AGENCY REVIEW DRAFT
Ephrata Landfill Feasibility Study

Grant County Department of Public Works
and
City of Ephrata

August 2012

Parametrix

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Ephrata Landfill Feasibility Study

Prepared for

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and

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August 2012 | 555-1860-011 (06/01C)

CITATION

Parametrix. 2012. Agency Review Draft Ephrata Landfill Feasibility Study. Prepared by Parametrix, Bellevue, Washington. August 2012.

CERTIFICATION

The technical material and data contained in this document were prepared under the supervision and direction of the undersigned, whose seal, as a professional engineer licensed to practice as such, is affixed below.

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ACRONYMS AND ABBREVIATIONS

1,2-DCP	1,2-dichloropropane
95th UCL	95 percent upper confidence limit on the mean
AO	Agreed Order
ARAR	applicable or relevant and appropriate requirement
CAP	cleanup action plan
CFR	Code of Federal Regulations
City	City of Ephrata
CLARC	Cleanup Levels and Risk Calculation
COC	contaminant of concern
County	Grant County
CSM	conceptual site model
CUL	cleanup level
cy	cubic yards
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FS	feasibility study
GAC	granular activated carbon
gpm	gallons per minute
gpy	gallons per year
IHS	indicator hazardous substance
kg/yr	kilograms per year
LDR	land disposal restrictions
LNAPL	light non-aqueous phase liquid
MCL	maximum contaminant level
MNA	monitored natural attenuation
MTCA	Model Toxics Control Act
NES	north end soils
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PGG	Pacific Groundwater Group
POC	point of compliance
RI	remedial investigation

ACRONYMS AND ABBREVIATIONS (CONTINUED)

RI/FS	remedial investigation/feasibility study
sf	square feet
SFV	standard formula value
Site	Defined in Agreed Order DE 3810 as "… the extent of contamination caused by the release of hazardous substances at the Site."
SVE	soil vapor extraction
SVOC	semi-volatile organic compounds
SQER	small quantity emission rates
T	transmissivity
TCE	trichloroethene
VOC	volatile organic compound
WAC	Washington Administrative Code
WRF	City of Ephrata Water Reclamation Facility

1. INTRODUCTION

This feasibility study (FS) has been prepared for the Ephrata Landfill in Grant County, Washington (Figure 1), under the terms of Agreed Order (AO) DE 3810, dated January 30, 2007, between Grant County (the County), the City of Ephrata (the City), and the Washington State Department of Ecology (Ecology). The AO provides the administrative framework for conducting work described by the Interim Remedial Action Plan (Parametrix 2006) and for completing a remedial investigation/feasibility study (RI/FS) to address historical releases of hazardous substances. The Remedial Investigation (RI) report (PGG 2010) was previously submitted and accepted by Ecology as an agency review draft. An agency review draft RI Addendum (PGG 2012) was submitted to Ecology on August 28, 2012.

1.1 PURPOSE AND REGULATORY FRAMEWORK

This FS was prepared consistent with the AO and to comply with the Model Toxics Control Act (MTCA), Chapter 70.105D Revised Code of Washington, and its implementing regulations, Chapter 173-340 Washington Administrative Code (WAC), including WAC 173-340-350, which specifies procedures for conducting an FS. The purpose of the FS is to develop and evaluate cleanup action alternatives to enable a cleanup action to be selected for the Site. Each alternative may consist of one or more cleanup action components. Specific requirements under the MTCA cleanup regulations for identifying, screening, and evaluating cleanup actions are noted where appropriate throughout this FS.

1.2 OVERVIEW OF THE FEASIBILITY STUDY

This FS is presented in eight sections.

- Section 1 Introduction. Includes the purpose and regulatory framework for completing this FS, as well as landfill and interim action background summary information.
- Section 2 Hydrogeologic Understanding. Summarizes key information from the RI activities, including the nature and extent of contamination and identification of contaminants, and further hydrogeologic calculations supporting the FS.
- Section 3 Applicable Local, State, and Federal Laws. Summarizes the approach for complying with substantive requirements of applicable state and federal laws, including legally applicable requirements and relevant and appropriate requirements.
- Section 4 Identification of Indicator Hazardous Substances and Development of Cleanup Levels. Describes the conceptual Site model (CSM), identification of indicator hazardous substances (IHSs), and development of cleanup levels (CULs).
- Section 5 Proposed Cleanup Standards. Discusses the selection of CULs and points of compliance (POCs) for soil and groundwater.
- Section 6 Cleanup Action Technologies and Components. Discusses the screening of cleanup technologies and development of cleanup action components.
- Section 7 Cleanup Action Alternatives. Develops, evaluates, and compares each cleanup action alternative based on threshold and other requirements, and recommends a preferred cleanup action alternative.
- Section 8 References. Provides complete citations for documents cited in this FS.

