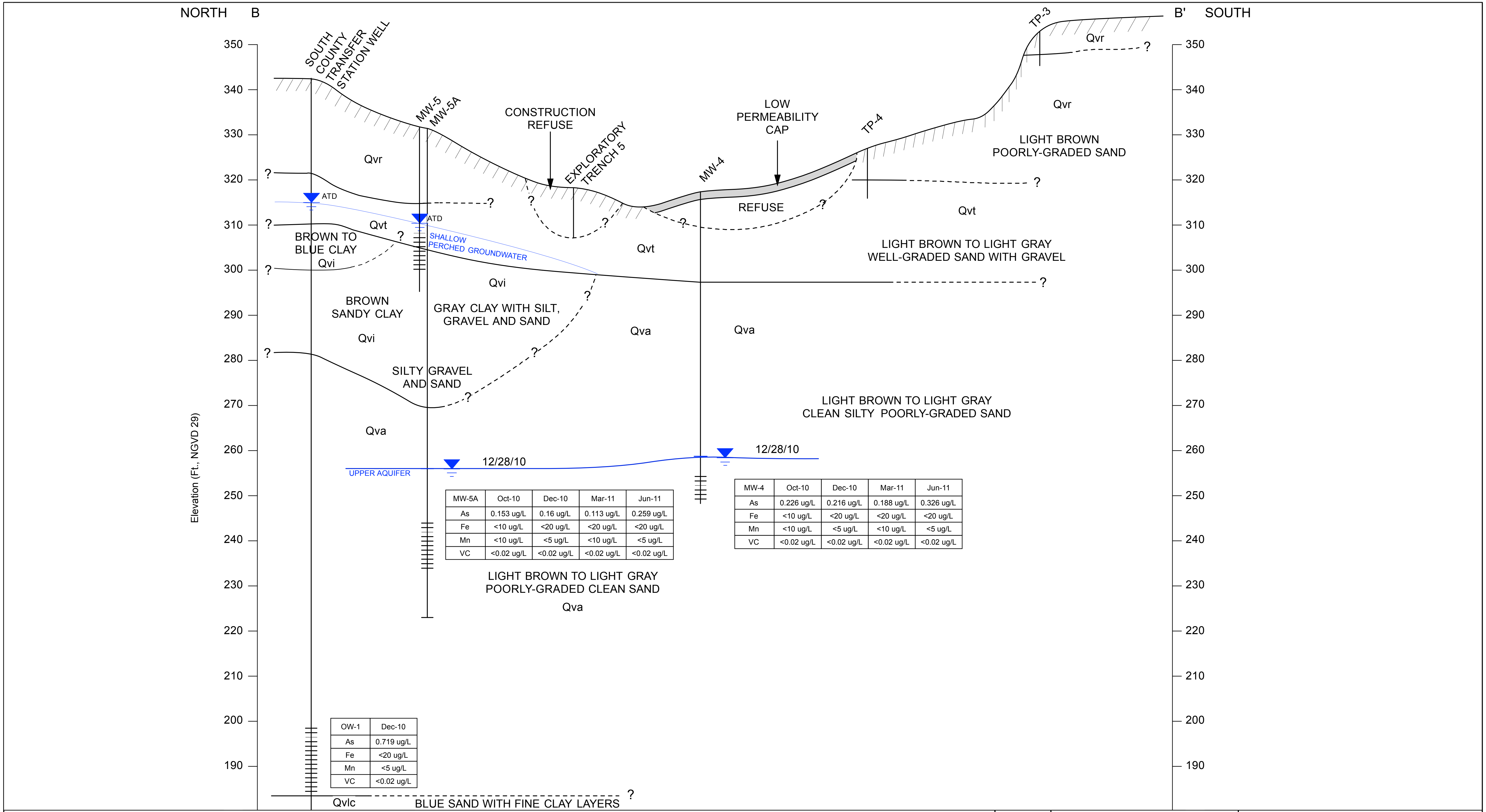
FIGURE 4-2a

GEOLOGIC CROSS SECTION A - A'
THROUGH OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON



MW-5A	Oct-10	Dec-10	Mar-11	Jun-11
As	0.153 ug/L	0.16 ug/L	0.113 ug/L	0.259 ug/L
Fe	<10 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	<10 ug/L	<5 ug/L	<10 ug/L	<5 ug/L
VC	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-4	Oct-10	Dec-10	Mar-11	Jun-11
As	0.226 ug/L	0.216 ug/L	0.188 ug/L	0.326 ug/L
Fe	<10 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	<10 ug/L	<5 ug/L	<10 ug/L	<5 ug/L
VC	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

OW-1	Dec-10
As	0.719 ug/L
Fe	<20 ug/L
Mn	<5 ug/L
VC	<0.02 ug/L

KEY:

⁄⁄⁄⁄	GROUND SURFACE
∼	LITHOLOGIC CONTACT, DASHED WHERE INFERRED.
╪	MONITORING WELL AND SCREENED INTERVAL
▼	WATER LEVEL ON 12/28/10
ATD	AT TIME OF DRILLING
TP	TEST PIT

0 50 100 200

SCALE: 1" = 200'

Qvr	**Recessional Outwash Deposits -** Stratified sand and gravel moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow.
Qvi	**Ice-Contact Deposits -** Deposits similar in texture to unit Qvr but locally containing much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till.
Qvt	**Till -** Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms undulating surface a few tens of meters thick. Also found sporadically within areas mapped as unit Qvi.
Qva	**Advance Outwash Deposits -** Well-bedded sand and gravel; deposited by streams and rivers that issued from front of advancing ice sheet. Generally unoxidized; almost devoid of silt or clay, except near base of unit.
Qvlc	**Lawton Clay -** Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial or lowland lakes.

Source: Geologic map of the Olalla 7.5' Quadrangle, King, Kitsap and Pierce Counties, WA. By Derek B. Booth and Kathy Goetz Troost 2005.

PROJECT	60101.0 OLALLA, WASHINGTON		
PREPARED FOR	KITSAP COUNTY		
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON		
SHEET 1 of 1	**DRAWN BY** KLA	**REVIEWED BY** DCK	**DATE** 04/14/14

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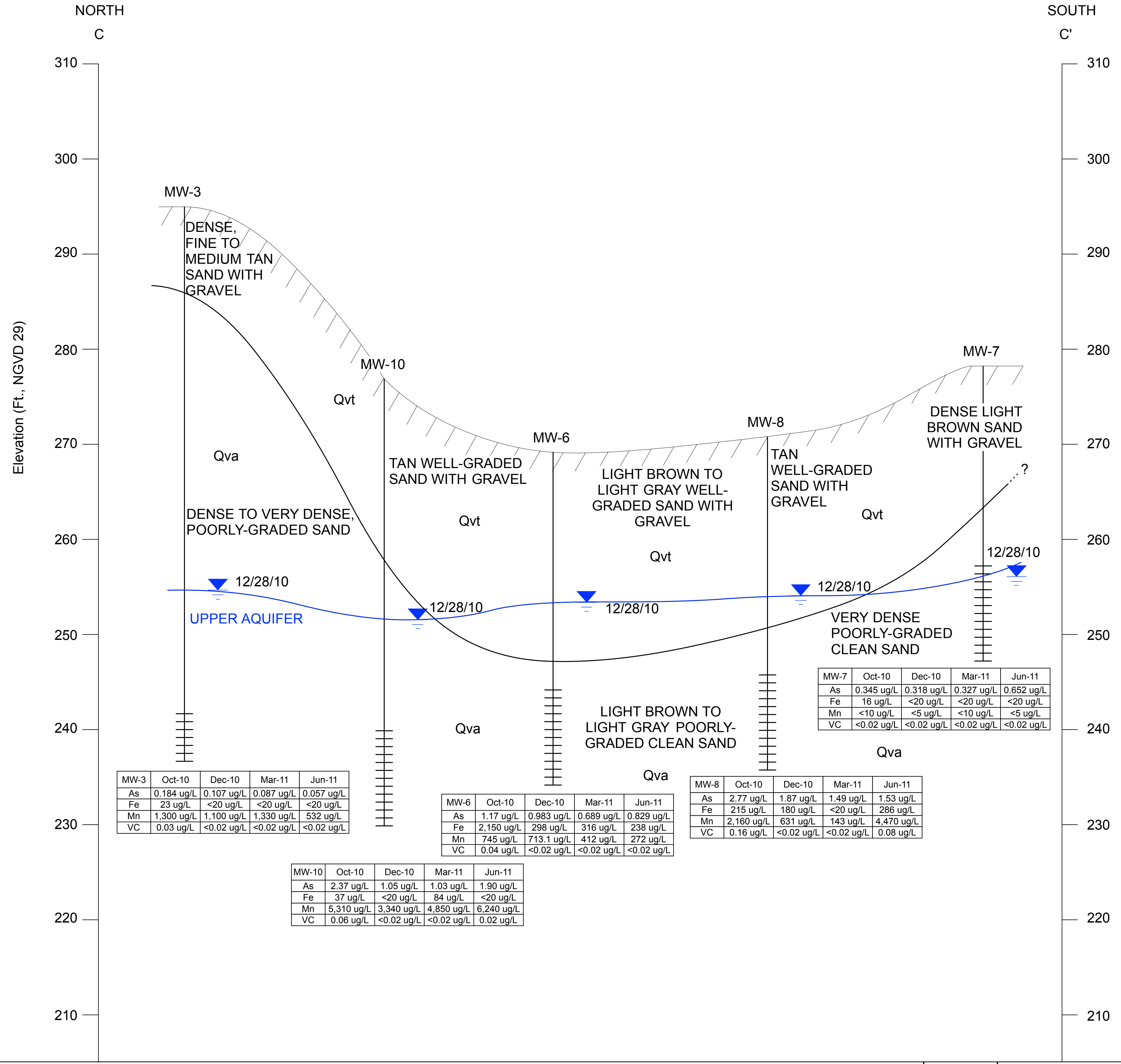
FIGURE 4-2b

GEOLOGIC CROSS SECTION B - B'
THROUGH OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON



MW-7	Oct-10	Dec-10	Mar-11	Jun-11
As	0.345 ug/L	0.318 ug/L	0.327 ug/L	0.652 ug/L
Fe	16 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	<10 ug/L	<5 ug/L	<10 ug/L	<5 ug/L
VC	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-3	Oct-10	Dec-10	Mar-11	Jun-11
As	0.184 ug/L	0.107 ug/L	0.087 ug/L	0.057 ug/L
Fe	23 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	1,300 ug/L	1,100 ug/L	1,330 ug/L	532 ug/L
VC	0.03 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-8	Oct-10	Dec-10	Mar-11	Jun-11
As	2.77 ug/L	1.87 ug/L	1.49 ug/L	1.53 ug/L
Fe	215 ug/L	180 ug/L	<20 ug/L	286 ug/L
Mn	2,160 ug/L	631 ug/L	143 ug/L	4,470 ug/L
VC	0.16 ug/L	<0.02 ug/L	<0.02 ug/L	0.08 ug/L

MW-6	Oct-10	Dec-10	Mar-11	Jun-11
As	1.17 ug/L	0.983 ug/L	0.689 ug/L	0.829 ug/L
Fe	2,150 ug/L	298 ug/L	316 ug/L	238 ug/L
Mn	745 ug/L	713.1 ug/L	412 ug/L	272 ug/L
VC	0.04 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-10	Oct-10	Dec-10	Mar-11	Jun-11
As	2.37 ug/L	1.05 ug/L	1.03 ug/L	1.90 ug/L
Fe	37 ug/L	<20 ug/L	84 ug/L	<20 ug/L
Mn	5,310 ug/L	3,340 ug/L	4,850 ug/L	6,240 ug/L
VC	0.06 ug/L	<0.02 ug/L	<0.02 ug/L	0.02 ug/L

KEY:

GROUND SURFACE

LITHOLOGIC CONTACT, DASHED WHERE INFERRED.

MONITORING WELL AND SCREENED INTERVAL

WATER LEVEL ON 12/28/10

0 25 50 100

SCALE: 1" = 100'

Qvr	**Recessional Outwash Deposits -** Stratified sand and gravel moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow.
Qvi	**Ice-Contact Deposits -** Deposits similar in texture to unit Qvr but locally containing much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till.
Qvt	**Till -** Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms undulating surface a few tens of meters thick. Also found sporadically within areas mapped as unit Qvi.
Qva	**Advance Outwash Deposits -** Well-bedded sand and gravel; deposited by streams and rivers that issued from front of advancing ice sheet. Generally unoxidized; almost devoid of silt or clay, except near base of unit.
Qvlc	**Lawton Clay -** Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial or lowland lakes.

Source: Geologic map of the Olalla 7.5' Quadrangle, King, Kitsap and Pierce Counties, WA. By Derek B. Booth and Kathy Goetz Troost 2005.

PROJECT	60101.0 OLALLA, WASHINGTON		
PREPARED FOR	KITSAP COUNTY		
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON		
SHEET *1 of 1*	**DRAWN BY** *KLA*	**REVIEWED BY** *DCK*	**DATE** *02/13/12*

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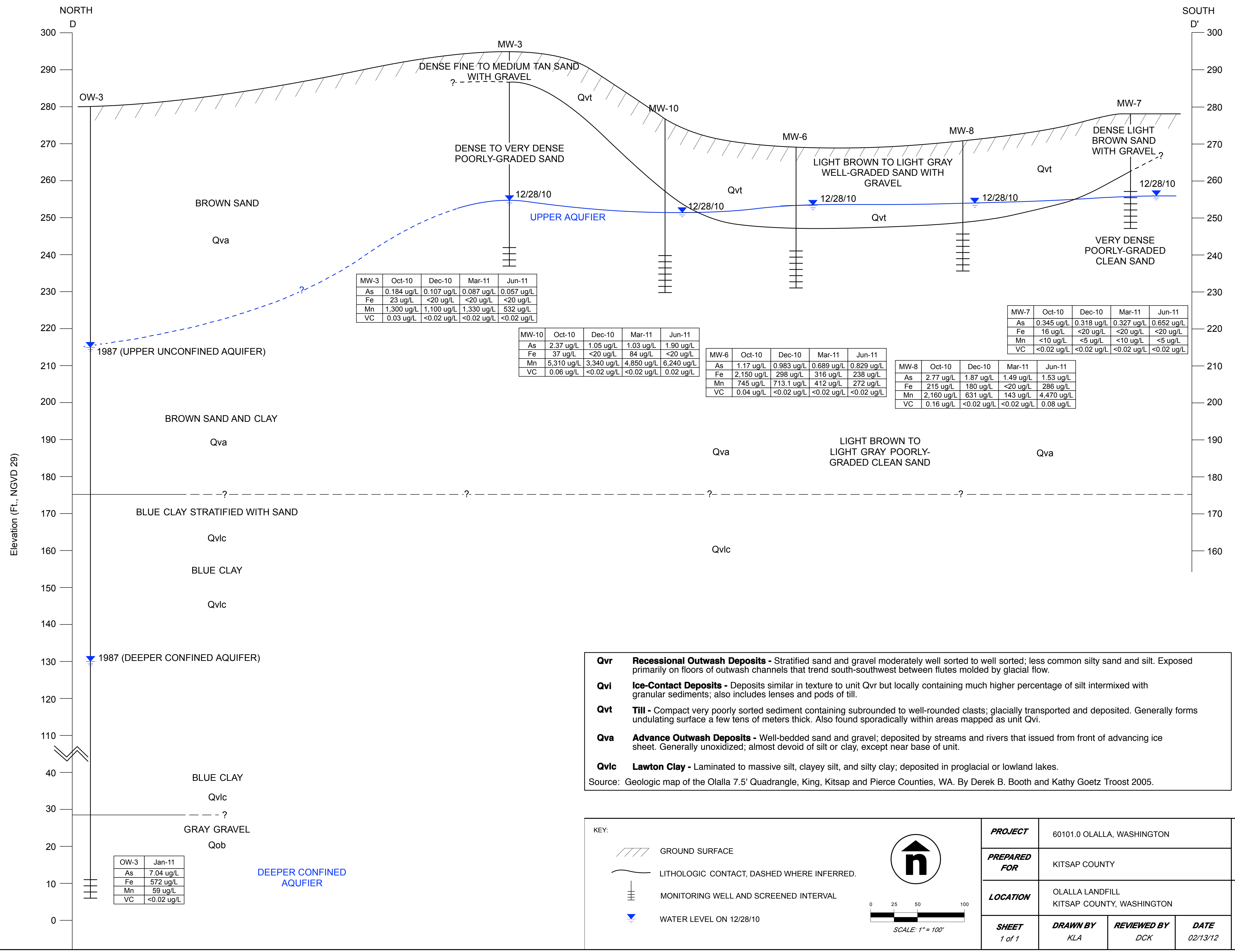
FIGURE 4-2c

GEOLOGIC CROSS SECTION C - C'
THROUGH OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON



MW-3	Oct-10	Dec-10	Mar-11	Jun-11
As	0.184 ug/L	0.107 ug/L	0.087 ug/L	0.057 ug/L
Fe	23 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	1,300 ug/L	1,100 ug/L	1,330 ug/L	532 ug/L
VC	0.03 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-10	Oct-10	Dec-10	Mar-11	Jun-11
As	2.37 ug/L	1.05 ug/L	1.03 ug/L	1.90 ug/L
Fe	37 ug/L	<20 ug/L	84 ug/L	<20 ug/L
Mn	5,310 ug/L	3,340 ug/L	4,850 ug/L	6,240 ug/L
VC	0.06 ug/L	<0.02 ug/L	<0.02 ug/L	0.02 ug/L

MW-6	Oct-10	Dec-10	Mar-11	Jun-11
As	1.17 ug/L	0.983 ug/L	0.689 ug/L	0.829 ug/L
Fe	2,150 ug/L	298 ug/L	316 ug/L	238 ug/L
Mn	745 ug/L	713.1 ug/L	412 ug/L	272 ug/L
VC	0.04 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-8	Oct-10	Dec-10	Mar-11	Jun-11
As	2.77 ug/L	1.87 ug/L	1.49 ug/L	1.53 ug/L
Fe	215 ug/L	180 ug/L	<20 ug/L	286 ug/L
Mn	2,160 ug/L	631 ug/L	143 ug/L	4,470 ug/L
VC	0.16 ug/L	<0.02 ug/L	<0.02 ug/L	0.08 ug/L

MW-7	Oct-10	Dec-10	Mar-11	Jun-11
As	0.345 ug/L	0.318 ug/L	0.327 ug/L	0.652 ug/L
Fe	16 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	<10 ug/L	<5 ug/L	<10 ug/L	<5 ug/L
VC	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

OW-3	Jan-11
As	7.04 ug/L
Fe	572 ug/L
Mn	59 ug/L
VC	<0.02 ug/L

Qvr	**Recessional Outwash Deposits -** Stratified sand and gravel moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow.
Qvi	**Ice-Contact Deposits -** Deposits similar in texture to unit Qvr but locally containing much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till.
Qvt	**Till -** Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms undulating surface a few tens of meters thick. Also found sporadically within areas mapped as unit Qvi.
Qva	**Advance Outwash Deposits -** Well-bedded sand and gravel; deposited by streams and rivers that issued from front of advancing ice sheet. Generally unoxidized; almost devoid of silt or clay, except near base of unit.
Qvlc	**Lawton Clay -** Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial or lowland lakes.

Source: Geologic map of the Olalla 7.5' Quadrangle, King, Kitsap and Pierce Counties, WA. By Derek B. Booth and Kathy Goetz Troost 2005.

KEY:

╱╱╱╱	GROUND SURFACE
~	LITHOLOGIC CONTACT, DASHED WHERE INFERRED.
╪	MONITORING WELL AND SCREENED INTERVAL
▼	WATER LEVEL ON 12/28/10

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*KLA*	*DCK*	*02/13/12*

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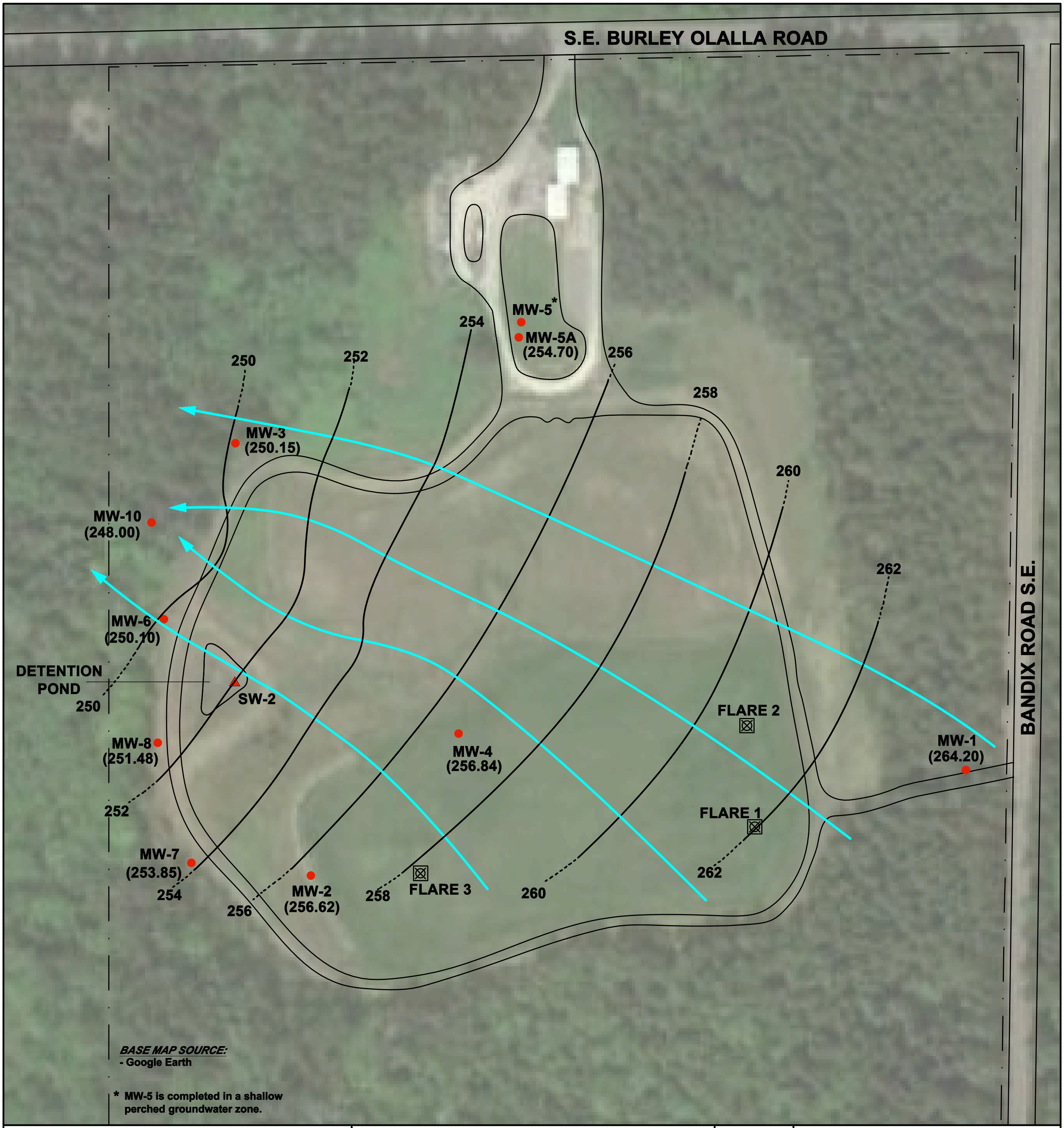
FIGURE 4-2d

GEOLOGIC CROSS SECTION D - D'
THROUGH OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON



BASE MAP SOURCE:
- Google Earth

*** MW-5 is completed in a shallow perched groundwater zone.**

KEY:

—— : GROUNDWATER ELEVATION CONTOUR

⟵ : INFERRED GROUNDWATER FLOW PATH

— · — : APPROXIMATE PROPERTY BOUNDARY

≈ : PERIMETER ACCESS ROAD

MW-2 ● : MONITORING WELL

SW-2 ▲ : SURFACE WATER SAMPLING LOCATION

☒ : LANDFILL GAS FLARE

N

0 50 100 200

SCALE: 1" = 200'

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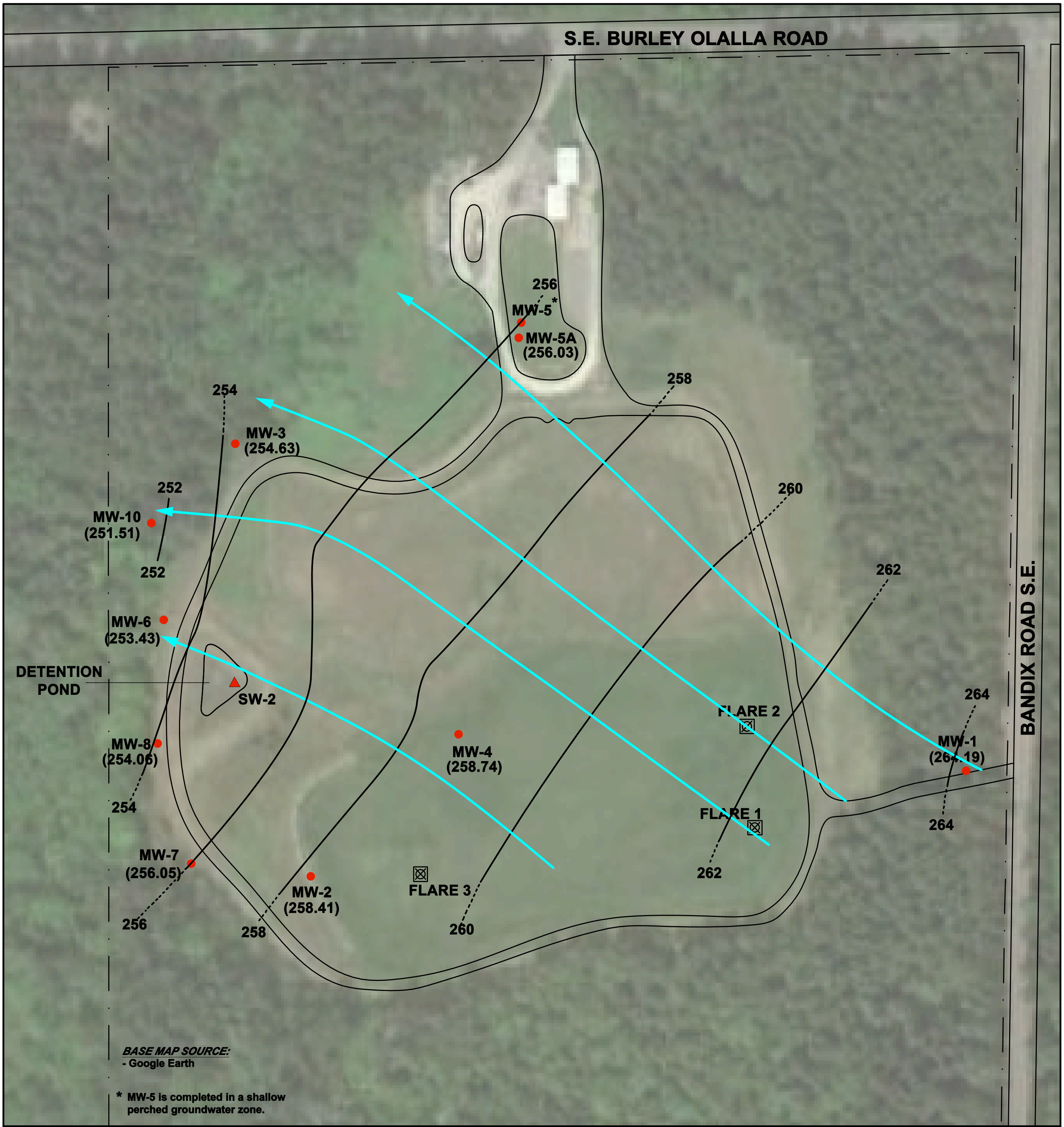
FIGURE 4-3a

OLALLA LANDFILL GROUNDWATER
ELEVATION CONTOUR MAP OCTOBER 28, 2010
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ARM*	*DCK*	*02/13/12*



BASE MAP SOURCE:
- Google Earth

*** MW-5 is completed in a shallow perched groundwater zone.**

KEY:

- —— : GROUNDWATER ELEVATION CONTOUR
- ← : INFERRED GROUNDWATER FLOW PATH
- — · — : APPROXIMATE PROPERTY BOUNDARY
- ≈ : PERIMETER ACCESS ROAD
- **MW-2** ● : MONITORING WELL
- **SW-2** ▲ : SURFACE WATER SAMPLING LOCATION
- ☒ : LANDFILL GAS FLARE

N

0 50 100 200

SCALE: 1" = 200'

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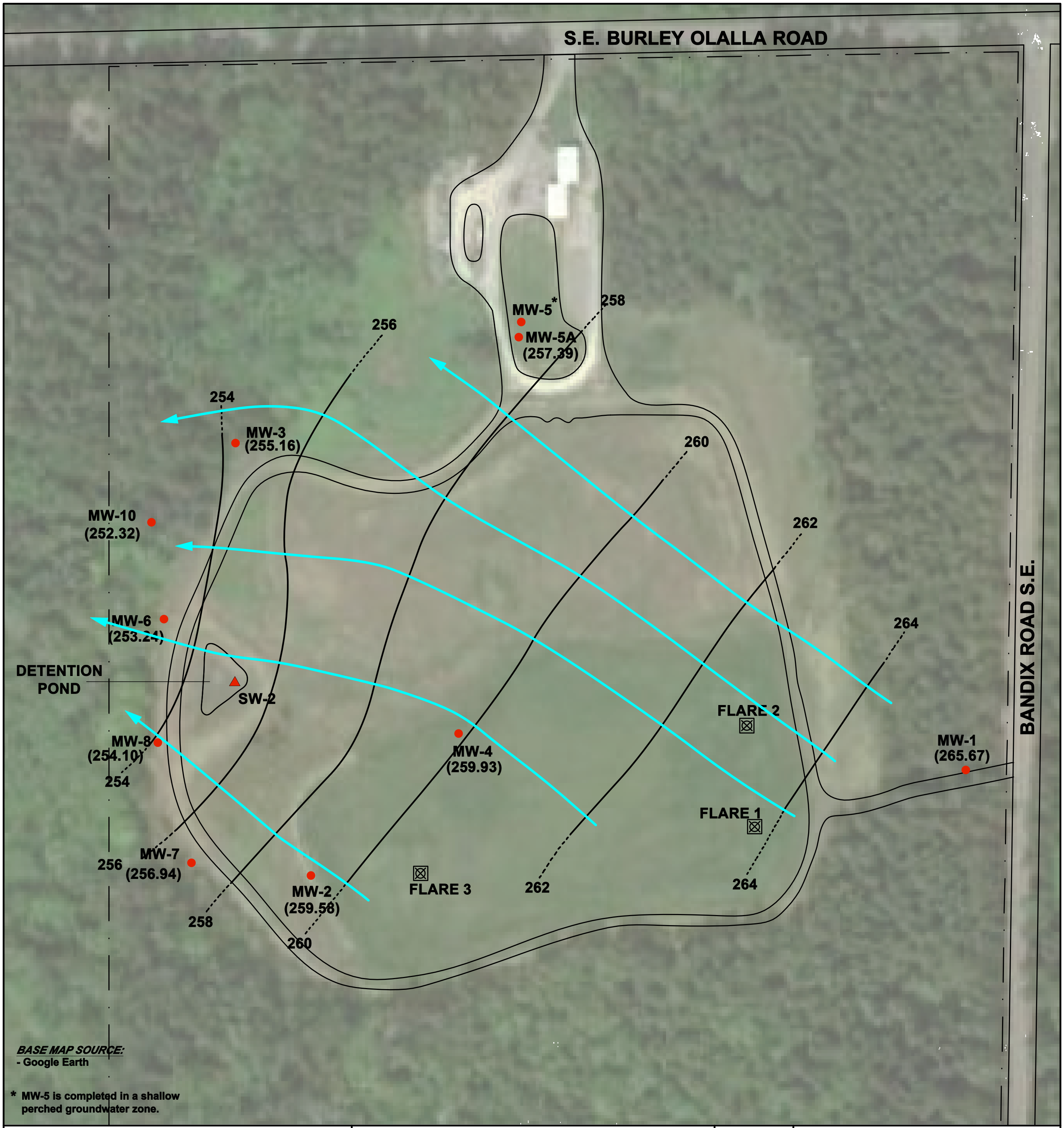
Issaquah, Washington 98027

FIGURE 4-3b

OLALLA LANDFILL GROUNDWATER
ELEVATION CONTOUR MAP DECEMBER 28, 2010
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ARM*	*DCK*	*02/13/12*



BASE MAP SOURCE:
- Google Earth

* MW-5 is completed in a shallow perched groundwater zone.

KEY:

- ——— : GROUNDWATER ELEVATION CONTOUR
- → : INFERRED GROUNDWATER FLOW PATH
- — · — : APPROXIMATE PROPERTY BOUNDARY
- ═ : PERIMETER ACCESS ROAD
- MW-2 ● : MONITORING WELL
- SW-2 ▲ : SURFACE WATER SAMPLING LOCATION
- ⊠ : LANDFILL GAS FLARE

N

0 50 100 200

SCALE: 1" = 200'

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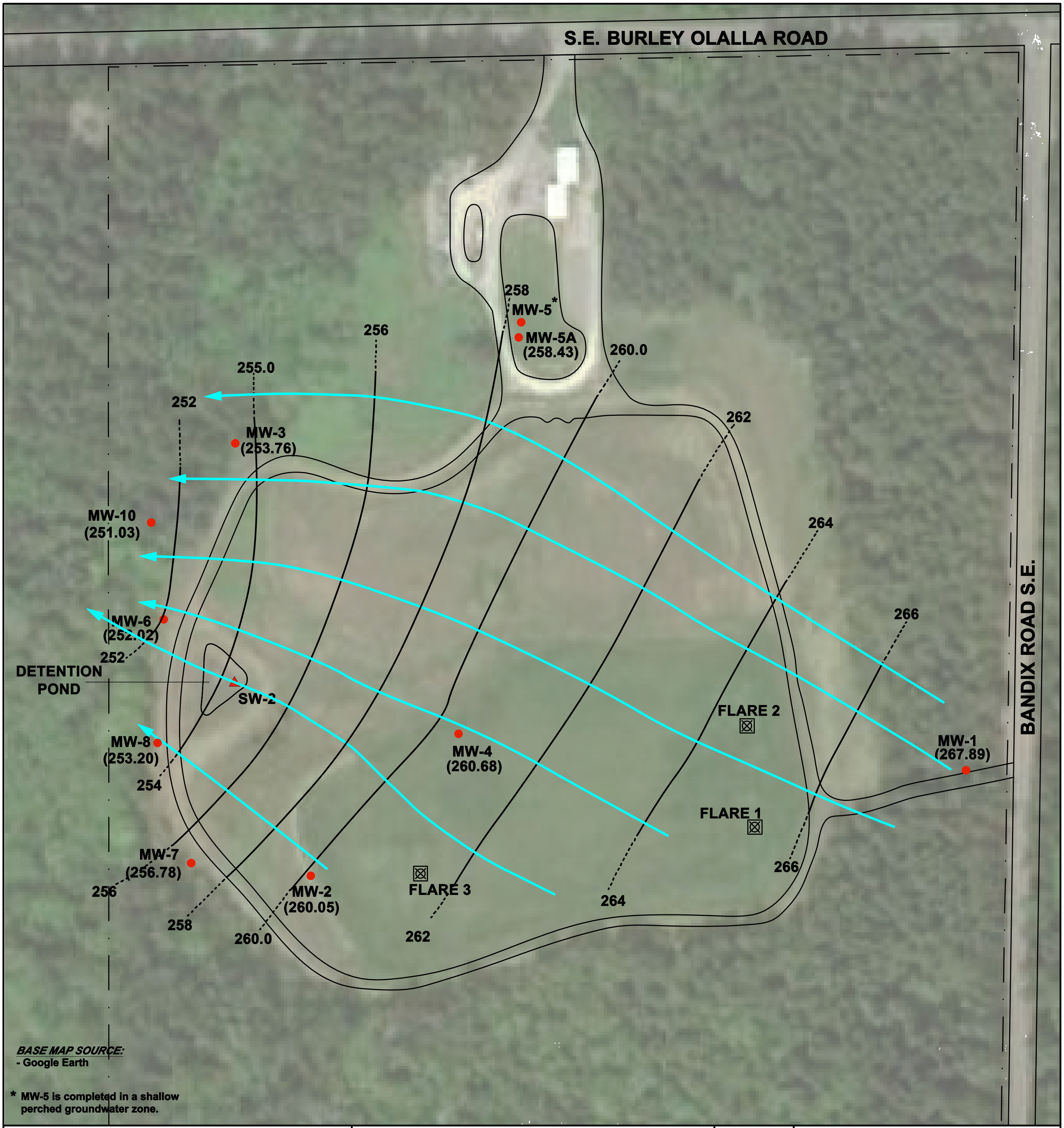
FIGURE 4-3c

OLALLA LANDFILL GROUNDWATER
ELEVATION CONTOUR MAP MARCH 23, 2011
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ALW*	*DCK*	*12/11/12*



BASE MAP SOURCE:
- Google Earth

*** MW-5 is completed in a shallow perched groundwater zone.**

KEY:

- ——— : GROUNDWATER ELEVATION CONTOUR
- ⟵ : INFERRED GROUNDWATER FLOW PATH
- — · — : APPROXIMATE PROPERTY BOUNDARY
- ≈ : PERIMETER ACCESS ROAD
- **MW-2** ● : MONITORING WELL
- **SW-2** ▲ : SURFACE WATER SAMPLING LOCATION
- ☒ : LANDFILL GAS FLARE

N

0 50 100 200

SCALE: 1" = 200'

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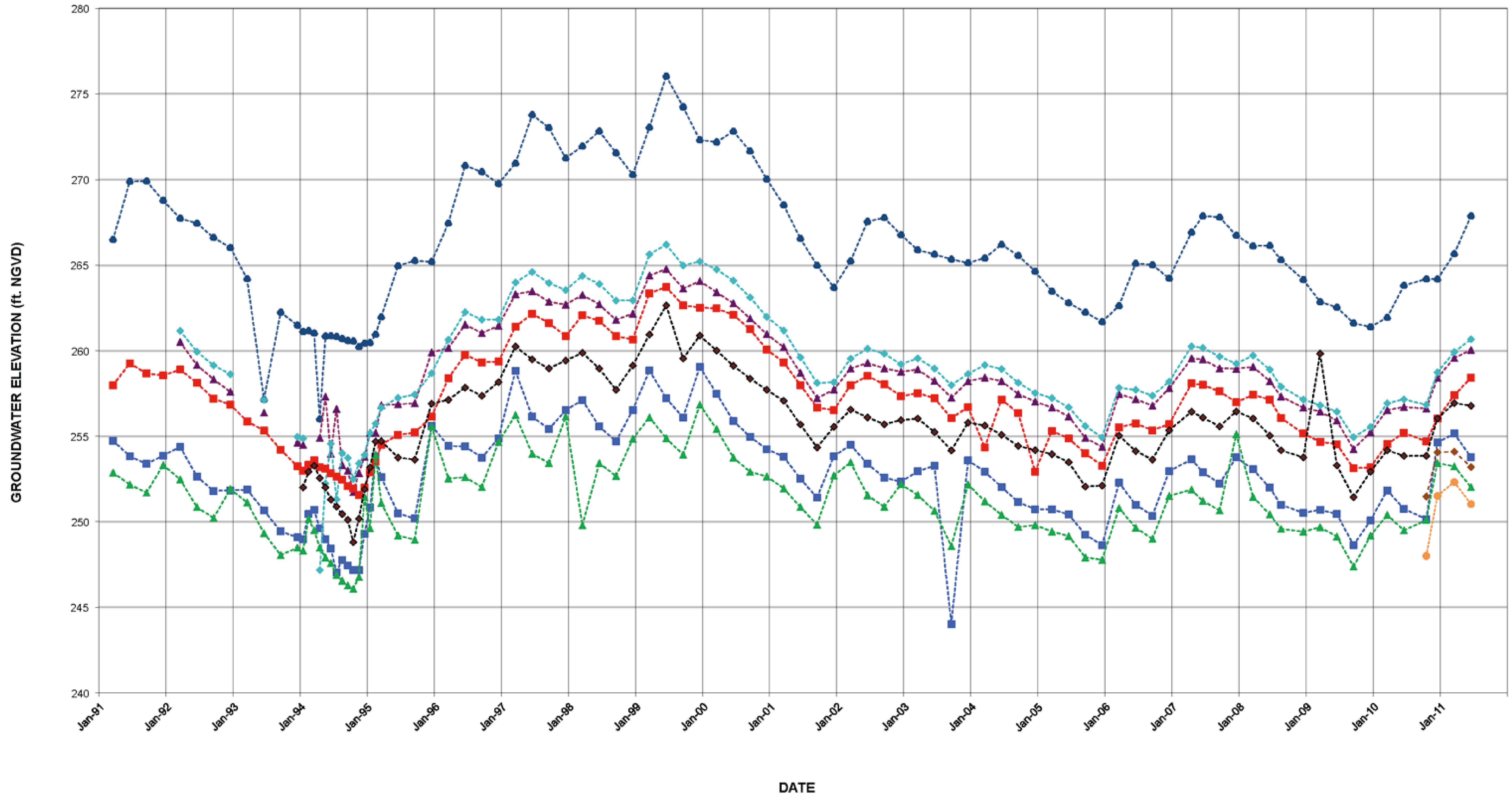
FIGURE 4-3d

OLALLA LANDFILL GROUNDWATER ELEVATION CONTOUR MAP
JUNE 1 AND 2, 2011
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ALW*	*DCK*	*12/11/12*

OLALLA LANDFILL
Groundwater Elevations



PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	**DRAWN BY**	**REVIEWED BY**	**DATE**
1 of 1	ARM	DCK	02/16/12

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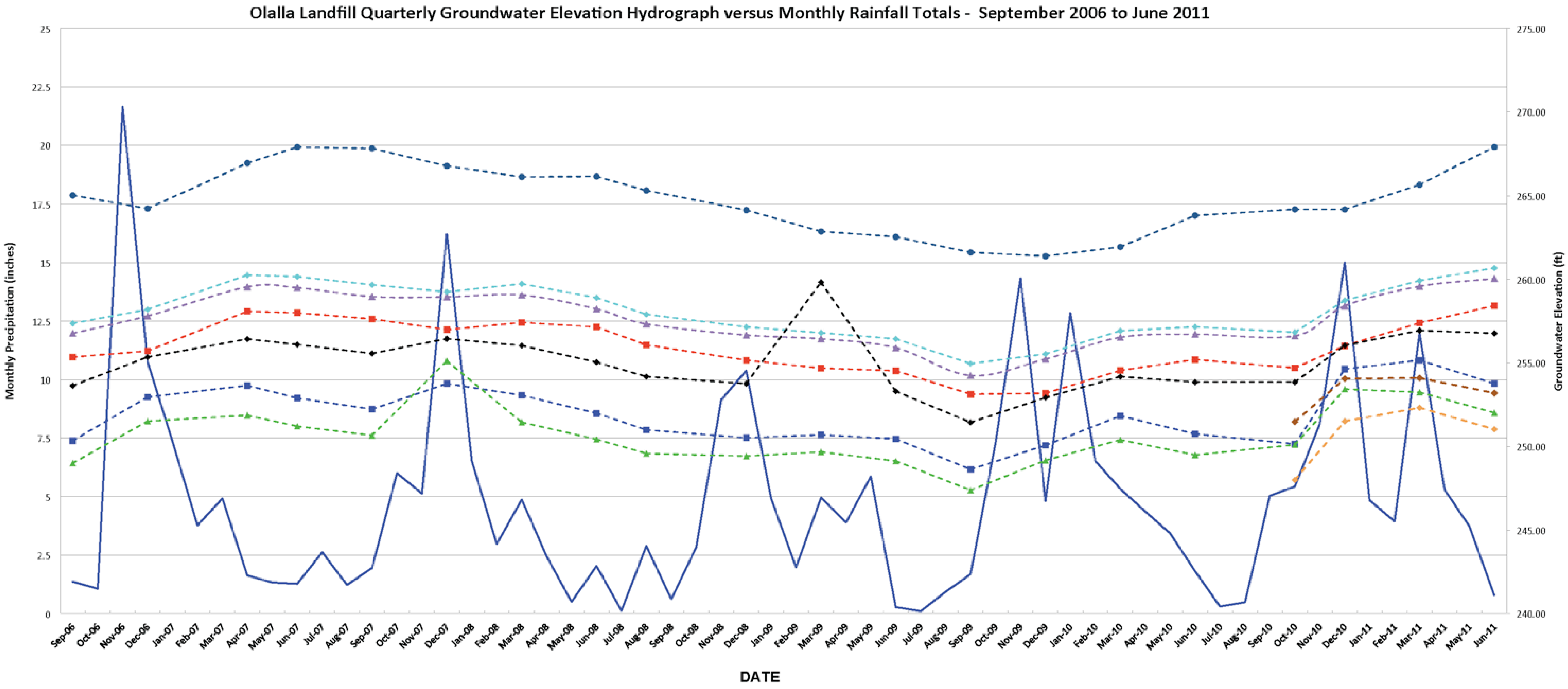
FIGURE 4-4a

GROUNDWATER ELEVATION HYDROLOGY



PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	DRAWN BY	REVIEWED BY	DATE
1 of 1	ARM	DCK	03/05/12