Estimates of cleanup action performance, restoration timeframes, and costs in this FS reflect uncertainties in key parameters for assessing cleanup action performance and restoration timeframes. Uncertainties, which are evaluated to an extent in the FS supporting calculations (Appendix A) and fate and transport modeling (Appendix B), are typical for hydrogeologic calculations for a geologically complex area. Uncertainties result in large ranges in possible performance and restoration timeframes for the cleanup action alternatives evaluated; however, for the purposes of developing a preferred cleanup action alternative, best-estimate values based on professional judgment were used.

1.3 SITE BACKGROUND

The Ephrata Landfill is located approximately 3 miles south of the city of Ephrata on the east side of Highway 28 in the western portion of Section 33, Township 21 North, Range 26 East, Willamette Meridian (Figure 1). An old, unlined landfill (original landfill) is situated on the north part of the landfill property and a new, lined landfill (new landfill) occupies the south part of the property (Figure 1). The City began operating the original landfill in approximately 1942 and owned and operated it until 1974. The City owned the original landfill and leased additional property from the U. S. Bureau of Reclamation. In 1974, the City and the County entered into the first of a series of agreements under which the County leased the original landfill and operated the facility. The Bureau of Reclamation transferred its property to the County in 1990, and the City deeded the original landfill property to the County in 1994. Both properties are now the Ephrata Landfill property. The original landfill was capped in 2008 as an interim remedial action under the AO. The new landfill remains the primary solid waste disposal facility for Grant County.

Filling began in the northwest portion of the original landfill and expanded south and east until the new landfill was opened in 2004. Burning was allowed in the early history of the original landfill, but practices were not documented. Unintentional fires have occurred more recently in the original landfill. The original landfill was permitted by Grant County Health District, first under Chapter 173-301 WAC, then Chapter 173-304 WAC, and finally Chapter 173-351 WAC. The new landfill is permitted under Chapter 173-351 WAC. Current solid waste-related facilities at the landfill are shown in Figure 1 and consist of the original landfill, the new landfill, a leachate evaporation pond, a scale and maintenance shop, a water supply well, two lysimeters, and numerous landfill gas and groundwater monitoring wells.

The County recently acquired the Whitson parcel, which abuts the northeast corner of the landfill property (Figure 1). With this acquisition, the County had the Whitson water supply well modified such that the lower portion of the boring was sealed and a new 2-inch monitoring well was installed in accordance with Chapter 173-160 WAC. The new well was completed in the Interflow aquifer. The Whitson well was an open boring from 19 to 294 feet below groundwater surface between 1997 and 2012 and is believed to have enhanced vertical migration of shallow groundwater contaminants to deeper aquifers. The sealing of the lower portion of the boring has now reduced the potential for vertical migration.

The County also recently built a new scale and maintenance shop just east of the landfill property, adjacent to the area between the original and new landfills. The old scale and maintenance shop, which were located on the northwest corner of the landfill property, were removed.

1.4 INTERIM REMEDIAL ACTIONS

Several interim actions required under the AO are complete, including:

- Removal and disposal of approximately 2,300 buried industrial waste drums and associated contaminated soils and liquids at the north end of the original landfill in 2008
- Capping of the original landfill and drum disposal area (after drum removal) and the construction of landfill gas and surface water control systems in 2008
- Extraction of contaminated groundwater from the Hole[1] in 2008 and 2009
- Extraction of shallow, contaminated groundwater from the P1 zone (described in detail in PGG 2010), near where the drums were removed, from 2009 through 2011
- Light non-aqueous phase liquid (LNAPL) removal from wells MW-34p1 and MW-36p1 (completed in the P1 zone) with absorbent socks, which continues

The aforementioned drums were buried in the original landfill. The area from which the drums and associated contaminated soils and liquids were removed is referred to herein as the drum area (Figure 1), and the drums themselves as the removed drums.

During the RI, contaminants around the old scale and maintenance shop were detected. Some refuse was also observed in test pits and borings. This area, which lies immediately north of the original landfill, was not capped. The uncapped contaminated soil and refuse is referred to herein as north end soils (Figure 1).

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[1] The Hole is a 20-foot-deep depression in the basalt surface beneath the original landfill (Figure 1). Water level measurements indicate the lower 5 to 7 feet of soil/refuse within this depression are saturated with groundwater. The area of saturation in the Hole is about 1.5 acres, and the volume of saturated refuse is about 8,000 cubic yards.

2. HYDROGEOLOGIC UNDERSTANDING

Results of the RI (PGG 2010), as amended (PGG 2012), provide the foundation for the FS by characterizing local and regional hydrogeology and the extent of soil, gas, and groundwater contamination. The RI also describes the Site as complex, involving multiple aquifers and water-bearing zones of differing extents, as well as two groundwater contaminant plumes originating from contaminant sources listed below[2]. The hydrogeologic and contaminant model is crucial for understanding the CSM, IHS identification approach, and development of CULs (Section 4). The hydrogeologic and contaminant model is similarly crucial for understanding the selection and effectiveness of possible cleanup action components and alternatives (Sections 6 and 7, respectively). To support evaluations in this FS given the complexity of the Site, this section provides a review of the hydrogeology and groundwater contaminant plumes and sources.