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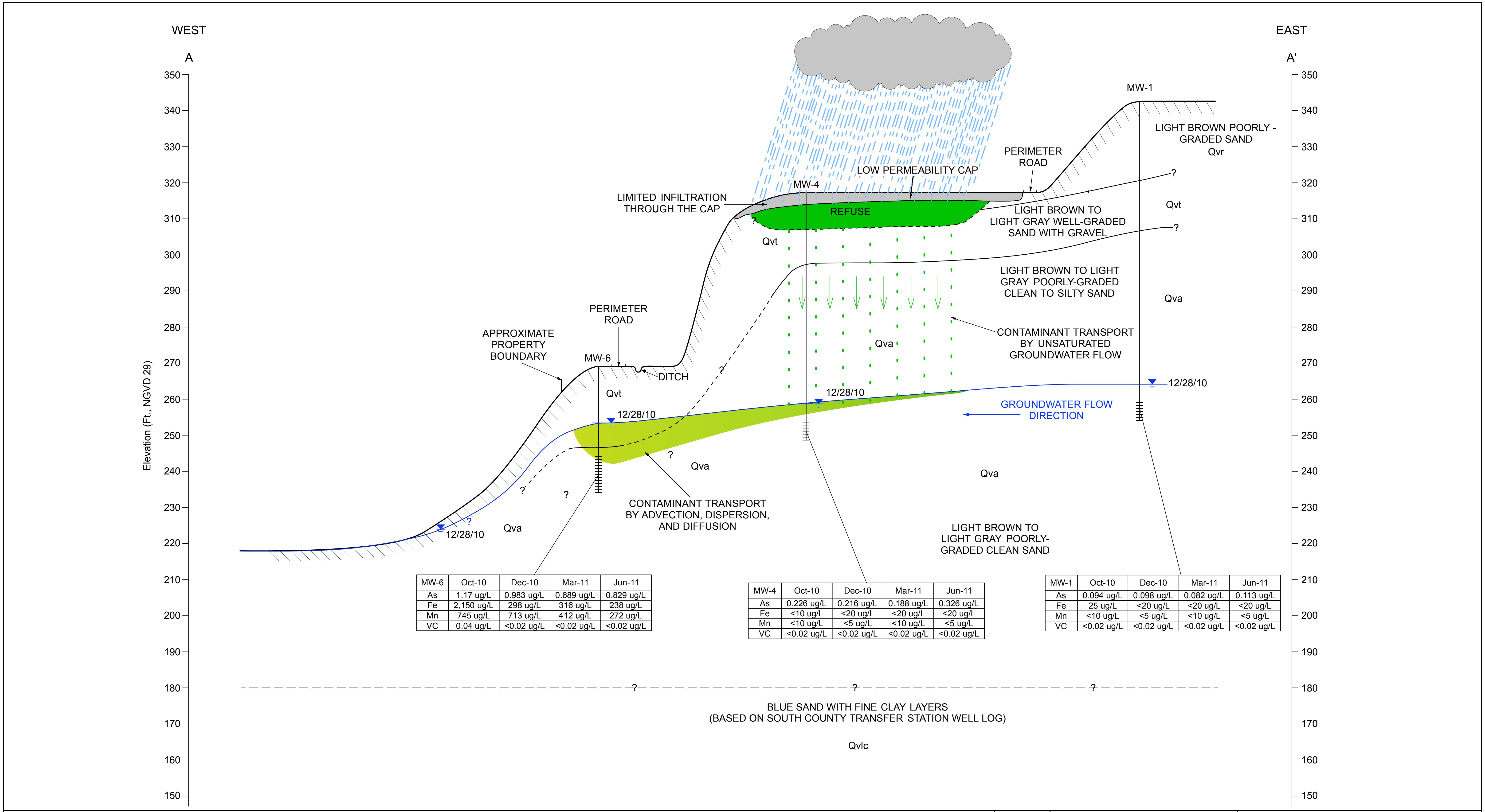
FIGURE 4-4b

OLALLA LANDFILL QUARTERLY
GROUNDWATER ELEVATION VERSUS
MONTHLY RAINFALL TOTALS -
SEPTEMBER 2006 TO JUNE 2011



MW-6	Oct-10	Dec-10	Mar-11	Jun-11
As	1.17 ug/L	0.983 ug/L	0.689 ug/L	0.829 ug/L
Fe	2,150 ug/L	298 ug/L	316 ug/L	238 ug/L
Mn	745 ug/L	713 ug/L	412 ug/L	272 ug/L
VC	0.04 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-4	Oct-10	Dec-10	Mar-11	Jun-11
As	0.226 ug/L	0.216 ug/L	0.188 ug/L	0.326 ug/L
Fe	<10 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	<10 ug/L	<5 ug/L	<10 ug/L	<5 ug/L
VC	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

MW-1	Oct-10	Dec-10	Mar-11	Jun-11
As	0.094 ug/L	0.098 ug/L	0.082 ug/L	0.113 ug/L
Fe	25 ug/L	<20 ug/L	<20 ug/L	<20 ug/L
Mn	<10 ug/L	<5 ug/L	<10 ug/L	<5 ug/L
VC	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L	<0.02 ug/L

KEY:

GROUND SURFACE

LITHOLOGIC CONTACT, DASHED WHERE INFERRED.

MONITORING WELL AND SCREENED INTERVAL

▼ WATER LEVEL ON 12/28/10

0 50 100 200

SCALE: 1" = 200'

Qvr	**Recessional Outwash Deposits -** Stratified sand and gravel moderately well sorted to well sorted; less common silty sand and silt. Exposed primarily on floors of outwash channels that trend south-southwest between flutes molded by glacial flow.
Qvi	**Ice-Contact Deposits -** Deposits similar in texture to unit Qvr but locally containing much higher percentage of silt intermixed with granular sediments; also includes lenses and pods of till.
Qvt	**Till -** Compact very poorly sorted sediment containing subrounded to well-rounded clasts; glacially transported and deposited. Generally forms undulating surface a few tens of meters thick. Also found sporadically within areas mapped as unit Qvi.
Qva	**Advance Outwash Deposits -** Well-bedded sand and gravel; deposited by streams and rivers that issued from front of advancing ice sheet. Generally unoxidized; almost devoid of silt or clay, except near base of unit.
Qvlc	**Lawton Clay -** Laminated to massive silt, clayey silt, and silty clay; deposited in proglacial or lowland lakes.

Source: Geologic map of the Olalla 7.5' Quadrangle, King, Kitsap and Pierce Counties, WA. By Derek B. Booth and Kathy Goetz Troost 2005.

PROJECT	60101.0 OLALLA, WASHINGTON		
PREPARED FOR	KITSAP COUNTY		
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON		
SHEET *1 of 1*	**DRAWN BY** *ALW*	**REVIEWED BY** *DCK*	**DATE** *12/10/12*

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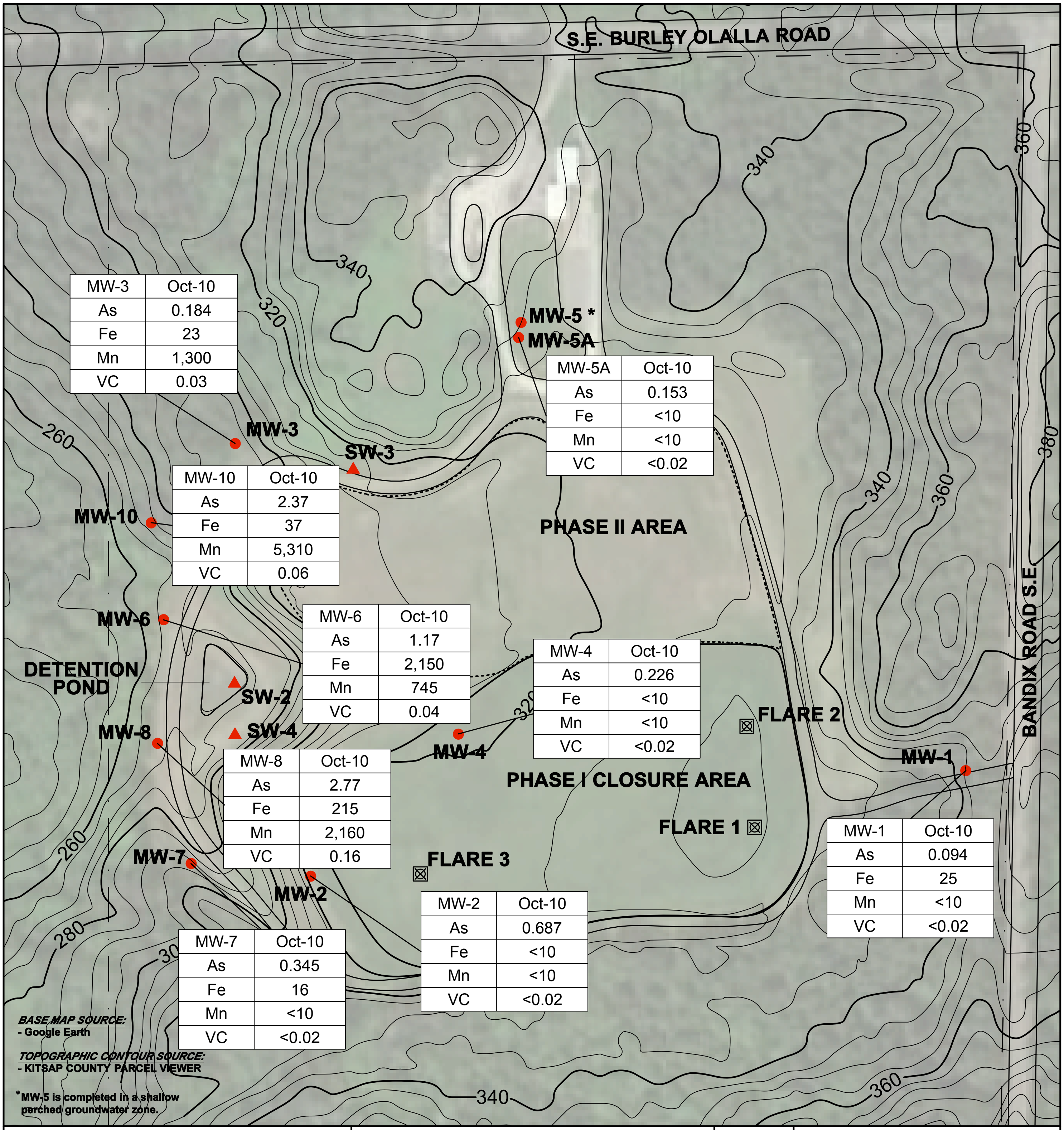
FIGURE 4-5

CONCEPTUAL MODEL OF CONTAMINANT TRANSPORT THROUGH OLALLA LANDFILL
KITSAP COUNTY, WASHINGTON



MW-3	Oct-10
As	0.184
Fe	23
Mn	1,300
VC	0.03

MW-5A	Oct-10
As	0.153
Fe	<10
Mn	<10
VC	<0.02

MW-10	Oct-10
As	2.37
Fe	37
Mn	5,310
VC	0.06

MW-6	Oct-10
As	1.17
Fe	2,150
Mn	745
VC	0.04

MW-4	Oct-10
As	0.226
Fe	<10
Mn	<10
VC	<0.02

MW-8	Oct-10
As	2.77
Fe	215
Mn	2,160
VC	0.16

MW-1	Oct-10
As	0.094
Fe	25
Mn	<10
VC	<0.02

MW-2	Oct-10
As	0.687
Fe	<10
Mn	<10
VC	<0.02

MW-7	Oct-10
As	0.345
Fe	16
Mn	<10
VC	<0.02

BASE MAP SOURCE:
- Google Earth

TOPOGRAPHIC CONTOUR SOURCE:
- KITSAP COUNTY PARCEL VIEWER

*MW-5 is completed in a shallow perched groundwater zone.

KEY:

— · —: APPROXIMATE PROPERTY BOUNDARY
═: PERIMETER ACCESS ROAD
MW-2 ●: MONITORING WELL
SW-2 ▲: SURFACE WATER SAMPLING LOCATION
300: TOPOGRAPHIC ELEVATION CONTOURS
☒: LANDFILL GAS FLARE

N

0 50 100 200

SCALE: 1" = 200'

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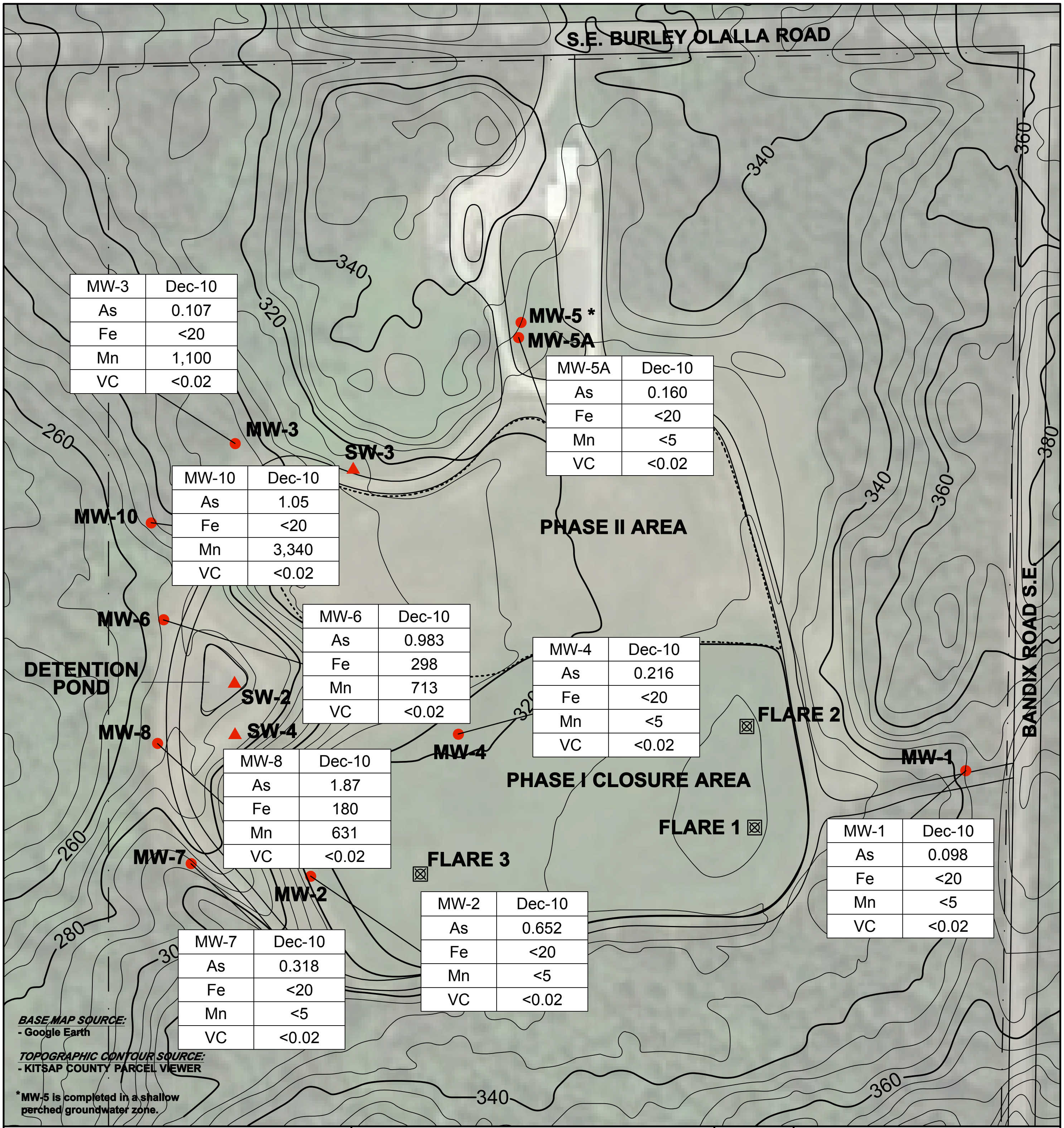
FIGURE 4-6a

OCTOBER 2010 MONITORING WELL
ANALYTICAL RESULTS IN µg/L

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ARM*	*DCK*	*02/14/12*



MW-3	Dec-10
As	0.107
Fe	<20
Mn	1,100
VC	<0.02

MW-5A	Dec-10
As	0.160
Fe	<20
Mn	<5
VC	<0.02

MW-10	Dec-10
As	1.05
Fe	<20
Mn	3,340
VC	<0.02

MW-6	Dec-10
As	0.983
Fe	298
Mn	713
VC	<0.02

MW-4	Dec-10
As	0.216
Fe	<20
Mn	<5
VC	<0.02

MW-8	Dec-10
As	1.87
Fe	180
Mn	631
VC	<0.02

MW-1	Dec-10
As	0.098
Fe	<20
Mn	<5
VC	<0.02

MW-2	Dec-10
As	0.652
Fe	<20
Mn	<5
VC	<0.02

MW-7	Dec-10
As	0.318
Fe	<20
Mn	<5
VC	<0.02

BASE MAP SOURCE:
- Google Earth

TOPOGRAPHIC CONTOUR SOURCE:
- KITSAP COUNTY PARCEL VIEWER

***MW-5 is completed in a shallow perched groundwater zone.**

KEY:

— · —: APPROXIMATE PROPERTY BOUNDARY
═══: PERIMETER ACCESS ROAD
MW-2 ●: MONITORING WELL
SW-2 ▲: SURFACE WATER SAMPLING LOCATION
300: TOPOGRAPHIC ELEVATION CONTOURS
☒: LANDFILL GAS FLARE

N

0 50 100 200

SCALE: 1" = 200'

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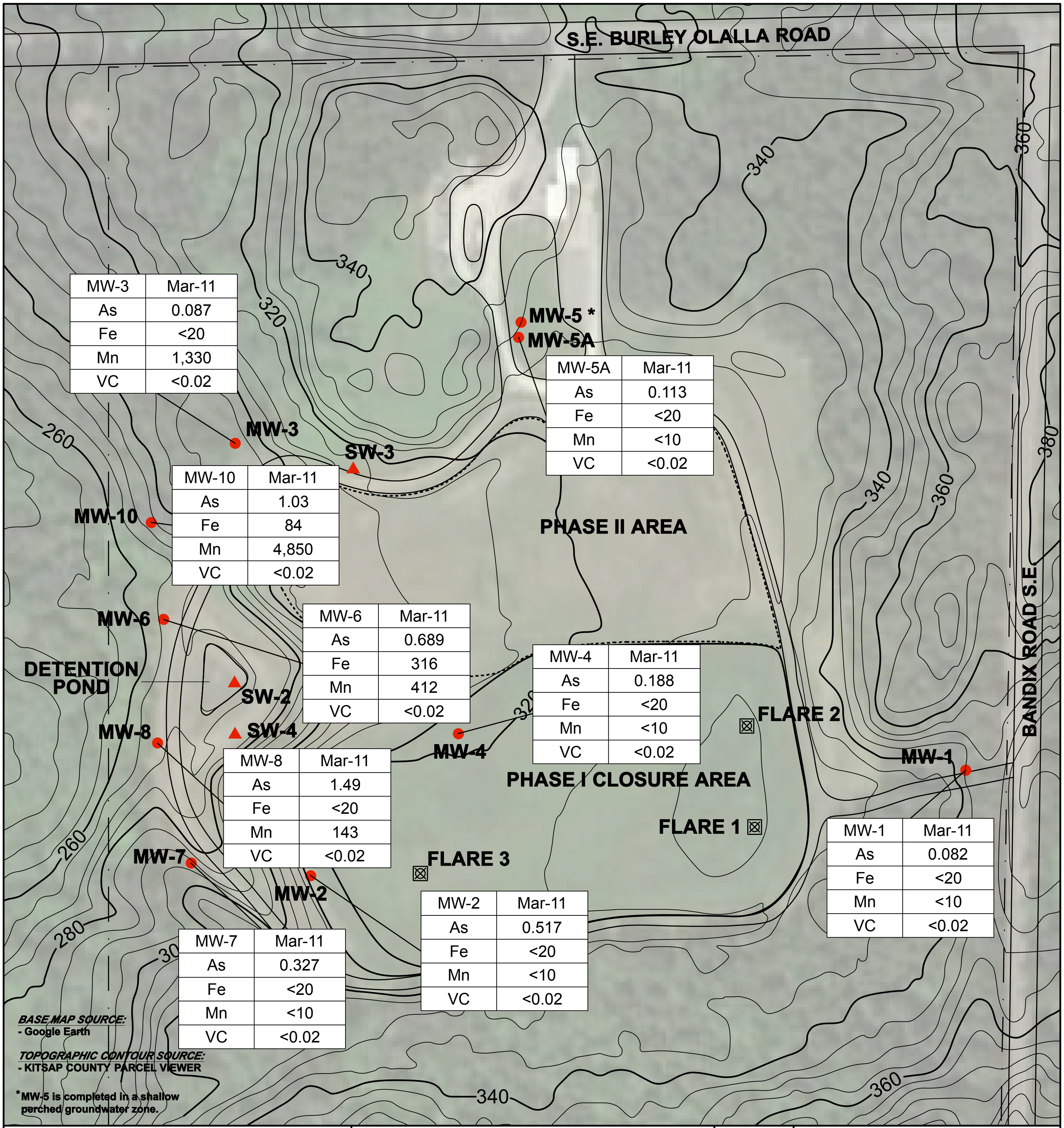
FIGURE 4-6b

DECEMBER 2010 MONITORING WELL
ANALYTICAL RESULTS IN µg/L

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ARM*	*DCK*	*02/14/12*



MW-3	Mar-11
As	0.087
Fe	<20
Mn	1,330
VC	<0.02

MW-5A	Mar-11
As	0.113
Fe	<20
Mn	<10
VC	<0.02

MW-10	Mar-11
As	1.03
Fe	84
Mn	4,850
VC	<0.02

MW-6	Mar-11
As	0.689
Fe	316
Mn	412
VC	<0.02

MW-4	Mar-11
As	0.188
Fe	<20
Mn	<10
VC	<0.02

MW-8	Mar-11
As	1.49
Fe	<20
Mn	143
VC	<0.02

MW-1	Mar-11
As	0.082
Fe	<20
Mn	<10
VC	<0.02

MW-2	Mar-11
As	0.517
Fe	<20
Mn	<10
VC	<0.02

MW-7	Mar-11
As	0.327
Fe	<20
Mn	<10
VC	<0.02

BASE MAP SOURCE:
- Google Earth

TOPOGRAPHIC CONTOUR SOURCE:
- KITSAP COUNTY PARCEL VIEWER

*MW-5 is completed in a shallow perched groundwater zone.

KEY:

— · —: **APPROXIMATE PROPERTY BOUNDARY**
═: **PERIMETER ACCESS ROAD**
MW-2 ●: **MONITORING WELL**
SW-2 ▲: **SURFACE WATER SAMPLING LOCATION**
300: **TOPOGRAPHIC ELEVATION CONTOURS**
☒: **LANDFILL GAS FLARE**

N

0 50 100 200

SCALE: 1" = 200'

epi ENVIRONMENTAL PARTNERS INC
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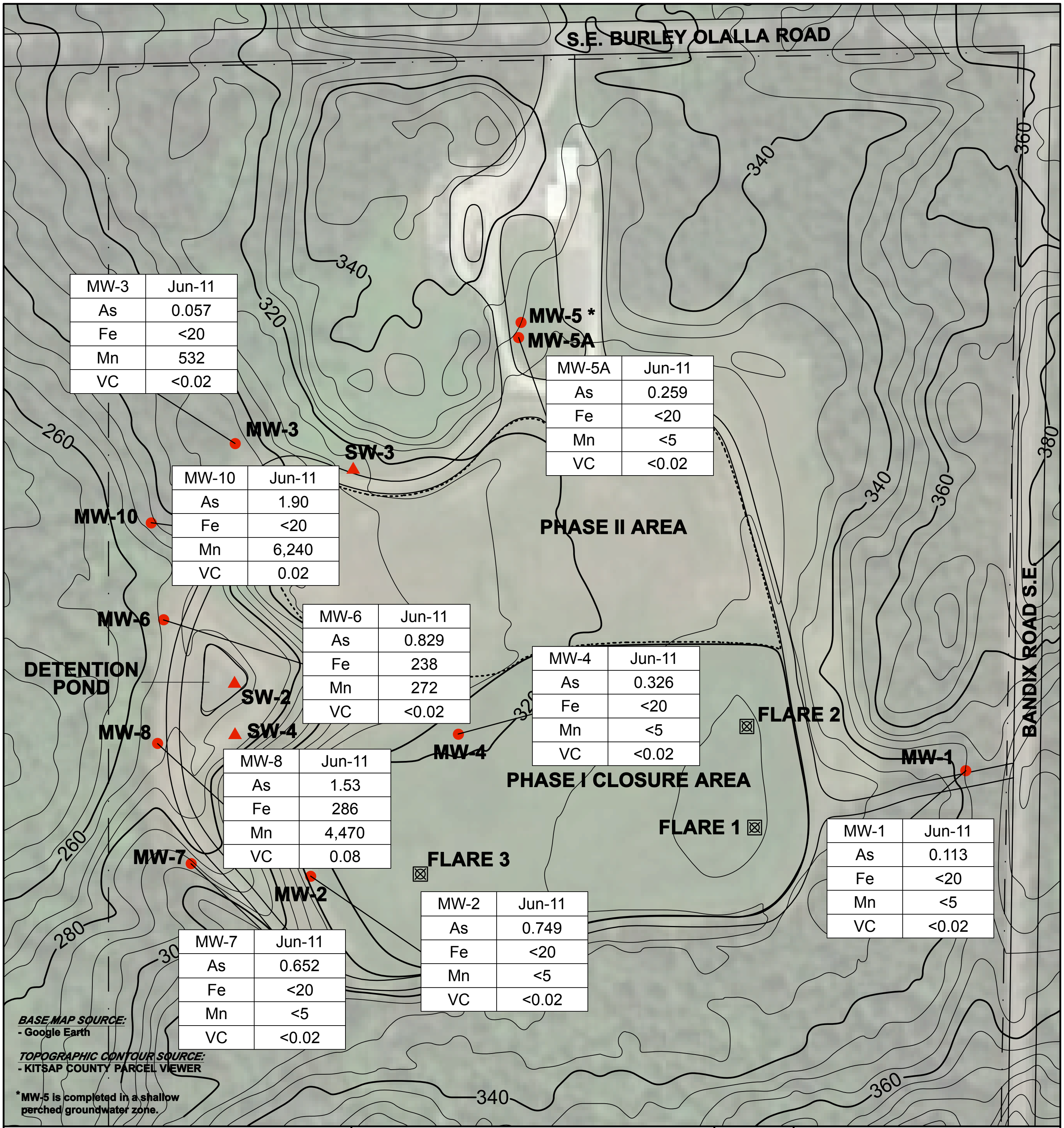
FIGURE 4-6c

MARCH 2011 MONITORING WELL
ANALYTICAL RESULTS IN µg/L

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*MMM*	*DCK*	*07/22/11*



MW-3	Jun-11
As	0.057
Fe	<20
Mn	532
VC	<0.02

MW-5A	Jun-11
As	0.259
Fe	<20
Mn	<5
VC	<0.02

MW-10	Jun-11
As	1.90
Fe	<20
Mn	6,240
VC	0.02

MW-6	Jun-11
As	0.829
Fe	238
Mn	272
VC	<0.02

MW-4	Jun-11
As	0.326
Fe	<20
Mn	<5
VC	<0.02

MW-8	Jun-11
As	1.53
Fe	286
Mn	4,470
VC	0.08

MW-1	Jun-11
As	0.113
Fe	<20
Mn	<5
VC	<0.02

MW-2	Jun-11
As	0.749
Fe	<20
Mn	<5
VC	<0.02

MW-7	Jun-11
As	0.652
Fe	<20
Mn	<5
VC	<0.02

BASE MAP SOURCE:
- Google Earth

TOPOGRAPHIC CONTOUR SOURCE:
- KITSAP COUNTY PARCEL VIEWER

*MW-5 is completed in a shallow perched groundwater zone.

KEY:

— · — : **APPROXIMATE PROPERTY BOUNDARY**
═ : **PERIMETER ACCESS ROAD**
MW-2 ● : **MONITORING WELL**
SW-2 ▲ : **SURFACE WATER SAMPLING LOCATION**
300 : **TOPOGRAPHIC ELEVATION CONTOURS**
☒ : **LANDFILL GAS FLARE**

N

0 50 100 200

SCALE: 1" = 200'

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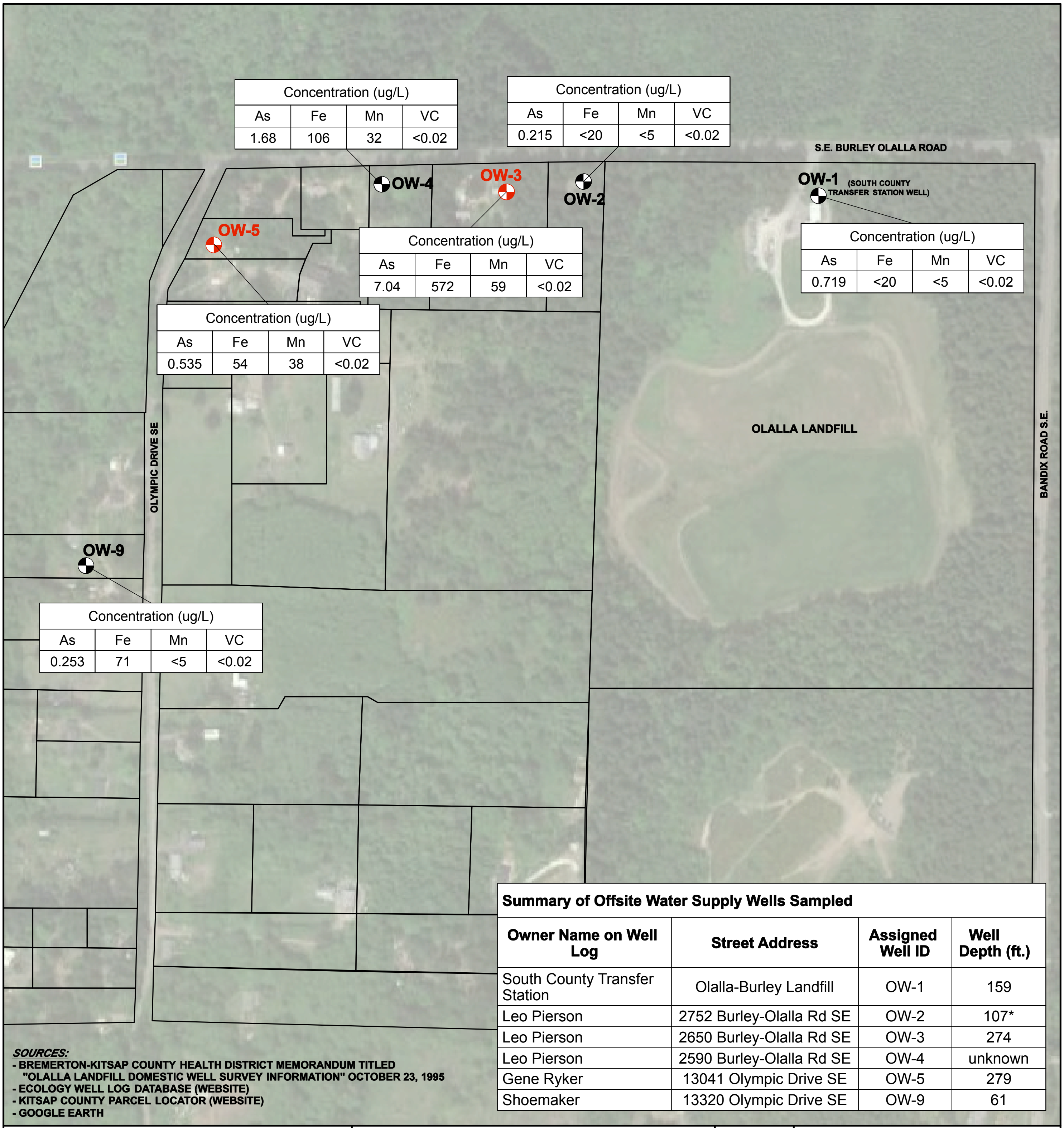
FIGURE 4-6d

JUNE 2011 MONITORING WELL
ANALYTICAL RESULTS IN µg/L

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*MMM*	*DCK*	*07/22/11*



Concentration (ug/L)			
As	Fe	Mn	VC
1.68	106	32	<0.02

Concentration (ug/L)			
As	Fe	Mn	VC
0.215	<20	<5	<0.02

Concentration (ug/L)			
As	Fe	Mn	VC
7.04	572	59	<0.02

Concentration (ug/L)			
As	Fe	Mn	VC
0.719	<20	<5	<0.02

Concentration (ug/L)			
As	Fe	Mn	VC
0.535	54	38	<0.02

Concentration (ug/L)			
As	Fe	Mn	VC
0.253	71	<5	<0.02

Summary of Offsite Water Supply Wells Sampled

Owner Name on Well Log	Street Address	Assigned Well ID	Well Depth (ft.)
South County Transfer Station	Olalla-Burley Landfill	OW-1	159
Leo Pierson	2752 Burley-Olalla Rd SE	OW-2	107*
Leo Pierson	2650 Burley-Olalla Rd SE	OW-3	274
Leo Pierson	2590 Burley-Olalla Rd SE	OW-4	unknown
Gene Ryker	13041 Olympic Drive SE	OW-5	279
Shoemaker	13320 Olympic Drive SE	OW-9	61

SOURCES:
- **BREMERTON-KITSAP COUNTY HEALTH DISTRICT MEMORANDUM TITLED "OLALLA LANDFILL DOMESTIC WELL SURVEY INFORMATION" OCTOBER 23, 1995**
- **ECOLOGY WELL LOG DATABASE (WEBSITE)**
- **KITSAP COUNTY PARCEL LOCATOR (WEBSITE)**
- **GOOGLE EARTH**

KEY:

*** Well information provided by owner. Well log not available in KCHD records or Ecology Well Log database.**

◐ **: OFFSITE WELL LOCATION (UPPER AQUIFER)**

◐ **: OFFSITE WELL LOCATION (DEEPER AQUIFER)**

——— **: PARCEL BOUNDARY**

N

0 100 200 400

SCALE: 1" = 400'

ENVIRONMENTAL PARTNERS INC

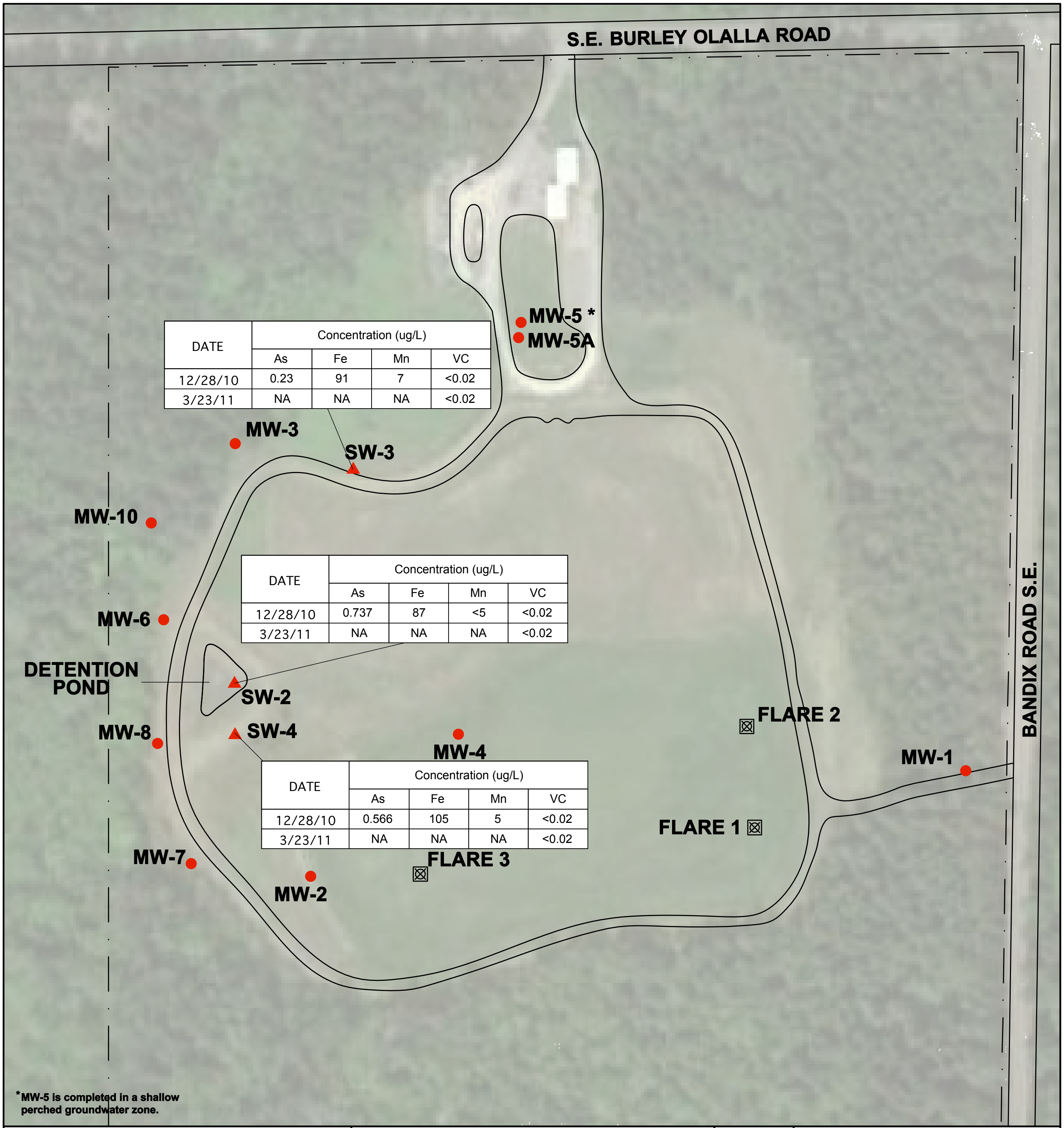
295 NE Gilman Boulevard, Suite 201
Issaquah, Washington 98027

FIGURE 4-7

WATER SUPPLY WELL
LOCATIONS WITH ANALYTICAL RESULTS
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL RI/FS KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ARM*	*DCK*	*02/16/12*



SW-3:

DATE	Concentration (ug/L)			
	As	Fe	Mn	VC
12/28/10	0.23	91	7	<0.02
3/23/11	NA	NA	NA	<0.02

SW-2:

DATE	Concentration (ug/L)			
	As	Fe	Mn	VC
12/28/10	0.737	87	<5	<0.02
3/23/11	NA	NA	NA	<0.02

SW-4:

DATE	Concentration (ug/L)			
	As	Fe	Mn	VC
12/28/10	0.566	105	5	<0.02
3/23/11	NA	NA	NA	<0.02

*MW-5 is completed in a shallow perched groundwater zone.

KEY:

— · —: APPROXIMATE PROPERTY BOUNDARY

═: PERIMETER ACCESS ROAD

MW-2 ●: MONITORING WELL

SW-2 ▲: SURFACE WATER SAMPLING LOCATION

☒: LANDFILL GAS FLARE

NA: NOT ANALYZED

N

0 50 100 200

SCALE: 1" = 200'

ENVIRONMENTAL PARTNERS INC

295 NE Gilman Boulevard, Suite 201
Issaquah, Washington 98027

FIGURE 5-1

SURFACE WATER SAMPLE LOCATIONS
WITH ANALYTICAL RESULTS
KITSAP COUNTY, WASHINGTON

PROJECT	60101.0 OLALLA, WASHINGTON
PREPARED FOR	KITSAP COUNTY
LOCATION	OLALLA LANDFILL KITSAP COUNTY, WASHINGTON

SHEET	***DRAWN BY***	***REVIEWED BY***	***DATE***
1 of 1	*ALW*	*DCK*	*12/13/12*

BASE MAP SOURCE:
- Google Earth

TOPOGRAPHIC CONTOUR SOURCE:
- KITSAP COUNTY PARCEL VIEWER

***MW-5 is completed in a shallow perched groundwater zone.**

Parametrix DATE: August 29, 2013 FILE: PU1578121-F01-1

N

0 200
SCALE IN FEET

LEGEND

▨ **GEOMEMBRANE CAP**

Figure 12-1
Alternative 2
Ollala Landfill
Kitsap County

BASE MAP SOURCE:
- Google Earth

TOPOGRAPHIC CONTOUR SOURCE:
- KITSAP COUNTY PARCEL VIEWER

*MW-5 is completed in a shallow perched groundwater zone.

Parametrix DATE: December 10, 2012 FILE: PU1578121-F01

LEGEND

△ AIR SPARGE WELLS

⊙ INJECTION WELLS

Figure 12-2
Alternative 3
Ollala Landfill
Kitsap County

Tables

Table 1-1. Summary of Data Gaps and Investigation Methods

RI Data Gap and Work Plan Task	Rationale for Identified Data Gap	Documented in RI/FS Section	Comments
GROUNDWATER			
Install two new downgradient monitoring wells with screens set to match site-specific geology.	The distance between downgradient wells MW-3, MW-6, and MW-7 was too great. There was the potential for contaminants to be transported between the existing downgradient monitoring wells without being detected.	Section 2.1.1	Completed October 2010.
Obtain aquifer matrix samples during drilling for sieve analysis.	The hydraulic conductivity of the aquifer was calculated in slug tests performed in MW-1, MW-2, MW-3, and MW-4. Slug test results can be affected by variations in well construction and development. The consulting team wanted to calculate hydraulic conductivity based on aquifer materials only without potential influences from well construction.	Sampling documented in Section 2.1.1 Sieve analysis results in Appendix D	Completed October 2010.
Redevelop and sample MW-2 and MW-4.	Wells MW-2 and MW-4 have not been sampled since February 1990 (for dissolved metals) and there is no documentation indicating that they were developed following installation.	Section 2.1.1.3 Well development field data sheets in Appendix D	Completed October 2010.
Survey elevations of old and new monitoring wells.	Monitoring wells at the Landfill were installed and surveyed over a period of many years by several consultants but were never all surveyed together as a network from a common datum and benchmark.	Section 2.1.1.4 Survey data in Appendix E	Completed December 2010.
Update the inventory of domestic water wells in the vicinity of the Landfill; select wells for sampling.	Off-site domestic wells were last sampled in September 1997. New domestic wells have been installed in the area since that time.	Section 2.1.4 Sampling results in Section 3.8	Completed December 2010.

(Table Continues)

Table 1-1. Summary of Data Gaps and Investigation Methods (Continued)

RI Data Gap and Work Plan Task	Rationale for Identified Data Gap	Documented in RI/FS Section	Comments
GROUNDWATER (Continued)			
Perform two groundwater monitoring events with the Appendix III expanded list of parameters, as part of four quarterly RI sampling events.	Groundwater sampling has been performed for a limited list of constituents under WAC 173-304-407 and the SWHP since 1992. Constituent groups such as SVOCs, and PCBs, included in the Appendix III constituent list, needed to be analyzed to determine the constituents of concern for the Landfill.	Section 4.6	Quarterly events completed in October 2010, December 2010, March 2011, and June 2011. October and March events included WAC 173-351-990 Appendix III parameter list; December and June sampling events included SWHP list of parameters.
Complete domestic well inventory and select wells to sample, in coordination with KPHD; collect samples from domestic wells.	Off-site domestic wells were last sampled in September 1997. New domestic wells have been installed in the area since 1997 and an updated data set including previously sampled domestic wells and new domestic wells was needed to evaluate potential off-site impacts to groundwater.	Section 2.1.4 Sampling results in Section 3.8	Completed late December 2010 and early January 2011.
If arsenic data from MW-1 and MW-5A are insufficient to document background, perform a data search of arsenic data in regional groundwater.	Arsenic is routinely detected in samples from all wells, including upgradient and cross gradient wells, at concentrations greater than the WA State Primary Groundwater Standard.	Section 10.1 and Appendix H	Regional arsenic data have been obtained from a variety of sources including the USGS, Kitsap Public Health District, and are presented in this RI/FS report.
Locate and sample seeps and springs on private property west of the Landfill.	Historically seeps/springs were reported on the downgradient property to the west of the Landfill but were not sampled for contaminants.	Section 2.2.2	Seeps have been historically identified in the private property immediately to the west of the Landfill. KCPW was unable to obtain permission from the property owner to enter the property.

(Table Continues)

Table 1-1. Summary of Data Gaps and Investigation Methods (Continued)

RI Data Gap and Work Plan Task	Rationale for Identified Data Gap	Documented in RI/FS Section	Comments
GROUNDWATER (Continued)			
Install additional monitoring wells to determine downgradient extent of Landfill impacts to groundwater.	Vinyl chloride, arsenic, iron, and manganese have been detected in samples from downgradient wells at concentrations greater than regulatory standards. The downgradient extent of groundwater with constituents at concentrations greater than regulatory standards was not evaluated historically.	Section 2.1 and 2.1.1 Data are shown on Figures 4-6a through 4-6d Full data set is presented on Tables 4-4b through 4-4e	Vinyl chloride was not detected in samples from any of the downgradient monitoring wells during four of the last six sampling events and has never been detected in samples from off-site water supply wells. There is no need to install wells farther downgradient because the edge of the vinyl chloride plume is approximately at the current downgradient monitoring well network.
Locate and sample potential perched zones of leachate in the Landfill.	The geologic log for interior monitoring well MW-4 notes wet refuse in the 2 to 8 ft. bgs interval. The wet refuse does not represent a perched zone of leachate or groundwater. The geologic log for interior well MW-2 does not indicate any wet intervals until the uppermost aquifer was encountered at approximately 57 ft. bgs.	Hydrogeology is discussed in Section 4.1	No potential perched zones have been noted in geologic logs for interior Landfill wells MW-2 and MW-4.
SURFACE WATER			
Collect surface water samples from station SW-2 and from new stations SW-3 and SW-4 when water is present.	Surface water has historically been sampled and analyzed from one location, SW-2, for a small list of constituents that does not include the Landfill-specific COCs. More extensive sampling and analysis was necessary for the RI.	Methods in Section 2.2 Results in Section 4.0 Data are summarized in Tables 4-4c and 4-4d	During quarterly monitoring in December 2010 and March 2011 there was sufficient surface water for sampling at one or more surface water sampling locations and samples were obtained.

(Table Continues)

Table 1-1. Summary of Data Gaps and Investigation Methods (Continued)

RI Data Gap and Work Plan Task	Rationale for Identified Data Gap	Documented in RI/FS Section	Comments
SOLID WASTE			
Evaluate aerial photos and other historical data for Phase II area; determine if refuse was present in areas upgradient of MW-3 and MW-6.	Based on historical groundwater flow directions MW-3 appeared to be cross gradient to the Landfill. COC detections in samples from MW-3 were thought to potentially be due to landfill gas migration and residual impacts from refuse that was formerly located outside of the Landfill footprint.	Section 1.3	Completed September 2010.
Prepare updated map of the Phase II area showing capped versus uncapped areas and areas with solid waste.	Historical information regarding the Phase II area of the Landfill was incomplete and did not confirm whether or not the Phase II area of the Landfill contained refuse or was capped.	Figure 1-2	All Phase II Area is capped with a soil cover and contains primarily inert waste and demolition waste. Putrescible solid waste was not detected in test trenches installed in the Phase II Area.
Excavate test pits and trenches in Phase II area.	Historical information regarding the Phase II area of the Landfill was incomplete and did not confirm whether or not the Phase II area of the Landfill contained refuse or was capped. Test pits were dug during Landfill closure activities but none were completed in the Phase II area of the Landfill.	Methods in Section 2.3 Results in Section 6.0 Test pit logs and photos in Appendix J	Completed October 2010.
If refuse is found in trenches, delineate the depths, thickness, and lateral extent of refuse.	Potential data gap is dependent on the results of the prior identified data gap.	Rationale for no additional investigation work in Section 6.3	Completed October 2010. Inert waste and demolition waste was noted in shallow soil at four of the five test trenches. Trench sidewalls would not remain stable to allow deeper excavation beyond approximately 8 feet bgs.

(Table Continues)

Table 1-1. Summary of Data Gaps and Investigation Methods (Continued)

RI Data Gap and Work Plan Task	Rationale for Identified Data Gap	Documented in RI/FS Section	Comments
SOLID WASTE (Continued)			
If refuse is found in Phase II area, evaluate potential costs and benefits of removing refuse.	Potential data gap is dependent on the results of the prior identified data gap.	Rationale for no additional action in Section 6.3	Inert waste and demolition waste is not considered refuse and only has to be covered with a soil cap per WAC 173-304-461(6), which is consistent with current conditions.
LANDFILL GAS			
Review as-built data for the three passive flares.	Flare construction details were necessary to design sampling methods that would yield representative samples of landfill gas.	As-built Landfill gas collection system alignment is shown in Figure 2-5	Completed September 2010.
Plug the three passive flares; test for gas pressure, field parameters, and TO-15 organic compounds.	Landfill gas is monitored quarterly for field parameters methane, oxygen, carbon dioxide, and pressure but was never sampled and analyzed for the potential presence of VOCs.	Methods in Section 2.4 Results in Section 7.0 and Table 7-1 Laboratory data sheets in Appendix K	Completed October 2010.
Evaluate VOC concentrations in LF gas and potential for partitioning to groundwater.	Historical groundwater flow directions were based on incorrect monitoring well measuring point elevations, which indicated that MW-3 was predominantly cross gradient to the Landfill. Vinyl chloride detections in samples from MW-3 were thought to be potentially due to partitioning from landfill gas to groundwater.	Section 7.0 Results in Section 7.0 and Table 7-1 Laboratory data sheets in Appendix K	Completed February 2011; chlorinated VOCs, specifically vinyl chloride, not detected in landfill gas samples. Very low to no potential for landfill gas to cause VOC impacts in groundwater.
Compare water quality data from MW-3 and MW-6 to gas data to check for vinyl chloride transport.	Prior to re-surveying all wells during the RI vinyl chloride detections in samples from MW-3 were thought to be potentially due to partitioning from landfill gas to groundwater.	Section 7.0 Results in Section 7.0 and Table 7-1 Laboratory data sheets in Appendix K	Completed February 2011; no indications of landfill gas transport of vinyl chloride to groundwater. No vinyl chloride or other chlorinated VOCs in the landfill gas samples.

(Table Continues)

Table 1-1. Summary of Data Gaps and Investigation Methods (Continued)

RI Data Gap and Work Plan Task	Rationale for Identified Data Gap	Documented in RI/FS Section	Comments
LANDFILL GAS (Continued)			
If vinyl chloride detected in samples from MW-3 and MW-6 is likely due to gas transport, evaluate the need for installation of gas probes between the edge of refuse and MW-3 and MW-6.	Potential data gap is dependent on the results of the prior identified data gap.	Section 7.0 Results in Section 7.0 and Table 7-1 Laboratory data sheets in Appendix K	Landfill gas does not contain detectable concentrations of chlorinated VOCs including vinyl chloride. In addition, corrected well measuring point elevations demonstrate that both MW-3 and MW-6 are downgradient of the Phase I Area of the Landfill.

Table 2-1. Monitoring Well Construction Summary at Olalla Landfill

Well I.D.	Northing	Easting	Surface Elevation (ft NGVD)	Top of Casing Elevation (ft NGVD)	Total Depth (ft bgs)	Screened Interval (ft bgs)
MW-1	161858.133	560525.840	342.53	343.79	88	83-88
MW-2	161704.534	559572.839	318.95	323.25	73	68-73
MW-3	162333.903	559463.060	294.95	296.95	58	50-55
MW-4	161911.192	559787.735	317.35	320.93	69	63-68
MW-5A	162487.878	559875.742	331.43	332.53	108	86-96
MW-6	162077.699	559358.970	269.14	271.17	35	25-35
MW-7	161723.016	559398.979	278.21	280.43	33	21-31
MW-8	161897.813	559350.147	270.73	272.85	38	25-35
MW-10	162218.490	559340.899	276.84	279.21	47	37-47

Notes:
ft = feet
NGVD = National Geodetic Vertical Datum (1929)
bgs = below ground surface

Table 2-2. Survey Results Summary

Station	Northing	Easting	Reference Elevation (Ft. NGVD)[a]	Description
MONITORING WELLS				
MW-1	161858.133	560525.840	343.79	measuring point at pump wellhead
MW-2	161704.534	559572.839	323.25	measuring point, top of PVC casing
MW-3	162333.903	559463.060	296.95	measuring point at pump wellhead
MW-4	161911.192	559787.735	320.93	measuring point, top of PVC casing
MW-5	162510.115	559878.901	332.78	measuring point, top of PVC casing
MW-5A	162487.878	559875.742	332.53	measuring point at pump wellhead
MW-6	162077.699	559358.970	271.17	measuring point at pump wellhead
MW-7	161723.016	559398.979	280.43	measuring point at pump wellhead
MW-8	161897.813	559350.147	272.85	measuring point at pump wellhead
MW-10	162218.490	559340.899	279.21	measuring point at pump wellhead
FLARES				
Flare 1	161775.469	560218.662	332.40	ground surface elevation
Flare 2	161922.669	560207.322	330.27	ground surface elevation
Flare 3	161707.727	559732.444	323.76	ground surface elevation
TEST PITS				
TP-1	162289.111	559988.875	321.87	north end of trench, ground surface elevation
TP-1	162259.235	559993.205	322.39	south end of trench, ground surface elevation
TP-2	162135.942	560120.834	325.20	north end of trench, ground surface elevation
TP-2	162107.804	560128.212	324.72	south end of trench, ground surface elevation
TP-3	162123.185	559944.476	319.53	north end of trench, ground surface elevation
TP-3	162090.903	559947.172	319.26	south end of trench, ground surface elevation
TP-4	162118.139	559675.923	310.22	north end of trench, ground surface elevation
TP-4	162065.499	559677.316	309.76	south end of trench, ground surface elevation
TP-5	162201.740	559810.304	314.31	north end of trench, ground surface elevation
TP-5	162173.560	559815.981	314.43	south end of trench, ground surface elevation

[a] National Geodetic Vertical Datum (1929).

Table 4-1 Depth to Groundwater and Elevation Summary

Station	Reference Elevation (Ft. NGVD)[a]	Depth to Water (feet)	Groundwater Elevation (Ft. NGVD)[a]
OCTOBER 28, 2010			
MW-1	343.79	79.59	264.20
MW-2	323.25	66.63	256.62
MW-3	296.95	46.80	250.15
MW-4	320.93	64.09	256.84
MW-5A	332.53	77.83	254.70
MW-6	271.17	21.07	250.10
MW-7	280.43	26.58	253.85
MW-8	272.85	21.37	251.48
MW-10	279.21	31.21	248.00
DECEMBER 28, 2010			
MW-1	343.79	79.60	264.19
MW-2	323.25	64.84	258.41
MW-3	296.95	42.32	254.63
MW-4	320.93	62.19	258.74
MW-5A	332.53	76.50	256.03
MW-6	271.17	17.74	253.43
MW-7	280.43	24.38	256.05
MW-8	272.85	18.79	254.06
MW-10	279.21	27.70	251.51
MARCH 23, 2011			
MW-1	343.79	78.12	265.67
MW-2	323.25	63.67	259.58
MW-3	296.95	41.79	255.16
MW-4	320.93	61.00	259.93
MW-5A	332.53	75.14	257.39
MW-6	271.17	17.93	253.24
MW-7	280.43	23.49	256.94
MW-8	272.85	18.75	254.10
MW-10	279.21	26.89	252.32
JUNE 1 AND 2, 2011			
MW-1	343.79	75.90	267.89
MW-2	323.25	63.20	260.05
MW-3	296.95	43.19	253.76
MW-4	320.93	60.25	260.68
MW-5A	332.53	74.10	258.43
MW-6	271.17	19.15	252.02
MW-7	280.43	23.65	256.78
MW-8	272.85	19.65	253.20
MW-10	279.21	28.18	251.03

[a] National Geodetic Vertical Datum (1929)

Table 4-2. Olalla Landfill RI/FS Calculated Groundwater Flow Velocities

Measurement Date	Calculated Hydraulic Gradient, (L/L)	Calculated Groundwater Flow Velocity (ft/day)
October 28, 2010	0.0136	2.12
December 28, 2010	0.0098	1.53
March 23, 2011	0.0122	1.90
June 1 and 2, 2011	0.0139	2.17

Table 4-3. Olalla Landfill RI/FS Groundwater Quality Screening Level Summary

Landfill-Specific COC	WA State Drinking Water Standard	WA State Groundwater Standard	MTCA Method A	MTCA Method B, Carcinogenic	MTCA Method B, Non-Carcinogenic
Arsenic	10 μg/L	0.05 μg/L	5.0 μg/L	0.058 μg/L	4.8 μg/L
Iron	300 μg/L[a]	300 μg/L[a]	NA	NA	11,000 μg/L
Manganese	50 μg/L[a]	50 μg/L[a]	NA	NA	2,200 μg/L
Vinyl Chloride	2.0 μg/L	0.02 μg/L	0.2 μg/L	0.029 μg/L	240 μg/L

[a] Secondary standard.

NA = Not Applicable

Table 4-4a. October 2010 Baseline Interior Monitoring Well Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-2	MW-4
CONVENTIONALS					
ALKALINITY	-----	-----	mg/L	56.5	57.3
AMMONIA NITROGEN	-----	-----	mg/L	10 U	10 U
BICARBONATE	-----	-----	mg/L	47.3	47.6
CARBONATE	-----	-----	mg/L	1.0 U	1.0 U
CHEMICAL OXYGEN DEMAND	-----	-----	mg/L	NA	NA
CHLORIDE	250**	250**	mg/L	1.86	2.44
FECAL COLIFORM	-----	-----	#/100 mL		
NITRATE NITROGEN	10*	10*	mg/L	NA	NA
NITRITE NITROGEN	1*	-----	mg/L	NA	NA
pH (FIELD)	-----	6.5-8.5**	-log H+	NA	NA
pH (LABORATORY)	-----	6.5-8.5**	-log H+	7.1	7.0
SPECIFIC CONDUCTANCE	700**	-----	umhos/cm	NA	NA
SULFATE	250**	250**	mg/L	4.48	3.42
TEMPERATURE	-----	-----	°C	NA	NA

(Table Continues)

Table 4-4a. October 2010 Baseline Interior Monitoring Well Groundwater Quality Data Summary

	State Drinking Water Standards (a)	**State Ground-water Standards (b)**	**Units**	**MW-2**	**MW-4**
CONVENTIONALS (Continued)					
TOTAL DISSOLVED SOLIDS	-----	-----	mg/L	78.0	70.0
TOTAL COLIFORM	1/100 mL*	1/100 mL*	#/100 mL	NA	NA
TOTAL ORGANIC CARBON	-----	-----	mg/L	0.250 U	0.250 U
DISSOLVED METALS					
ARSENIC	10*	0.05*	µg/L	**0.670**	**0.212**
ANTIMONY	6*	-----	µg/L	2 U	2 U
BARIUM	2,000*	1,000*	µg/L	10 U	10 U
BERYLLIUM	4*	-----	µg/L	1 U	1 U
CADMIUM	5*	10*	µg/L	1 U	1 U
CALCIUM	-----	-----	µg/L	7,060	7,460
CHROMIUM	100*	50*	µg/L	3.1	1.1
COBALT	-----	-----	µg/L	10 U	10 U
COPPER	1,300***	1,000**	µg/L	1 U	1 U
IRON	300**	300**	µg/L	20 U	20 U
LEAD	15***	50*	µg/L	1 U	1 U
MAGNESIUM	-----	-----	µg/L	5,360	5,430
MANGANESE	50**	50**	µg/L	10 U	10 U
MERCURY	2*	2*	µg/L	2 U	2 U
NICKEL	100	-----	µg/L	5 U	5 U
POTASSIUM	-----	-----	µg/L	911	805
SELENIUM	50*	-----	µg/L	5 U	5
SILVER	100**	50*	µg/L	1 U	1
SODIUM	20,000***	-----	µg/L	4,230	4,440
THALLIUM	2*	-----	µg/L	2 U	2
TIN	-----	-----	µg/L	40 U	40
VANADIUM	-----	-----	µg/L	5.1	3.2
ZINC	5,000**	5000**	µg/L	11	12
VOLATILE ORGANIC COMPOUNDS					
Vinyl Chloride by SIM	2	0.02	µg/L	0.02 U	0.02 U
BROMOBENZENE	-----	-----	µg/L	0.4 U	0.4 U
BROMOCHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U
BROMOMETHANE	-----	-----	µg/L	0.4 U	0.4 U
N-BUTYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U
SEC-BUTYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U
TERT-BUTLYBENZENE	-----	-----	µg/L	0.4 U	0.4 U

(Table Continues)

Table 4-4a. October 2010 Baseline Interior Monitoring Well Groundwater Quality Data Summary

	State Drinking Water Standards (a)	**State Ground-water Standards (b)**	**Units**	**MW-2**	**MW-4**
VOLATILE ORGANIC COMPOUNDS (Continued)					
CARBON TETRACHLORIDE	5	0.3	µg/L	0.4 U	0.4 U
CHLOROBENZENE	100	-----	µg/L	0.4 U	0.4 U
CHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U
CHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U
2-CHLOROTOLUENE	-----	-----	µg/L	0.4 U	0.4 U
4-CHLOROTOLUENE	-----	-----	µg/L	0.4 U	0.4 U
1,2-DIBROMO-3-CHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U
1,2-DIBROMOETHANE	-----	0.001	µg/L	0.4 U	0.4 U
DIBRROMOETHANE	-----	-----	µg/L	0.4 U	0.4 U
1,2-DICHLOROBENZENE	600	-----	µg/L	0.4 U	0.4 U
1,3-DICHLOROBENZENE	-----	-----	µg/L	0.4 U	0.4 U
1,4-DICHLOROBENZENE	75	4	µg/L	0.4 U	0.4 U
DICHLORODIFLUOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U
1,1-DICHLOROETHANE	-----	1	µg/L	0.4 U	0.4 U
1,2-DICHLOROETHANE	5	0.5	µg/L	0.4 U	0.4 U
1,1-DICHLOROETHENE	7	-----	µg/L	0.4 U	0.4 U
CIS-1,2-DICHLOROETHENE	70	-----	µg/L	0.4 U	0.4 U
TRANS-1,2-DICHLOROETHENE	100	-----	µg/L	0.4 U	0.4 U
1,2-DICHLOROPROPANE	5	0.6	µg/L	0.4 U	0.4 U
1,3-DICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U
2,2-DICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U
1,1-DICHLOROPROPENE	-----	-----	µg/L	0.4 U	0.4 U
CIS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4 U	0.4 U
TRANS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4 U	0.4 U
HEXACHLOROBUTADIENE	-----	-----	µg/L	0.4 U	0.4 U
ISOPROPYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U
4-ISOPROPYLTOLUENE	-----	-----	µg/L	0.4 U	0.4 U
METHYLENE CHLORIDE	5	5	µg/L	0.4 U	0.4 U
NAPHTHALENE	-----	-----	µg/L	0.4 U	0.4 U
N-PROPYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U
STYRENE	100	-----	µg/L	0.4 U	0.4 U
1,1,1,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U
1,1,2,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U
TETRACHLOROETHENE	5	0.8	µg/L	0.4 U	0.4 U
1,2,3-TRICHLOROBENZENE	-----	-----	µg/L	0.4 U	0.4 U

(Table Continues)

Table 4-4a. October 2010 Baseline Interior Monitoring Well Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-2	MW-4
VOLATILE ORGANIC COMPOUNDS (Continued)					
1,2,4-TRICHLOROBENZENE	70	-----	µg/L	0.4 U	0.4 U
1,1,1-TRICHLOROETHANE	200	200	µg/L	0.4 U	0.4 U
1,1,2-TRICHLOROETHANE	5	-----	µg/L	0.4 U	0.4 U
TRICHLOROETHENE	5	3	µg/L	0.4 U	0.4 U
TRICHLOROFLUOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U
1,2,3-TRICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U
1,2,4-TRIMETHYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U
1,3,5-TRIMETHYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U
VINYL CHLORIDE by SIM	2	0.02	µg/L	0.02 U	0.02 U
BENZENE	5	1	µg/L	0.4 U	0.4 U
TOLUENE	1000	-----	µg/L	0.4 U	0.4 U
ETHYLBENZENE	700	-----	µg/L	0.4 U	0.4 U
P/M-XYLENE	10	-----	µg/L	0.4 U	0.4 U
O-XYLENE	10	-----	µg/L	0.4 U	0.4 U
CHLOROFORM	-----	7	µg/L	0.4 U	0.4 U
BROMODICHLOROMETHANE	-----	0.5	µg/L	0.4 U	0.4 U
DIBROMOCHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U
BROMOFORM	-----	5	µg/L	0.4 U	0.4 U
ACETONE	-----	-----	µg/L	0.4 U	0.4 U
2-BUTANONE	-----	-----	µg/L	0.4 U	0.4 U
2-HEXANONE	-----	-----	µg/L	0.4 U	0.4 U
4-METHYL-2-PENTANONE	-----	-----	µg/L	0.4 U	0.4 U
CARBON DISULFIDE	-----	-----	µg/L	0.4 U	0.4 U
2-CHLORO VINYL ETHER	-----	-----	µg/L	0.4 U	0.4 U
ACRYLONITRILE	-----	0.07	µg/L	0.4 U	0.4 U
ALLYL CHLORIDE	-----	-----	µg/L	0.4 U	0.4 U
1-CHLOROBUTANE	-----	-----	µg/L	0.4 U	0.4 U
TRANS-1,4-DICHLORO-2-BUTENE	-----	-----	µg/L	0.4 U	0.4 U
DIETHYL ETHER	-----	-----	µg/L	0.4 U	0.4 U
ETHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U
HEXACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U
IODOMETHANE	-----	-----	µg/L	0.4 U	0.4 U
METHACRYLONITRILE	-----	-----	µg/L	0.4 U	0.4 U
METHYL ACRYLATE	-----	-----	µg/L	0.4 U	0.4 U
METHYL-t-BUTYL-ETHER	-----	-----	µg/L	0.4 U	0.4 U

(Table Continues)

Table 4-4a. October 2010 Baseline Interior Monitoring Well Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-2	MW-4
VOLATILE ORGANIC COMPOUNDS (Continued)					
METHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U
NITROBENZENE	-----	-----	µg/L	0.4 U	0.4 U
2-NITROPROPANE	-----	-----	µg/L	0.4 U	0.4 U
PENTACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U
VINYL ACETATE	-----	-----	µg/L	NA	NA

▨ Concentration exceeds State Drinking Water Standards or Groundwater Standards

Standards:

WAC 246-290-310

WAC 173-200-040

* Primary Standard

** Secondary Standard

*** Action level for corrosion control for copper and lead. Recommended level of concern for consumers with restricted daily sodium intake.

Data Qualifiers:

U = Indicates compound was analyzed for, but not detected at the specified detection limit.

J = Estimated value - Compound positively identified, but below specified detection limit.

NA = Not Analyzed

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Table 4-4b. October 2010 Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1		MW-2		MW-3		MW-4		MW-5A		MW-6		MW-7		MW-9 (FD)		MW-8		MW-10	
CONVENTIONALS																							
ALKALINITY	-----	-----	mg/L	64.4		57.5		209		63.5		79.4		259		67.6		209		206		257	
AMMONIA NITROGEN	-----	-----	mg/L	0.010	U	0.010	U	0.010	U	0.010	U	0.010	U	0.018		0.010	U	0.010	U	0.016		0.024	
BICARBONATE	-----	-----	mg/L	45.1		51.3		132		57.9		59.3		196		56.7		114		163		197	
CARBONATE	-----	-----	mg/L	1.0	U	1.0	U	1.0	U	1.0	U	1.0	U	1.0	U	1.0	U	1.0	U	1.0	U	1.0	U
CHEMICAL OXYGEN DEMAND	-----	-----	mg/L	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U	12.3		10.0	U	10.0	U
CHLORIDE	250**	250**	mg/L	2.64		2.01		2.64		2.40		1.92		2.01		1.37		2.64		1.96		0.88	
DISSOLVED OXYGEN (field)	-----	-----	mg/L	9.76		8.75		0.40		8.23		9.25		0.30		5.55		NA		0.15		0.46	
FECAL COLIFORM	-----	-----	#/100 mL	2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U
FLOW RATE (PURGE RATE)	-----	-----	mL/min.	450		300		440		300		500		500		420		NA		400		450	
NITRATE NITROGEN	10*	10*	mg/L	0.126		0.347		0.033		0.470		0.341		0.010	U	0.615		0.033		0.010	U	0.010	U
NITRITE NITROGEN	1*	-----	mg/L	0.003		0.002	U	0.002	U	0.002	U	0.002	U	0.002		0.002	U	0.002	U	0.003		0.002	U
ORP	-----	-----	mV	16.3		128		199		137		175		9.0		148		NA		63		135	
pH (field)	-----	6.5-8.5**	-log H+	**6.3**		7.0		**6.2**		7.1		6.6		6.5		6.8		NA		6.5		6.5	
pH (laboratory)	-----	6.5-8.5**	-log H+	6.7		7.3		6.6		7.4		6.8		6.9		7.1		**6.4**		6.9		6.9	
SPECIFIC CONDUCTANCE	700**	-----	umhos/cm	150		132		427		143		173		515		153		NA		374		499	
SULFATE	250**	250**	mg/L	3.80		2.83		9.56		2.48		3.74		18.7		4.38		10.4		6.35		21.5	
TEMPERATURE	-----	-----	°C	10.5		14.1		13.5		14.3		13.4		12.3		12.9		NA		12.7		12.1	
TOTAL DISSOLVED SOLIDS	-----	-----	mg/L	90.5		111		239		112		112		270		97.5		288		224		299	
TOTAL COLIFORM	1/100 mL*	1/100 mL*	#/100 mL	**30**		**52**		2	U	**4**		**4**		2	U	2	U	2	U	**62**		2	U
TOTAL ORGANIC CARBON	-----	-----	mg/L	0.338		0.250	U	1.81		0.250	U	0.250	U	1.93		0.436		2.11		1.42		2.83	
TURBIDITY	-----	-----	NTU	39.3		22.1		0.4		2.7		17.0		6.4		8.5		NA		22.3		9.5	
DISSOLVED METALS																							
ARSENIC	10*	0.05*	µg/L	**0.094**		**0.687**		**0.184**		**0.226**		**0.153**		**1.17**		**0.345**		**0.179**		**2.770**		**2.370**	
ANTIMONY	6*	-----	µg/L	2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U
BARIUM	2,000*	1,000*	µg/L	5	U	5	U	14		5	U	5		18		5	U	14		14		15	
BERYLLIUM	4*	-----	µg/L	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U
CADMIUM	5*	10*	µg/L	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U
CALCIUM	-----	-----	µg/L	11,500		8,270		43,000		9,330		11,600		39,300		10,400		42,100		35,400		41,000	
CHROMIUM	100*	50*	µg/L	4.3		3.6		1	U	3.0		3.1		3.1		3.2		1	U	1	U	1	U
COBALT	-----	-----	µg/L	10	U	10	U	10	U	10	U	10	U	38		10	U	10	U	10	U	10	U
COPPER	1,300***	1,000**	µg/L	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1.7	

Table 4-4b. October 2010 Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1		MW-2		MW-3		MW-4		MW-5A		MW-6		MW-7		MW-9 (FD)		MW-8		MW-10	
DISSOLVED METALS (Continued)																							
IRON	300**	300**	µg/L	25		10	U	23		10	U	10	U	**2,150**		16		25		215		37	
LEAD	15***	50*	µg/L	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U
MAGNESIUM	-----	-----	µg/L	5,710		6,030		14,100		6,690		8,740		23,100		7,370		13,800		16,700		21,900	
MANGANESE	50**	50**	µg/L	10	U	10	U	**1,300**		10	U	10	U	**745**		10	U	**1,280**		**2,160**		**5,310**	
MERCURY	2*	2*	µg/L	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U
NICKEL	100	-----	µg/L	28.8		5	U	5	U	5	U	5	U	5	U	5	U	5	U	8.7		19.9	
POTASSIUM	-----	-----	µg/L	712		1,030		951		874		821		1,930		825		927		1,760		1,360	
SELENIUM	50*	-----	µg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
SILVER	100**	50*	µg/L	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U	1	U
SODIUM	20,000***	-----	µg/L	4,500		4,530		10,900		4,720		5,030		11,700		4,770		11,200		11,000		14,800	
THALLIUM	2*	-----	µg/L	2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U	2	U
TIN	-----	-----	µg/L	40	U	40	U	40	U	40	U	40	U	40	U	40	U	40	U	40	U	40	U
VANADIUM	-----	-----	µg/L	30	U	3.8		30	U	30	U	30	U	30	U	30	U	30	U	30	U	30	U
ZINC	5,000**	5000**	µg/L	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U
VOLATILE ORGANIC COMPOUNDS																							
VINYL CHLORIDE by SIM	2	0.02	µg/L	0.02	U	0.02	U	**0.03**		0.02	U	0.02	U	**0.04**		0.02	U	**0.03**		**0.16**		**0.06**	
BROMOBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMOCHLOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMOMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
N-BUTYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
SEC-BUTLYBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TERT-BUTLYBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CARBON TETRACHLORIDE	5	0.3	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROBENZENE	100	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	**0.4**		0.4	U	0.4	U	0.4	U	0.4	U
CHLOROETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2-CHLOROTOLUENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
4-CHLOROTOLUENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DIBROMO-3-CHLOROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DIBROMOETHANE	-----	0.001	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
DIBRROMOETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U

Table 4-4b. October 2010 Groundwater Quality Data Summary

	State Drinking Water Standards (a)	**State Ground-water Standards (b)**	**Units**	**MW-1**	**MW-2**	**MW-3**	**MW-4**	**MW-5A**	**MW-6**	**MW-7**	**MW-9 (FD)**	**MW-8**	**MW-10**
VOLATILE ORGANIC COMPOUNDS (Continued)													
1,2-DICHLOROBENZENE	600	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,3-DICHLOROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,4-DICHLOROBENZENE	75	4	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
DICHLORODIFLUOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1-DICHLOROETHANE	-----	1	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2-DICHLOROETHANE	5	0.5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1-DICHLOROETHENE	7	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CIS-1,2-DICHLOROETHENE	70	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRANS-1,2-DICHLOROETHENE	100	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2-DICHLOROPROPANE	5	0.6	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,3-DICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2,2-DICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1-DICHLOROPROPENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CIS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	**0.2 J**	0.4 U
TRANS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
HEXACHLOROBUTADIENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ISOPROPYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
4-ISOPROPYLTOLUENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYLENE CHLORIDE	5	5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
NAPHTHALENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
N-PROPYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
STYRENE	100	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1,1,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1,2,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TETRACHLOROETHENE	5	0.8	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2,3-TRICHLOROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2,4-TRICHLOROBENZENE	70	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1,1-TRICHLOROETHANE	200	200	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1,2-TRICHLOROETHANE	5	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRICHLOROETHENE	5	3	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRICHLOROFLUOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U

Table 4-4b. October 2010 Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-9 (FD)	MW-8	MW-10
VOLATILE ORGANIC COMPOUNDS (Continued)													
1,2,3-TRICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2,4-TRIMETHYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,3,5-TRIMETHYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
VINYL CHLORIDE by SIM	2	0.02	µg/L	0.02 U	0.02 U	**0.03**	0.02 U	0.02 U	**0.04**	0.02 U	**0.03**	**0.16**	**0.06**
BENZENE	5	1	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TOLUENE	1000	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ETHYLBENZENE	700	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
P/M-XYLENE	10	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
O-XYLENE	10	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CHLOROFORM	-----	7	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
BROMODICHLOROMETHANE	-----	0.5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
DIBROMOCHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
BROMOFORM	-----	5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ACETONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-BUTANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-HEXANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
4-METHYL-2-PENTANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CARBON DISULFIDE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-CHLORO VINYL ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ACRYLONITRILE	-----	0.07	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ALLYL CHLORIDE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1-CHLOROBUTANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRANS-1,4-DICHLORO-2-BUTENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
DIETHYL ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ETHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
HEXACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
IODOMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHACRYLONITRILE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYL ACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYL-t-BUTYL-ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U

Table 4-4b. October 2010 Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-9 (FD)	MW-8	MW-10
VOLATILE ORGANIC COMPOUNDS (Continued)													
NITROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-NITROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
PENTACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U

▨ Concentration exceeds State Drinking Water Standards or Groundwater Standards

Subsample: FD = Field Duplicate of MW-3 labeled MW-9
Standards: All Standards listed for VOCs are Primary Standards WAC 246-290-310 WAC 173-200-040
U = Indicates compound was analyzed for, but not detected at the specified detection limit.
J = Estimated value - Compound positively identified, but below specified detection limit.
NA = Not Analyzed

Table 4-4c. December 2010 Groundwater and Surface Water Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-17 (FD)	MW-8	MW-10	SW-2	SW-3	SW-4
CONVENTIONALS																
ALKALINITY	-----	-----	mg/L	66.3	58.1	178	60.6	103	75.0	51.8	75.4	50.2	196	18.3	6.18	15.8
AMMONIA NITROGEN	-----	-----	mg/L	0.010 U	0.010 U	0.010 U	0.010 U	0.010 U	0.011	0.010 U	0.014	0.017	0.022	0.010 U	0.010 U	0.010 U
BICARBONATE	-----	-----	mg/L	35.5	48.1	69.7	51.9	62.2	48.0	35.8	47.0	35.9	122.0	15.9	2.91	11.5
CARBONATE	-----	-----	mg/L	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
CHEMICAL OXYGEN DEMAND	-----	-----	mg/L	10.0 U	86.5	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	24.2	17.8	25.5
CHLORIDE	250**	250**	mg/L	2.40	1.76	2.59	2.54	1.86	0.98	1.37	1.08	1.17	0.88	1.56	2.15	1.76
DISSOLVED OXYGEN (field)	-----	-----	mg/L	10.45	10.15	4.68	9.36	9.52	4.28	8.41	NA	8.10	4.11	13.24	11.43	12.64
FECAL COLIFORM	-----	-----	#/100 mL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4	46	1
FLOW RATE (PURGE RATE)	-----	-----	mL/min.	500	420	490	420	480	500	500	NA	440	300	228000	228,000	30000
NITRATE NITROGEN	10*	10*	mg/L	0.122	0.369	0.373	0.550	0.441	0.010 U	0.594	0.010 U	0.424	0.010 U	0.010 U	0.171	0.227
NITRITE NITROGEN	1*	-----	mg/L	0.002 U	0.002	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.003	0.002 U	0.003	0.002	0.003
ORP	-----	-----	mV	129	64	170	55	121	-24	81	NA	6	135	196	168	178
pH (field)	-----	6.5-8.5**	-log H+	**6.4**	7.1	**6.2**	7.1	6.6	6.6	6.8	NA	6.8	6.5	**5.7**	**6.1**	**6.0**
pH (laboratory)	-----	6.5-8.5**	-log H+	**6.4**	7.0	**6.2**	7.1	6.5	6.6	6.7	6.6	6.8	6.6	7.2	**6.3**	6.8
SPECIFIC CONDUCTANCE	700**	-----	umhos/cm	130	114	358	127	194	163	129	NA	101	352	53	310	490
SULFATE	250**	250**	mg/L	3.69	3.34	17.10	3.02	3.18	9.90	3.50	10.30	3.02	14.2	1.00 U	1.00 U	1.00 U
TEMPERATURE	-----	-----	°C	12.6	13.7	12.5	13.9	13.5	12.7	12.1	NA	12.8	12.4	6.6	6.7	6.7
TOTAL COLIFORM	1/100 mL*	1/100 mL*	#/100 mL	1 U	1 U	1 U	**10**	1 U	1 U	1 U	1 U	1 U	1U	NA	NA	NA
TOTAL ORGANIC CARBON	-----	-----	mg/L	0.250 U	0.429	2.31	0.250 U	0.328	2.58	0.358	2.62	0.607	2.86	7.95	5.83	8.55
TURBIDITY	-----	-----	NTU	0.4	8.6	NA	0.3	<0.1	NA	NA	NA	<0.1	0.3	115.0	127.0	20.0
DISSOLVED METALS																
ARSENIC	10*	0.05*	µg/L	**0.098**	**0.652**	**0.107**	**0.216**	**0.160**	**0.983**	**0.318**	**0.979**	**1.87**	**1.05**	**0.737**	**0.230**	**0.566**
BARIUM	2,000*	1,000*	µg/L	5 U	5 U	9	5 U	5 U	5 U	5 U	5 U	5 U	7	7	6	5
CALCIUM	-----	-----	µg/L	9,930	7,240	35,900	8,190	12,100	12,300	9,300	12,000	9,640	30,100	6,810	2,550	6,550
IRON	300**	300**	µg/L	20 U	20 U	20 U	20 U	20 U	298	20 U	268	180	20 U	87	91	105
MANGANESE	50**	50**	µg/L	5 U	5 U	**1,100**	5 U	5 U	**713**	5 U	**698**	**631**	**3,340**	5 U	7	5
POTASSIUM	-----	-----	µg/L	708	1,060	907	882	915	991	806	973	677	1,120	500 U	500 U	500 U
SODIUM	20,000***	-----	µg/L	4,270	4,320	8,210	4,540	5,360	6,510	4,290	6,380	4,360	9,510	2,280	1,710	2,110
ZINC	5,000**	5,000**	µg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	18	6	19

Table 4-4c. December 2010 Groundwater and Surface Water Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-17 (FD)	MW-8	MW-10	SW-2	SW-3	SW-4
VOLATILE ORGANIC COMPOUNDS																
VINYL CHLORIDE by SIM	2	0.02	µg/L	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
BROMOBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
BROMOCHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
BROMOMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
N-BUTYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
SEC-BUTLYBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TERT-BUTLYBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CARBON TETRACHLORIDE	5	0.3	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CHLOROBENZENE	100	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.8	0.4 U	0.7	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-CHLOROTOLUENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
4-CHLOROTOLUENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2-DIBROMO-3-CHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2-DIBROMOETHANE	-----	0.001	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
DIBRROMOETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2-DICHLOROBENZENE	600	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,3-DICHLOROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,4-DICHLOROBENZENE	75	4	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
DICHLORODIFLUOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1-DICHLOROETHANE	-----	1	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2-DICHLOROETHANE	5	0.5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1-DICHLOROETHENE	7	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CIS-1,2-DICHLOROETHENE	70	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRANS-1,2-DICHLOROETHENE	100	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2-DICHLOROPROPANE	5	0.6	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,3-DICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2,2-DICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1-DICHLOROPROPENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CIS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRANS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U

Table 4-4c. December 2010 Groundwater and Surface Water Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-17 (FD)	MW-8	MW-10	SW-2	SW-3	SW-4
HEXACHLOROBUTADIENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
VOLATILE ORGANIC COMPOUNDS (Continued)																
ISOPROPYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
4-ISOPROPYLTOLUENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYLENE CHLORIDE	5	5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
NAPHTHALENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
N-PROPYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
STYRENE	100	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1,1,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1,2,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TETRACHLOROETHENE	5	0.8	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2,3-TRICHLOROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2,4-TRICHLOROBENZENE	70	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1,1-TRICHLOROETHANE	200	200	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,1,2-TRICHLOROETHANE	5	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRICHLOROETHENE	5	3	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRICHLOROFLUOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2,3-TRICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,2,4-TRIMETHYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1,3,5-TRIMETHYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
VINYL CHLORIDE by SIM	2	0.02	µg/L	0.02 U	0 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
BENZENE	5	1	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TOLUENE	1000	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ETHYLBENZENE	700	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
P/M-XYLENE	10	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
O-XYLENE	10	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
CHLOROFORM	-----	7	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
BROMODICHLOROMETHANE	-----	0.5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
DIBROMOCHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
BROMOFORM	-----	5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ACETONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-BUTANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U

Table 4-4c. December 2010 Groundwater and Surface Water Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-17 (FD)	MW-8	MW-10	SW-2	SW-3	SW-4
2-HEXANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
4-METHYL-2-PENTANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
VOLATILE ORGANIC COMPOUNDS (Continued)																
CARBON DISULFIDE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-CHLORO VINYL ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ACRYLONITRILE	-----	0.07	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ALLYL CHLORIDE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1-CHLOROBUTANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRANS-1,4-DICHLORO-2-BUTENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
DIETHYL ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ETHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
HEXACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
IODOMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHACRYLONITRILE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYL ACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYL-t-BUTYL-ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
NITROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-NITROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
PENTACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U

▨ Concentration exceeds State Drinking Water Standards or Groundwater Standards

Subsample: FD = Field Duplicate of MW-6 labeled MW-17, incorrectly assigned sample number OL-MW-6-1 in field notes and lab data sheets.
Standards: All Standards listed for VOCs are Primary Standards WAC 246-290-310 WAC 173-200-040
U = Indicates compound was analyzed for, but not detected at the specified detection limit.
J = Estimated value - Compound positively identified, but below specified detection limit.
NA = Not Analyzed

Table 4-4d. March 2011 Groundwater and Surface Water Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-11 (FD)	MW-8	MW-10	SW-3	SW-4
CONVENTIONALS															
ALKALINITY	-----	-----	mg/L	60.8	55.2	134	68.1	72.7	67.5	67.0	65.1	59.0	257	NA	NA
AMMONIA NITROGEN	-----	-----	mg/L	0.010 U	0.010 U	0.010 U	0.010 U	0.010 U	0.010 U	0.012	0.010 U	0.010 U	0.017	0.010 U	0.010 U
BICARBONATE	-----	-----	mg/L	38.3	47.3	67.8	59.1	57.3	53.2	54.3	52.2	48.4	162	NA	NA
CARBONATE	-----	-----	mg/L	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	NA	NA
CHEMICAL OXYGEN DEMAND	-----	-----	mg/L	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	NA	NA
CHLORIDE	250**	250**	mg/L	2.64	2.15	2.74	2.54	2.05	1.25	1.25	1.27	1.17	3.07	NA	NA
DISSOLVED OXYGEN (field)	-----	-----	mg/L	10.99	10.50	0.00	9.45	11.61	0.00	5.90	NA	4.88	0.00	13.60	13.23
FECAL COLIFORM	-----	-----	#/100 mL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	2 U
FLOW RATE (PURGE RATE)	-----	-----	mL/min.	450	420	420	300	300	350	390	NA	410	390	3800	300
NITRATE NITROGEN	10*	10*	mg/L	0.254	0.389	0.200	0.536	0.192	0.011	0.549	0.550	0.131	0.292	0.080	0.147
NITRITE NITROGEN	1*	-----	mg/L	0.002 U	0.002 U	0.003	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002	0.002
ORP	-----	-----	mV	137	72	161	79	92	-32	104	NA	39	93	133	129
pH (field)	-----	6.5-8.5**	-log H+	**6.0**	6.7	**5.9**	6.8	6.5	**6.4**	**6.2**	NA	6.5	**6.3**	6.8	6.8
pH (laboratory)	-----	6.5-8.5**	-log H+	6.6	7.1	**6.4**	7.2	6.9	6.9	7.0	7.0	7.0	6.6	NA	NA
SPECIFIC CONDUCTANCE	700**	-----	umhos/cm	234	197	**709**	244	275	291	298	NA	190	**999**	61	77
SULFATE	250**	250**	mg/L	4.03	2.62	49.2	2.46	3.82	5.84	3.08	4.32	1.42	27.0	NA	NA
TEMPERATURE	-----	-----	°C	13.7	13.4	12.5	14.5	13.4	12.7	11.8	NA	11.7	12.4	11.1	9.4
TOTAL DISSOLVED SOLIDS	-----	-----	mg/L	85.0	100	212	101	148	109	109	103	118	326	NA	NA
TOTAL COLIFORM	1/100 mL*	1/100 mL*	#/100 mL	2 U	**2**	2 U	**4**	2 U	2 U	2 U	2 U	2 U	2 U	NA	NA
TOTAL ORGANIC CARBON	-----	-----	mg/L	0.250 U	0.250 U	1.28	0.250 U	0.250 U	1.14	0.370	0.400	0.250 U	3.04	NA	NA
TURBIDITY	-----	-----	NTU	<1	<1	61.1	9.45	<1	37.1	<1	NA	4.88	0.00	<1	<1
DISSOLVED METALS															
ARSENIC	10*	0.05*	µg/L	**0.082**	**0.517**	**0.087**	**0.188**	**0.113**	**0.689**	**0.327**	**0.349**	**1.49**	**1.03**	NA	NA
ANTIMONY	6*	-----	µg/L	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	NA	NA
BARIUM	2,000*	1,000*	µg/L	5 U	5 U	12	5 U	5 U	5 U	5 U	5 U	5 U	16	NA	NA
BERYLLIUM	4*	-----	µg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	NA	NA
CADMIUM	5*	10*	µg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	NA	NA
CALCIUM	-----	-----	µg/L	8,960	6,760	31,700	8,540	8,730	8,880	8,690	8,860	9,280	39,300	NA	NA

Table 4-4d. March 2011 Groundwater and Surface Water Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-11 (FD)	MW-8	MW-10	SW-3	SW-4
DISSOLVED METALS (Continued)															
CHROMIUM	100	50	µg/L	2.3	3.4	1.4	2.4	3.6	1 U	3.5	3.4	1.3	2.0	NA	NA
COBALT	-----	-----	µg/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	NA	NA
COPPER	1,300***	1,000**	µg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	NA	NA
IRON	300**	300**	µg/L	20 U	20 U	20 U	20 U	20 U	**316**	20 U	20 U	20 U	84	NA	NA
LEAD	15***	50*	µg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	NA	NA
MAGNESIUM	-----	-----	µg/L	5,840	6,010	11,700	7,640	8,450	6,430	7,000	7,210	4,690	24,800	NA	NA
MANGANESE	50**	50**	µg/L	10 U	10 U	**1,330**	10 U	10 U	**412**	10 U	10 U	**143**	**4,850**	NA	NA
MERCURY	2*	2*	µg/L	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	NA	NA
NICKEL	100	-----	µg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	22.7	NA	NA
POTASSIUM	-----	-----	µg/L	711	1,060	871	942	811	890	818	821	680	1,440	NA	NA
SELENIUM	50*	-----	µg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	NA	NA
SILVER	100**	50*	µg/L	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	NA	NA
SODIUM	20,000***	-----	µg/L	4,050	4,020	6,440	4,540	4,490	4,820	3,830	3,830	4,110	10,800	NA	NA
THALLIUM	2*	-----	µg/L	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	NA	NA
TIN	-----	-----	µg/L	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	NA	NA
VANADIUM	-----	-----	µg/L	3 U	4.0	3 U	3.2	3.0	3 U	3 U	3 U	3 U	3 U	NA	NA
ZINC	5,000**	5,000**	µg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	NA	NA
VOLATILE ORGANIC COMPOUNDS															
VINYL CHLORIDE by SIM	2	0.02	µg/L	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
BROMOBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
BROMOCHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
BROMOMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
N-BUTYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
SEC-BUTLYBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
TERT-BUTLYBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
CARBON TETRACHLORIDE	5	0.3	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
CHLOROBENZENE	100	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
CHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
CHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
2-CHLOROTOLUENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA

Table 4-4d. March 2011 Groundwater and Surface Water Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-11 (FD)	MW-8	MW-10	SW-3	SW-4
VOLATILE ORGANIC COMPOUNDS (Continued)															
4-CHLOROTOLUENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,2-DIBROMO-3-CHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,2-DIBROMOETHANE	-----	0.001	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
DIBRROMOETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,2-DICHLOROBENZENE	600	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,3-DICHLOROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,4-DICHLOROBENZENE	75	4	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
DICHLORODIFLUOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,1-DICHLOROETHANE	-----	1	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,2-DICHLOROETHANE	5	0.5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,1-DICHLOROETHENE	7	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
CIS-1,2-DICHLOROETHENE	70	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
TRANS-1,2-DICHLOROETHENE	100	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,2-DICHLOROPROPANE	5	0.6	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,3-DICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
2,2-DICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,1-DICHLOROPROPENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
CIS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
TRANS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
HEXACHLOROBUTADIENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
ISOPROPYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
4-ISOPROPYLTOLUENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
METHYLENE CHLORIDE	5	5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
NAPHTHALENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
N-PROPYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
STYRENE	100	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,1,1,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,1,2,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
TETRACHLOROETHENE	5	0.8	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA

Table 4-4d. March 2011 Groundwater and Surface Water Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-11 (FD)	MW-8	MW-10	SW-3	SW-4
VOLATILE ORGANIC COMPOUNDS (Continued)															
1,2,3-TRICHLOROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,2,4-TRICHLOROBENZENE	70	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,1,1-TRICHLOROETHANE	200	200	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,1,2-TRICHLOROETHANE	5	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
TRICHLOROETHENE	5	3	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
TRICHLOROFLUOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,2,3-TRICHLOROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,2,4-TRIMETHYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
1,3,5-TRIMETHYLBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
VINYL CHLORIDE by SIM	2	0.02	µg/L	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	NA	NA
BENZENE	5	1	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
TOLUENE	1000	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
ETHYLBENZENE	700	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
P/M-XYLENE	10	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
O-XYLENE	10	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
CHLOROFORM	-----	7	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
BROMODICHLOROMETHANE	-----	0.5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
DIBROMOCHLOROMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
BROMOFORM	-----	5	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
ACETONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
2-BUTANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
2-HEXANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
4-METHYL-2-PENTANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
CARBON DISULFIDE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
TRANS-1,4-DICHLORO-2-BUTENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
DIETHYL ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
ETHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
HEXACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
IODOMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
METHACRYLONITRILE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
METHYL ACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA

Table 4-4d. March 2011 Groundwater and Surface Water Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-11 (FD)	MW-8	MW-10	SW-3	SW-4
VOLATILE ORGANIC COMPOUNDS (Continued)															
METHYL-t-BUTYL-ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
METHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
NITROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
2-NITROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA
PENTACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	NA	NA

▨ Concentration exceeds State Drinking Water Standards or Groundwater Standards

Subsample: FD = Field Duplicate of MW-7 was labeled MW-11
Standards: All Standards listed for VOCs are Primary Standards WAC 246-290-310 WAC 173-200-040
U = Indicates compound was analyzed for, but not detected at the specified detection limit.
J = Estimated value - Compound positively identified, but below specified detection limit.
NA = Not Analyzed

Table 4-4e. June 2011 Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-9 (FD)	MW-8	MW-10
CONVENTIONALS													
ALKALINITY	-----	-----	mg/L	67.0	53.6	80.9	58.8	54.4	54.0	70.3	81.0	156	306
AMMONIA NITROGEN	-----	-----	mg/L	0.010 U	0.010 U	0.010 U	0.010 U	0.010 U	0.010 U	0.010 U	0.010 U	0.033	0.018
BICARBONATE	-----	-----	mg/L	43.9	46.2	43.2	53.1	46.9	44.1	59.2	43.3	117	199
CARBONATE	-----	-----	mg/L	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U
CHEMICAL OXYGEN DEMAND	-----	-----	mg/L	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U
CHLORIDE	250**	250**	mg/L	2.74	2.15	2.64	2.74	1.76	1.17	0.96	2.64	2.15	6.06
DISSOLVED OXYGEN (field)	-----	-----	mg/L	9.67	8.56	0.00	8.92	9.23	0.00	3.85	NA	0.29	0.00
FECAL COLIFORM	-----	-----	#/100 mL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FLOW RATE (PURGE RATE)	-----	-----	mL/min.	460	400	320	320	360	350	320	NA	400	400
NITRATE NITROGEN	10*	10*	mg/L	0.142	0.415	0.017	0.532	0.247	0.010 U	0.716	0.015	0.065	0.315
NITRITE NITROGEN	1*	-----	mg/L	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002	0.002 U	0.002 U	0.002	0.002 U
ORP	-----	-----	mV	162	163	185	147	140	6	122	NA	26	159
pH (field)	-----	6.5-8.5**	-log H+	**6.4**	6.7	**6.2**	7.1	6.6	6.7	6.9	NA	6.7	6.5
pH (laboratory)	-----	6.5-8.5**	-log H+	6.6	7.2	**6.4**	7.3	7.2	7.0	7.1	**6.4**	6.8	6.6
SPECIFIC CONDUCTANCE	700**	-----	umhos/cm	167	134	234	150	147	141	168	NA	391	**759**
SULFATE	250**	250**	mg/L	12.8	2.67	18.6	18.9	9.07	11.9	15.7	18.8	9.41	53.2
TEMPERATURE	-----	-----	°C	12.6	14.0	12.9	14.2	14.6	12.9	12.8	NA	11.4	11.9
TOTAL DISSOLVED SOLIDS	500**	500**	mg/L	93.5	77.5	94.5	89.0	72.5	68.5	87.5	60.0	164	374
TOTAL COLIFORM	1/100 mL*	1/100 mL*	#/100 mL	1 U	**20**	1 U	1 U	1 U	1 U	**7**	1 U	1 U	1 U
TOTAL ORGANIC CARBON	-----	-----	mg/L	0.250 U	0.250 U	0.467	0.250 U	0.250 U	1.19	0.250 U	0.464	0.512	2.57
TURBIDITY	-----	-----	NTU	8.4	13.9	0.0	6.5	1.5	55.8	26.3	NA	42.2	0.0
DISSOLVED METALS													
ARSENIC	10*	0.05*	µg/L	**0.113**	**0.749**	**0.057**	**0.326**	**0.259**	**0.829**	**0.652**	**0.081**	**1.53**	**1.90**
BARIUM	2,000*	1,000*	µg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	7
CALCIUM	-----	-----	µg/L	11,200	7,530	17,800	8,320	7,490	9,000	9,960	17,900	24,500	53,200
IRON	300**	300**	µg/L	20 U	20 U	20 U	20 U	20 U	238	20 U	20 U	286	20 U
MANGANESE	50**	50**	µg/L	5 U	5 U	**532**	5 U	5 U	**272**	5 U	**527**	**4,470**	**6,240**
POTASSIUM	-----	-----	µg/L	651	912	577	756	572	677	691	567	1,080	1,430
SODIUM	20,000***	-----	µg/L	4,480	4,150	5,460	4,410	3,820	4,320	4,250	5,450	8,160	14,000
ZINC	5,000**	5,000**	µg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U

Table 4-4e. June 2011 Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1		MW-2		MW-3		MW-4		MW-5A		MW-6		MW-7		MW-9 (FD)		MW-8		MW-10	
VOLATILE ORGANIC COMPOUNDS																							
VINYL CHLORIDE by SIM	2*	0.02*	µg/L	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	**0.08**		0.02	
BROMOBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMOCHLOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMOMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
N-BUTYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
SEC-BUTLYBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TERT-BUTLYBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CARBON TETRACHLORIDE	5	0.3	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROBENZENE	100	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2-CHLOROTOLUENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
4-CHLOROTOLUENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DIBROMO-3-CHLOROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DIBROMOETHANE	-----	0.001	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
DIBRROMOETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DICHLOROBENZENE	600	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,3-DICHLOROBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,4-DICHLOROBENZENE	75	4	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
DICHLORODIFLUOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1-DICHLOROETHANE	-----	1	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DICHLOROETHANE	5	0.5	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1-DICHLOROETHENE	7	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CIS-1,2-DICHLOROETHENE	70	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TRANS-1,2-DICHLOROETHENE	100	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DICHLOROPROPANE	5	0.6	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,3-DICHLOROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2,2-DICHLOROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1-DICHLOROPROPENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CIS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TRANS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U

Table 4-4e. June 2011 Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1		MW-2		MW-3		MW-4		MW-5A		MW-6		MW-7		MW-9 (FD)		MW-8		MW-10	
HEXACHLOROBUTADIENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
VOLATILE ORGANIC COMPOUNDS (Continued)																							
ISOPROPYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
4-ISOPROPYLTOLUENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
METHYLENE CHLORIDE	5	5	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
NAPHTHALENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
N-PROPYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
STYRENE	100	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1,1,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1,2,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TETRACHLOROETHENE	5	0.8	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2,3-TRICHLOROBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2,4-TRICHLOROBENZENE	70	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1,1-TRICHLOROETHANE	200	200	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1,2-TRICHLOROETHANE	5	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TRICHLOROETHENE	5	3	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TRICHLOROFLUOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2,3-TRICHLOROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2,4-TRIMETHYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,3,5-TRIMETHYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
VINYL CHLORIDE by SIM	2	0.02	µg/L	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	**0.08**		0.02	
BENZENE	5	1	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TOLUENE	1000	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
ETHYLBENZENE	700	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
P/M-XYLENE	10	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
O-XYLENE	10	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROFORM	-----	7	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMODICHLOROMETHANE	-----	0.5	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
DIBROMOCHLOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMOFORM	-----	5	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
ACETONE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2-BUTANONE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U

Table 4-4e. June 2011 Groundwater Quality Data Summary

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	MW-1	MW-2	MW-3	MW-4	MW-5A	MW-6	MW-7	MW-9 (FD)	MW-8	MW-10
2-HEXANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
4-METHYL-2-PENTANONE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
VOLATILE ORGANIC COMPOUNDS (Continued)													
CARBON DISULFIDE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-CHLORO VINYL ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ACRYLONITRILE	-----	0.07	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ALLYL CHLORIDE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
1-CHLOROBUTANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
TRANS-1,4-DICHLORO-2-BUTENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
DIETHYL ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
ETHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
HEXACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
IODOMETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHACRYLONITRILE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYL ACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYL-t-BUTYL-ETHER	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
METHYL METHACRYLATE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
NITROBENZENE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
2-NITROPROPANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
PENTACHLOROETHANE	-----	-----	µg/L	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U

▨ Concentration exceeds State Drinking Water Standards or Groundwater Standards

Subsample: FD = Field Duplicate of MW-3 was labeled MW-9.
Standards: All Standards listed for VOCs are Primary Standards WAC 246-290-310 WAC 173-200-040
U = Indicates compound was analyzed for, but not detected at the specified detection limit.
J = Estimated value - Compound positively identified, but below specified detection limit.
NA = Not Analyzed

Table 4-5. Summary of Water Supply Well Sampling Results

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	OW-1		OW-2		OW-3		OW-4		OW-5		OW-9	
CONVENTIONALS															
DISSOLVED OXYGEN (field)	-----	-----	mg/L	9.51		8.91		<0.1		3.83		<0.1		4.50	
pH (field)	-----	6.5-8.5**	-log H+	8.0		7.1		7.0		8.3		7.0		7.1	
SPECIFIC CONDUCTANCE (field)	700**	-----	umhos/cm	165		421		377		122		386		180	
TEMPERATURE (field)	-----	-----	°C	8.1		9.9		6.5		10.5		9.8		11.1	
DISSOLVED METALS															
ARSENIC	10*	0.05*	µg/L	**0.719**		**0.215**		**7.04**		**1.68**		**0.535**		**0.253**	
IRON	300**	300**	µg/L	20	U	20	U	**572**		106		54		71	
MANGANESE	50**	50**	µg/L	5	U	5	U	**59**		32		38		5	U
VOLATILE ORGANIC COMPOUNDS															
VINYL CHLORIDE by SIM	2*	0.02*	µg/L	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U
BROMOBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMOCHLOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMOMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
N-BUTYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
SEC-BUTLYBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TERT-BUTLYBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CARBON TETRACHLORIDE	5	0.3	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROBENZENE	100	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2-CHLOROTOLUENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
4-CHLOROTOLUENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DIBROMO-3-CHLOROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DIBROMOETHANE	-----	0.001	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
DIBRROMOETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DICHLOROBENZENE	600	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,3-DICHLOROBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,4-DICHLOROBENZENE	75	4	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
DICHLORODIFLUOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1-DICHLOROETHANE	-----	1	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DICHLOROETHANE	5	0.5	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U

Table 4-5. Summary of Water Supply Well Sampling Results

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	OW-1		OW-2		OW-3		OW-4		OW-5		OW-9	
VOLATILE ORGANIC COMPOUNDS (Continued)															
1,1-DICHLOROETHENE	7	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CIS-1,2-DICHLOROETHENE	70	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TRANS-1,2-DICHLOROETHENE	100	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2-DICHLOROPROPANE	5	0.6	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,3-DICHLOROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2,2-DICHLOROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1-DICHLOROPROPENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CIS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TRANS-1,3-DICHLOROPROPENE	-----	0.2	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
HEXACHLOROBUTADIENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
ISOPROPYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
4-ISOPROPYLTOLUENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
METHYLENE CHLORIDE	5	5	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
NAPHTHALENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
N-PROPYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
STYRENE	100	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1,1,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1,2,2-TETRACHLOROETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TETRACHLOROETHENE	5	0.8	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2,3-TRICHLOROBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2,4-TRICHLOROBENZENE	70	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1,1-TRICHLOROETHANE	200	200	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,1,2-TRICHLOROETHANE	5	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TRICHLOROETHENE	5	3	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TRICHLOROFLUOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2,3-TRICHLOROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,2,4-TRIMETHYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1,3,5-TRIMETHYLBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
VINYL CHLORIDE by SIM	2	0.02	µg/L	0	U	0	U	0	U	0	U	0	U	0	U
BENZENE	5	1	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TOLUENE	1000	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U

Table 4-5. Summary of Water Supply Well Sampling Results

	State Drinking Water Standards (a)	State Ground-water Standards (b)	Units	OW-1		OW-2		OW-3		OW-4		OW-5		OW-9	
VOLATILE ORGANIC COMPOUNDS (Continued)															
ETHYLBENZENE	700	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
P/M-XYLENE	10	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
O-XYLENE	10	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CHLOROFORM	-----	7	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMODICHLOROMETHANE	-----	0.5	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
DIBROMOCHLOROMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
BROMOFORM	-----	5	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
ACETONE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2-BUTANONE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2-HEXANONE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
4-METHYL-2-PENTANONE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
CARBON DISULFIDE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2-CHLORO VINYL ETHER	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
ACRYLONITRILE	-----	0.07	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
ALLYL CHLORIDE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
1-CHLOROBUTANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
TRANS-1,4-DICHLORO-2-BUTENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
DIETHYL ETHER	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
ETHYL METHACRYLATE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
HEXACHLOROETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
IODOMETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
METHACRYLONITRILE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
METHYL ACRYLATE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
METHYL-t-BUTYL-ETHER	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
METHYL METHACRYLATE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
NITROBENZENE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
2-NITROPROPANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U
PENTACHLOROETHANE	-----	-----	µg/L	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U	0.4	U

▨ Concentration exceeds State Drinking Water Standards or Groundwater Standards

Standards: All Standards listed for VOCs are Primary Standards WAC 246-290-310 WAC 173-200-040

U = Indicates compound was analyzed for, but not detected at the specified detection limit.

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Table 7-1: Summary of Landfill Gas Field Measurements

October 15, 2010	**Flare #1**	**Flare #2**	**Flare #3**
METHANE, (% LEL)	0	240	8
METHANE, (% Volume)	0.0	12.0	0.4
OXYGEN, (%)	20.1	0.8	17.8
CARBON DIOXIDE, (%)	0.8	13.6	2.7
GAS TEMPERATURE, (°F)	55	55	57
PRESSURE (inches of water column)	0.0	0.0	0.0
AMBIENT TEMPERATURE, (°F)	52	52	52
December 28, 2010			
METHANE, (% LEL)	380	418	482
METHANE, (% Volume)	19.0	20.9	24.1
OXYGEN, (%)	0.5	0.4	0.9
CARBON DIOXIDE, (%)	9.3	9.6	3.6
GAS TEMPERATURE, (°F)	NM	NM	NM
PRESSURE (inches of water column)	10.3	0.3	0.2
AMBIENT TEMPERATURE, (°F)	40	40	40
March 23, 2011			
METHANE, (% LEL)	550	668	598
METHANE, (% Volume)	27.5	33.4	29.9
OXYGEN, (%)	4.7	1.7	1.3
CARBON DIOXIDE, (%)	6.8	7.9	7.8
GAS TEMPERATURE, (°F)	NM	NM	NM
PRESSURE (inches of water column)	10.2	10.2	10.5
AMBIENT TEMPERATURE, (°F)	50	50	50
June 1, 2011			
METHANE, (% LEL)	608	782	652
METHANE, (% Volume)	30.4	39.1	32.6
OXYGEN, (%)	1.6	1.0	1.5
CARBON DIOXIDE, (%)	8.8	8.6	8.6
GAS TEMPERATURE, (°F)	NM	NM	NM
PRESSURE (inches of water column)	0.1	0.0	0.0
AMBIENT TEMPERATURE, (°F)	58	58	58

NM = Not Measured.

Table 7-2. Summary of Detected Compounds – Landfill Gas Samples

	Concentration (μg/m3)			
Detected Constituent	**Flare No. 1**	**Flare No. 2**	**Flare No. 3**	**MTCA Method B Standard Formula Value**
Freon 11	11	94	36	320
Freon 12	6.6	190	24	91
Freon 114	ND	180	26	none
Acetone	28	110	19	none
Heptane	44	260	37	none
Hexane	ND	120	ND	320
Toluene	22	45	22	2,300

Notes:

Modified EPA Method TO-15 GC/MS Full Scan

ND = Not Detected

ug/m3 = micrograms per cubic meter

Samples collected 10/15/10

Only detected constituents are shown

Table 9-1. Potential Applicable or Relevant and Appropriate Requirements (ARARs)

ARAR	Description	Applicability
Soil		
Model Toxics Control Act (WAC 173-340-740, -747)	MTCA regulates the investigation and cleanup of releases to the environment that may pose a threat to human health or the environment. Establishes cleanup levels for soil, including derivation of soil concentrations protective of groundwater.	MTCA cleanup levels are applicable to Landfill soil outside the area of refuse containment.
Groundwater		
EPA Underground Injection Control Regulations (40 Code of Federal Regulations [CFR] 144 and 146)	Regulates injections of underground sources of drinking water by specific classes of injection wells.	Relevant to use of any remediation technologies that involve injections into drinking water aquifer.
Safe Drinking Water Act, Primary Drinking Water Regulations (40 CFR 141)	These regulations protect the quality of public drinking water supplies through regulation of chemical parameters and constituent concentrations as maximum contaminant levels (MCLs).	MCLs are potentially relevant and appropriate where groundwater is a potential source of drinking water.
Water Quality Standards for Groundwaters of the State of Washington (WAC 173-200)	Groundwaters in the state of Washington support many different beneficial uses. The purpose of these criteria is to establish maximum contaminant concentrations for the protection of a variety of beneficial uses of Washington's groundwater.	The requirements of WAC 173-200 are potentially relevant to all groundwater of the state that occurs in a saturated zone or stratum beneath the surface of land or below a surface water body.
Model Toxics Control Act (WAC 173-340-720)	MTCA regulates the investigation and cleanup of releases to the environment that may pose a threat to human health or the environment. Establishes cleanup levels for groundwater.	MTCA cleanup levels are applicable to Landfill groundwater. WAC 173-200-010(3)(c) states that clean up actions approved by the department (Ecology) under MTCA are not subject to the water quality standards for ground waters of the State of Washington contained within Chapter 173-200 WAC.
State Water Code and Water Rights (WAC 173-150 & 154)	Establishes rights of well owners to have adequate water supplies and establishes permit program for groundwater withdrawal.	Applies to groundwater extraction.
Surface Water		
Clean Water Act Section 304 – Federal Ambient Water Quality (National Recommended Water Quality Criteria, November 2002) (EPA-822-R-02-047)	Provides chemical concentrations for acceptable ambient water quality.	Potentially relevant and appropriate to ambient surface water quality and point-source discharges to surface water should remedial activities cause a release to surface water.
Clean Water Act, National Pollutant Discharge Elimination System (40 CFR Part 122-125) and Washington State National Pollutant Discharge Elimination System Permit Program (Chapter 173-220 WAC).	The National Pollutant Discharge Elimination System (NPDES) program requires that permits be obtained for point-source discharges of pollutants to surface water. Under this regulation, a point-source discharge to a surface water body cannot cause an exceedance of water quality standards in the receiving water body outside the mixing zone.	Substantive regulatory requirements of the NPDES permit program are potentially applicable to the direct discharge of treated groundwater to a surface water body.
Clean Water Act's National Toxics Rule (NTR) (40 CFR 131.36)	Provides values that have to be met for point-source discharges to surface water.	Potentially applicable to point-source discharges to surface water and on-site stormwater ditches should remedial activities cause release to surface water.
Stormwater Permit Program (40 CFR 122.26)	Best management practices (BMPs) must be used and appropriate monitoring performed to ensure that stormwater runoff does not cause an exceedance of water quality standards in a receiving surface water body.	Substantive requirements of the general stormwater permit program for stormwater discharges associated with construction activities disturbing over 1 acre are potentially applicable to remedial actions at the Landfill.
Stormwater Management (Chapter 173-220 WAC)	Best management practices (BMPs) must be used and appropriate monitoring performed to ensure that stormwater runoff does not cause an exceedance of water quality standards in a receiving surface water body.	Substantive requirements of the general stormwater permit program for stormwater discharges associated with construction activities disturbing over 1 acre are potentially applicable to remedial actions at the Landfill.
Washington State Water Quality Standards for Surface Waters (Chapter 173-201A WAC)	Washington State water quality standards protect freshwater aquatic life by specifying protection criteria by stretch of surface waters. Chapter 173-201A WAC provides limitations on other parameters such as turbidity, temperature, dissolved oxygen, and pH for protection of organisms. Tributaries of waters whose uses are designated salmon and trout spawning, core rearing and migration, or extraordinary primary contact recreation are protected at the same level as the waters themselves.	The substantive requirements of this regulation are potentially applicable for remedial actions affecting surface water.
Model Toxics Control Act (WAC 173-340-730)	MTCA regulates the investigation and cleanup of releases to the environment that may pose a threat to human health or the environment. Establishes cleanup levels for surface water.	MTCA cleanup levels may be applicable to the Landfill if remedial activities cause a release to surface water.

(Table Continues)

Table 9-1. Potential Applicable or Relevant and Appropriate Requirements (ARARs) (Continued)

ARAR	Description	Applicability
Air		
National Ambient Air Quality Standards (40 CFR 50.6, 50.12)	Provides acceptable ambient air quality levels for particulate matter and lead.	Applicable to earth-moving activities as well as to treatment processes that may include mixing or other processes that result in potential releases of particulates or lead.
National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 261)	Establishes specific emissions levels allowed for toxic air pollutants.	Applicable to treatment alternatives that may emit toxic pollutants to the air.
Model Toxics Control Act (WAC 173-340-750)	MTCA regulates the investigation and cleanup of releases to the environment that may pose a threat to human health or the environment. Establishes cleanup levels for air.	MTCA cleanup levels may be applicable to the Landfill if remedial activities cause a release to air.
Miscellaneous		
Endangered Species Act (50 CFR Parts 17, 402)	Section 7 of the Endangered Species Act (ESA) and 40 CFR Part 402 require that federal agencies consider the effects of their proposed actions on federal listed species. It requires consultation between the agency proposing the action and the U.S. Fish and Wildlife Service (USFWS) or National Oceanic and Atmospheric Administration (NOAA) Fisheries, as appropriate. Preparation of a biological assessment is conducted, addressing the potential effects to listed species in the area and methods to minimize those effects.	The ESA is potentially applicable to remedial actions at the Landfill because federal threatened species could possibly use the project area. Therefore, they could potentially be affected by remedial actions conducted at the Landfill.
Native American Graves Protection and Repatriation Act (43 CFR Part 10)	Native American Graves Protection and Repatriation Act regulations protect Native American burials from desecration through the removal and trafficking of human remains and “cultural items,” including funerary and sacred objects.	This Act is potentially applicable to remedial actions at the Landfill because it is possible that the disturbance of Native American materials could occur as a result of work in subsurface excavations at the Landfill. Such materials are not known to be present at the Landfill, but could be inadvertently uncovered during soil removal.
National Historic Preservation Act (36 CFR Parts 60, 63, and 800)	National Historic Preservation Act (NHPA) regulations require federal agencies to consider the possible effects on historic sites or structures of actions proposed for federal funding or approval. Historic sites or structures as defined in the regulations are those on or eligible for the National Register of Historic Places, generally at least 50 years old.	This Act is potentially applicable to subsurface work at the Landfill. No such sites are known to be present in the area.
State Environmental Policy Act (SEPA) (Chapter 197-11 WAC)	Requires a review of potential damage that occurs to the environment as a result of man’s activities.	SEPA checklist may be required prior to construction of a remediation system at the Landfill.
Resource Conservation and Recovery Act (RCRA) – Identification and Listing of Hazardous Waste (40 CFR Part 261-265, 270, and 271)	Defines those solid wastes, which are subject to regulation as hazardous wastes, and lists specific chemical and industry-source wastes.	Applicable to determining whether wastes are considered hazardous wastes under RCRA.
RCRA Land Disposal Restrictions (40 CFR 268)	Establishes standards for land disposal of RCRA hazardous waste. Requires treatment to diminish a waste’s toxicity and/or minimize contaminant migration.	Applicable if remedial activities generate and include land disposal of waste that is characterized as hazardous.
RCRA Subtitle D Nonhazardous Waste Management Standards (40 CFR 257)	Develops standards for the management of non-hazardous wastes.	Applicable if remedial activities generate and include the management of non-hazardous wastes.
Washington Hazardous Waste Management Act (Chapter 173-303 WAC)	Establishes standards for the generation, transport, treatment, storage, or disposal of designated dangerous waste in the state.	This regulation is potentially applicable to alternatives that would involve handling of contaminated media at the Landfill. The area of contamination policy allows contaminated media to be consolidated within the same area of a site without triggering Resource Conservation and Recovery Act or Washington dangerous waste regulations.
Department of Transportation of Hazardous Materials (49 CFR 105 – 180)	Establishes specific U.S. Department of Transportation rules and technical guidelines for the off-site transport of hazardous materials.	Applicable to remedial activities that involve the off-site transportation of hazardous waste.
Washington Minimum Functional Standards for Solid Waste Handling (Chapter 173-304 WAC)	Defines requirements for solid waste management and disposal facilities. Establishes standards for handling and disposal of solid non-hazardous waste in Washington.	Applies to closure of solid waste landfill, including capping, installation of gas system, and environmental monitoring. Future Landfill actions will comply with these regulations regardless of remediation alternative selected.
Washington Solid Waste Handling Standards (Chapter 173-350 WAC)	Defines requirements for solid waste management and disposal facilities. Establishes standards for handling and disposal of solid non-hazardous waste in Washington.	These regulations are potentially applicable to solid nonhazardous wastes and are potentially relevant and appropriate to on-site remedial actions governing contaminated media management.
Washington Water Well Construction Act Regulations (Chapter 173-160 WAC)	Provides requirements for water well construction.	These regulations are potentially applicable to the installation, operation, or closure of supply, monitoring and treatment wells at and around the Landfill.
Kitsap County Board of Health Ordinance 2010-1 – Solid Waste Regulations	Defines requirements for solid waste management and disposal facilities. Establishes standards for handling and disposal of solid non-hazardous waste in Kitsap County.	Governs the handling, storage, collection, transportation, treatment, utilization, processing and final disposal of all solid waste within Kitsap County. Future Landfill actions will comply with these regulations regardless of remediation alternative selected.

(Table Continues)

Table 9-1. Potential Applicable or Relevant and Appropriate Requirements (ARARs) (Continued)

ARAR	Description	Applicability
Miscellaneous (Continued)		
Kitsap County Municipal Code (Title 12 – Storm Water Drainage)	Local codes provide standards for stormwater management, including grading. Best management practices (BMPs) must be used and appropriate monitoring performed to ensure that stormwater runoff does not cause an exceedance of water quality standards in a receiving surface water body.	Applicable to stormwater generation and handling at the Landfill. Potentially applicable to point-source discharges to surface water and on-site stormwater ditches should remedial activities cause release to surface water.
Kitsap County Municipal Code (Title 13 – Water and Sewers)	Local codes provide standards for water supply and sanitary sewer.	Applicable if remedial activities require a water supply or discharges to the sanitary sewer.
Kitsap County Municipal Code (Title 14 – Building and Construction)	Local codes provide standards for all building and construction activities, including stormwater management, building construction, and grading.	Plans review and building permits may be required if remedial activities necessitate the construction of buildings.
Kitsap County Municipal Code (Title 18 – Environment)	Requires a review of potential damage that occurs to the environment as a result of man's activities in accordance with State SEPA requirements.	SEPA checklist may be required prior to construction of a remediation system at the Landfill.

Table 11-1. Cleanup Action Technologies

Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility Effectiveness	Implementability	Cost	Retained/ Rejected[2]
Land Use Controls	Land Use Controls	Not Applicable	This control is effective because it restricts the use of groundwater. It does not directly address contamination removal or treatment.	This is an acceptable method for preventing human contact with hazardous media. It can be difficult to implement due to potential public resistance, and the necessary cooperation of multiple agencies and local governments.	Low	**Retained**
Containment	Vertical Barriers	**Slurry Wall**—This is a physical barrier used to contain contaminated groundwater or divert it from a downgradient receptor.	This is an effective technology for preventing horizontal migration of contaminants. It provides containment only; it does not treat groundwater or provide source removal. Because no active treatment is occurring, additional remedial action may be required to control contaminant concentrations. Degradation of the slurry wall over time may occur.	This is a common, well-established, and accepted technology. It may be difficult to implement due to subsurface conditions, and the depth to groundwater. This approach has average O&M requirements.	High	Rejected due to implementability issues and cost.
	Hydraulic Containment	**Pumping**—Uses groundwater pumping to form a barrier and extract groundwater for treatment.	This is an effective technology for preventing contaminant migration. Groundwater modeling is often necessary to design a system to adequately prevent contaminant migration. It must be combined with a treatment technology for the extracted groundwater. The water must be disposed after treatment. This approach may be effective at the Landfill for groundwater migration control. It provides containment only; the water needs to be treated ex-situ and would not provide source removal.	This is a common, well-established, and accepted technology. It may be difficult to implement due to potential high groundwater extraction rates. Also, due to the treatment requirement for the extracted water and extremely limited disposal options for the treated water, the capital costs for this technology are substantial. This approach also has high O&M requirements.	High	Rejected due to implementability issues and cost.
	Low Permeability Cap	**Low Permeability Cap** – Uses low permeability material (e.g., bentonite amended soil, geomembrane) on the surface above solid waste to minimize the surface infiltration of precipitation.	This is an effective technology for minimizing vertical contaminant migration. This technology is currently being used at the Landfill over Phase I. Cap materials vary in permeability. It provides containment only, it does not treat groundwater or provide source removal.	This is a common, well-established, and accepted technology. It is currently being used to limit infiltration over the Phase I Area of the Landfill.	Medium	**Retained**
	Active Landfill Gas Extraction	**Landfill Gas System Enhancements**—Landfill gas is extracted using a vacuum-blower system and the extracted gas is destroyed using a flare system.	This system is technically feasible and has been effective at landfills including the Hansville Landfill in Kingston, Washington. It has been shown to be effective as a source control technique by reducing vinyl chloride and other VOC concentrations in groundwater within the covered landfill. Not effective in controlling inorganics (i.e., metals).	This common landfill technology is easy to implement. This approach has average O&M requirements. Due to low methane production because of the age of the Landfill, active flare system would not function.	Low to Medium	Rejected due to effectiveness and implementability issues.
Collection/ Treatment –	Ex Situ Biological Treatment (pump and treat)[3]	**Bioreactors**—Bioreactor is a generic term for a system that degrades contaminants in groundwater and soil with microorganisms.	A bioreactor is not an effective technology for treating metals and is mostly in the pilot-testing phase. Bioreactors are prone to upset. Nuisance microorganisms can predominate and reduce treatment effectiveness. Low ambient temperatures can reduce the biodegradation rate.	Bioreactors are a well-developed technology that has been used in the treatment of municipal and industrial wastewater; however, only recent studies have been performed to evaluate the effectiveness of bioreactors in treating groundwater from remediation sites. This approach has average O&M requirements.	High	Rejected due to effectiveness, implementability issues, and cost.
		Constructed Wetlands - A constructed wetland uses natural geochemical and biological processes in a wetland ecosystem to treat metals, explosives, and other contaminants in groundwater.	This is an effective technology and has been used to treat groundwater contaminated with inorganics. The process filters some materials and degrades others. The technology incorporates the principal components of wetland ecosystems that promote degradation and control of contaminants by plants: degradation by microbial activity and increased sorption, filtering, and precipitation.	The long-term effectiveness of constructed wetlands to contain or treat some contaminants is not well known. Wetland aging may contribute to a decrease in contaminant removal rates over time. Constructed wetlands, like other biological methods, are limited by the ability of the biota to withstand exposure to their environment. After the pumping of contaminated water ceases, the artificial wetland ecosystem changes. This could severely affect the plant and animal life that comes to depend on the wetland, and it may leave a waste byproduct contaminated with metals and other contaminants. This residue or sludge may have to be disposed or capped.	Low to Medium	Rejected due to implementability issues.

(Table Continues)

Table 11-1. Cleanup Action Technologies (Continued)

Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility Effectiveness	Implementability	Cost	Retained/ Rejected[2]
Collection/ Treatment (Cont.)	Ex Situ Physical/Chemical Treatment (pump and treat)[3]	**Air Stripping**—Volatile organics are removed from water by greatly increasing the surface area of the contaminated water exposed to air and inducing volatilization.	Air stripping is an effective technology for removing VOCs from groundwater; however, air stripping is not used for metals treatment. It is effective for removing more miscible compounds such as vinyl chloride and methylene chloride. This technology does not destroy contaminants; VOCs are transferred directly from water to air. Additional waste streams are generated that require treatment.	This is a common, well-established, and accepted technology. Off-gas treatment by activated carbon adsorption or catalytic oxidation may be needed. This approach has high O&M requirements including periodic column cleaning.	Medium	Rejected due to effectiveness and implementability issues.
		Adsorption – GAC—Contaminated water flows through granular activated carbon (GAC) to remove contaminants.	GAC is an effective technology for removal of most VOCs; however, its effectiveness is limited for water-soluble compounds and primarily acts as a filter for inorganics (e.g., metals). Carbon has a short-term duration, especially for high concentrations and would require a high frequency of operation and maintenance. This process requires transport and disposal or regeneration of spent carbon.	This is a common, well-established, and accepted technology that is readily implementable. This approach has high O&M requirements including monitoring of influent and effluent stream, replacement of carbon, and backwashing.	Medium to High	Rejected due to effectiveness, implementability issues, and cost.
		Adsorption- Activated Alumina—Treatment with activated alumina is a physical/chemical process by which ions in the feed water are adsorbed to the oxidized activated alumina surface	Activated alumina treatment is an effective technology for removing inorganics from groundwater. Small, point-of-use systems are available, which can include a simple filter-type cartridge. Other larger systems may require disposal or treatment of regeneration water.	This is a common, well-established, and accepted technology. Compact activated alumina treatment systems are available and can be used at wellhead locations or other on-site locations. It involves periodic regeneration or replacement of media. Regeneration processes requires the handling of hazardous chemicals and generates sludge with potentially hazardous characteristics. This approach has average to high O&M requirements.	Medium to High	Rejected due to implementability issues and cost.
		Adsorption–Manganese Greensand/Pyrolusite Filtration—This process converts soluble forms of arsenic, iron and manganese to insoluble forms by oxidizing with permanganate and then removing the inorganics floc by filtration.	Greensand/Pyrolusite filtration is a relatively low-cost, effective, and proven technology for inorganics removal. Regenerative backwashing would be required to ensure the effectiveness of the filtration. Regeneration water would require on-site treatment to remove inorganics.	This is a common, well-established, and accepted technology. This inorganics removal process is normally used in larger scale treatment applications and is not common for point-of-use treatment or small systems. Backwashing of the filter is necessary to remove accumulated sediments. This approach has high O&M requirements.	Medium to High	Rejected due to implementability issues and cost.
		Ion Exchange—This technology removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium.	Ion exchange is an effective technology for removing metals and other inorganics from groundwater. It has been effectively used in point-of-use applications for water softening. This technology can effectively remove certain inorganics; however, other inorganic materials such as total dissolved solids and nitrate can compete with the target inorganics and can affect the treatment time. Suspended solids and precipitated iron can cause clogging of ion exchange material. Systems containing high levels of these constituents may require pretreatment. Use of the ion exchange process to remove inorganics could require multiple ion-exchange units with different media. A primary disadvantage of ion exchange systems is the non-selective removal of non-target ions.	This is a common, well-established, and accepted technology. Point-of-use systems are available. Ion exchange resins require regeneration after they have absorbed to their capacity. The regenerative solution requires additional treatment. There are numerous types of resins; the appropriate resins for an application depend upon the characteristics of the water and the substances to be removed. Primary problems with ion exchange systems are fouling of the resins with biological growth or scale. Disinfection of groundwater prior to treatment may be necessary, with UV light exposure the preferred technology. This approach has average O&M requirements.	Medium	Rejected due to effectiveness, implementability issues, and cost.
		Coagulation/Filtration—In this treatment process, the physical or chemical properties of suspended material are altered to produce an agglomeration that will settle out of solution by gravity or will be removed by filtration.	Coagulation/filtration is an effective technology for removal of metals and possibly other inorganic material. Additional waste streams are generated that require treatment/disposal.	Coagulation/filtration treatment produces inorganic-contaminated sludge that must be disposed off-site. Due to the amount of coagulant needed, and the size of flash mixing basins and settling tanks, coagulation/filtration is not a point-of-use technology. This approach has high O&M requirements.	High	Rejected due to implementability issues and cost.

(Table Continues)

Table 11-1. Cleanup Action Technologies (Continued)

Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility Effectiveness	Implementability	Cost	Retained/ Rejected[2]
Collection Treatment (Cont.)	Ex Situ Physical/Chemical Treatment (pump and treat)[3]	**Separation** – Filtration, Reverse Osmosis, and Other Membrane Processes—Contaminants are separated from water by pressure-gradient forces or filtration.	This is an effective technology for removing VOCs and inorganics from groundwater. Potential issues arise with interference from products such as oil or organics. Additional waste streams are generated that require treatment/disposal. Reverse osmosis performance is adversely affected by the presence of turbidity, silica, scale-producing compounds, and other constituents. This technology requires extensive pretreatment for particle removal and often pretreatment for dissolved constituents.	This is an accepted technology with most processes commercially available; however, it is not commonly used for remediation sites. It is mainly used as a pre- or post-treatment process. This process has a high potential for fouling of membrane if suspended solid levels are high. This approach has high O&M requirements.	High	Rejected due to implementability issues and cost.
		Physical Separation—Contaminants are separated from water via hydrophobic materials, material density, and other physical characteristics	This is an effective technology for removing a wide variety of contaminants from groundwater. Potential issues arise with sizing of treatment structures. Additional waste streams are generated that require treatment/disposal.	This is an accepted technology with most processes commercially available; however, it is typically used for gross contamination and is mainly used as a pretreatment process. This approach has high O&M requirements.	Medium to High	Rejected due to implementability issues and cost.
In-Situ Treatment	In-Situ Biological Treatment	**Monitored Natural Attenuation**—Natural subsurface processes such as volatilization, biodegradation, and other physical and/or chemical processes are allowed to reduce contaminant concentrations in the aquifer.	This is an effective method to reduce VOC and inorganics contamination; however, it requires evaluation of contaminant degradation rates to determine if it is appropriate for a site. Current Landfill conditions indicate some attenuation of inorganics is occurring at the Landfill.	This is an accepted technology that has been implemented at numerous sites. It is easy to implement. A long-term groundwater monitoring system would be required to verify the effectiveness of this technology. Institutional controls may be required, and the Landfill may not be available for re-use until contaminant levels are reduced. This approach has low O&M requirements.	Low	**Retained**
		Phytoremediation—Uses trees or other vegetation to remediate contaminants in groundwater.	Phytoremediation has been successfully demonstrated to be an effective method to reduce VOCs and inorganics in groundwater. The technology is limited to shallow groundwater. The success of remediation depends on establishing a selected plant community. The success of this technology may be seasonal, depending on location. Other climatic factors will also influence its effectiveness.	It is difficult to implement due to depth to groundwater contamination. This is not a fully accepted remedial technology by many regulatory agencies. The establishment of the plants may require several seasons of irrigation, which could potentially mobilize contaminants into groundwater. There is a potential for high maintenance to ensure growth and plant life in more arid climates.	Low to Medium	Rejected due to effectiveness and implementability issues.
		Enhanced Bioremediation—Uses an electron donor and/or nutrients via various contact technologies (e.g., injection wells, recirculation wells) to stimulate indigenous bacteria to degrade contaminants.	Enhanced bioremediation is an effective technology for removing VOCs and immobilizing some inorganics from groundwater. Techniques for immobilizing metals are largely experimental. Groundwater circulation can limit effectiveness if it allows contaminants to escape. Effectiveness can also be limited by the spacing of injection points and heterogeneity of the subsurface material.	This is an established and accepted technology. It may be difficult to implement due to subsurface conditions, and the depth to groundwater. Pilot testing and microcosm testing may be needed to evaluate the use of enhanced bioremediation at the Landfill before proceeding with full-scale remedial action using this technology. This approach has high O&M requirements to ensure continued effectiveness of the contact technologies. Immobilization of inorganics can cause plugging of aquifer matrix. Cannot target specific inorganics.	Medium	Rejected due to effectiveness and implementability issues.

(Table Continues)

Table 11-1. Cleanup Action Technologies (Continued)

Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility Effectiveness	Implementability	Cost	Retained/ Rejected[2]
In-Situ Treatment (Cont.)	In-Situ Physical/Chemical Treatment	**Permeable Reactive Barrier**—A permeable barrier composed of a reactive material treats contaminated groundwater as it flows through it.	This is an effective technology for preventing the horizontal migration of VOCs and immobilizing inorganics. It would not prevent potential vertical migration. The long-term effectiveness of reactive treatment walls has not been fully verified. Loss of reactive capacity may occur over time and reactive medium may require replacement.	This is a common, well-established, and accepted technology. It may be difficult to implement due to subsurface conditions, and the depth to groundwater. Long-term operation (>30 years) would be required if source areas were not removed and treatment of source area contamination is not completed. This approach has average O&M requirements.	High	Rejected due to effectiveness and implementability issues, and cost.
		Electrochemical Remediation Technologies (ECRTs)- Use a proprietary AC/DC electrical signal to mobilize and remove metal contaminants.	This technology is in the field testing process and is not a proven technology. Metals migrated to electrodes need to be removed and disposed.	ECRTs reaction rates are inversely proportional to grain size, so ECRTs remediate faster in clays and silts than in sands and gravels. The working depth of the technology is limited by the availability of drilling technology to install the electrodes.	Medium to High	Rejected due to effectiveness and implementability issues, and cost.
		Chemical Oxidation/Oxygen Releasing Compounds—An oxidant such as permanganate is injected into the aquifer, causing rapid degradation of organic compounds and immobilization of inorganic compounds.	Chemical oxidation is an effective technology for destruction of VOCs from groundwater and various types of soil. Can also be used to change subsurface chemistry to immobilize inorganics. The effectiveness of this technology can be impacted by changes in soil permeability. Effectiveness is limited by low-permeability soils and rapid groundwater flow. This treatment can interfere with anaerobic degradation processes. It also can potentially mobilize some metals. A treatability study and reaction transport modeling is normally required to assess feasibility.	This is a well-established and accepted technology. It may be difficult to implement due to subsurface conditions and the depth to groundwater. Proper and uniform distribution of oxidant can be difficult in very heterogeneous materials. A performance monitoring program is required to assess the effectiveness of this technology. This approach has high O&M requirements.	Medium to High	Rejected due to effectiveness, implementation issues, and cost.
		Complexation – A proprietary compound is injected into the aquifer, causing changes to geochemical processes to remove inorganics by producing metal-organosulfur complexes.	The active compound is a benign organosulfur compound that is environmentally safe. Once the compound becomes hydrated and subject to microbial biodegradation, it slowly releases the organosulfur compound. Upon contact with metal ions, the organosulfur compound irreversibly reacts to produce a metal-organosulfur complex (complexation). This metal-organosulfur complex sorbs strongly to soil and is immobile in the subsurface. Over time, the immobilized metals may be incorporated into the soil matrix as sulfide solids. The immobilized metals are stable under low redox potential and may be stable under oxidizing conditions. Based on vendor documentation and bench-scale testing, the complexing compound is applicable to treat arsenic within the groundwater; however, our understanding of the chemical processes involved with complexation of arsenic would preclude the use of the compound under oxidizing conditions. Full-scale implementation of the compound has only been used to remediate hexavalent chromium.	This is an experimental and not widely accepted technology for the remediation of arsenic. It may be difficult to implement due to subsurface conditions and the depth to groundwater. Proper and uniform distribution of the compound can be difficult in very heterogeneous materials. Prior to full scale use, the effectiveness of this technology should be verified with bench and pilot-scale testing. A performance monitoring program is also required to assess the effectiveness of this technology. This approach has high O&M requirements.	Medium to High	**Retained due to its potential to work in concert with other in-situ treatment such as air sparging.**
		Air Sparging—Air or other compatible gas is injected through the contaminated aquifer, creating a “stripper” that removes volatile contaminants by volatilization. Also increases dissolved oxygen content of groundwater, thereby changing groundwater chemistry.	Air sparging is an effective technology for removal of VOCs; however, it can be less effective for many chlorinated VOCs. Effective at adding oxygen to subsurface. The effectiveness of this technology can be affected by very small changes in soil permeability/heterogeneity, which can lead to localized treatment around the sparge points or leave areas untreated. Oxygen added to the contaminated groundwater and possibly solid waste materials can enhance aerobic biodegradation of contaminants below and above the water table, but will have adverse effects on anaerobic degradation. The addition of air also increases the concentration of dissolved oxygen in groundwater and would potentially create aerobic geochemical conditions that would decrease the solubility of metals such as arsenic, iron, and manganese.	This is a well-established and accepted technology. Pilot testing will be needed to evaluate the use of air sparging at the Landfill before proceeding with full-scale remedial action using this technology. A performance monitoring program is required to assess the effectiveness of this technology. This approach has low O&M requirements.	Medium	**Retained**

(Table Continues)

Table 11-1. Cleanup Action Technologies (Continued)

Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility Effectiveness	Implementability	Cost	Retained/ Rejected[2]
In-Situ Treatment (Cont.)	In-Situ Physical/Chemical Treatment	**Groundwater Circulation Well**—Groundwater is pumped to the surface and aerated, removing most of the volatile compounds. Other treatment technologies can be added to remove inorganics. The off-gas is then treated and water is re-injected.	These wells are an effective technology for removal and treatment of VOCs and some inorganics in groundwater. Vapors that are stripped off may require treatment before being discharged to the atmosphere. Removed inorganics require disposal. Subsurface heterogeneity can interfere with uniform flow in the aquifer around the well. Effectiveness can be limited by well construction/short-circuiting of groundwater extraction/re-injection. The change in chemistry around the well can cause aquifer matrix plugging by inorganics.	This is an established and accepted technology. A performance monitoring program is required to assess the effectiveness of this technology. This approach has high O&M requirements. Washington State regulations require that injected water meet strict water quality standards.	Medium to High	Rejected due to effectiveness issues and cost.

[1] Cleanup technologies, descriptions, and applicability to the Landfill were primarily based on information from the Federal Remediation Technologies Roundtable website at www.ftr.gov, the CPEO website at http://www.cpeo.org/tree.html, and various related documents.

[2] The retained technologies result from qualitatively evaluating the potential technologies based on screening information prepared by EPA, CPEO, and other organizations for sites across the United States, using the screening criteria listed above, and are ultimately based on the experiences gained at similar sites and professional knowledge and judgment.

[3] Treated water disposal is a serious feasibility issue due to strict regulatory treatment standards for disposal to a Publicly Owned Treatment Works, surface water, or groundwater; and, lack of disposal options at the Landfill. Therefore, ex-situ treatment technologies are not retained.