The RI identified two water-bearing zones and seven aquifers, aquitards, and formations related to the Site. These are listed below from shallowest to deepest:

- P1 zone
- P2 zone
- Roza aquifer
- Interflow aquifer[3]
- Outwash aquifer
- Ringold aquifer
- Frenchman Springs aquifer
- Vantage aquitard
- Grand Ronde formation

The RI also identified the following contaminant sources, which vary in their relative contributions to the groundwater plumes:

- Releases from the removed drums
- Leachate from the original landfill (including saturated refuse in the Hole)
- Diffusion of volatile organic compounds (VOCs) from landfill gas from the original landfill
- Historic releases around the old scale and maintenance shop (north end soils)

The drum area, the original landfill and Hole, and north end soils, as well as portions of the P1 and P2 zones beneath those areas, are collectively considered the source area. LNAPL has been observed in an area of the P1 zone immediately south of the drum area; however, LNAPL has not been detected elsewhere in the P1 zone. VOC and semi-volatile organic compound (SVOC) concentrations in the drum area and the P1 zone underlying and near the

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[2] The RI also mentions a separate PCE plume in the Ringold aquifer north—northeast of the landfill near Dodson Road and a nitrate plume likely originating from chicken manure or other localized agricultural sources. These plumes are not considered to be releases from contaminant sources associated with the Ephrata Landfill or removed drums, and are not addressed in this FS.

[3] The Interflow aquifer may subcrop to the Outwash aquifer or the Ringold formation or both south of the original landfill.

drum area are the highest within the source area, and leakage from the removed drums is considered to be a major contaminant source.

The two plumes, both originating in the source area, are described as follows:

- The northerly plume originates in the drum area, the Hole, the old scale and maintenance shop area, and the north end of the original landfill. It extends generally northward from the landfill in the Roza aquifer, then to saturated alluvium and downward to the Interflow aquifer, toward the north and the northeast. Figure 2 shows the estimated extent of the northerly plume.
- The landfill plume originates beneath the original landfill and extends radially (in the directions of groundwater flow) in the Interflow aquifer to the west, south, and east, where the Interflow aquifer discharges to the Outwash aquifer. Some vertical migration to the deeper Frenchman Springs aquifer may also occur. Figure 2 shows the estimated extent of the landfill plume.

Outside the source area, these plumes consist of multiple plume components, each reflecting unique groundwater contaminant and exposure characteristics. Groundwater data collected for the RI were used to characterize the nature of contamination for each plume component in support of IHS development (Section 4).

The northerly plume comprises four plume components:

- Roza aquifer component. Data from monitoring well MW-44b were used to evaluate the northerly plume where it occurs to the north of the landfill at relatively shallow depths (i.e., where less attenuation has occurred compared to conditions farther from the landfill). Transmissivity (T) varies considerably in the Roza aquifer. A significantly higher transmissivity zone (high-T zone) underlies the northwest corner of the landfill near the old scale and maintenance shop (Figure 2).
- Whitson well component. Data from the Whitson well were used to evaluate the northerly plume where it occurs at a moderate distance from the landfill (i.e., farther north than MW-44b, where more attenuation has occurred). The Whitson well, which is no longer in use as a water supply well, is unique because it was the closest water supply well to the landfill within the northerly plume, and based on the driller’s log, it likely penetrated the Roza and Interflow aquifers and terminated in the Frenchman Springs aquifer. The driller’s log for the Whitson well indicates a 294-foot-deep bore, uncased below the 19-foot surface seal depth. The likelihood that vertical migration from the Roza aquifer to lower aquifers occurred makes this a unique plume component.
- Interflow aquifer component. Data from the Abrams, Pashkovsky-ACX157, Pashkovsky-ABX965, and Perez wells were used to evaluate the northerly plume where it occurs farther from the landfill and at relatively deeper depths (i.e., where even more attenuation has occurred).
- Saturated alluvium component. Data from monitoring well MW-53a were used to evaluate the northerly plume where it occurs in saturated alluvium relatively far from the landfill (i.e., where attenuation is relatively high). This location is unique because it is where the leading edge of the Roza aquifer component of the northerly plume is thought to discharge into shallow saturated alluvial sediments.

The landfill plume comprises two plume components:

- Outwash aquifer component. Data from monitoring wells MW-14a and MW-6a were used to evaluate the landfill plume where it occurs in the Outwash aquifer south of the original landfill. These wells are located where groundwater from the Interflow aquifer is thought to discharge into the Outwash aquifer (Figure 2).
- Frenchman Springs aquifer component. Data from monitoring well MW-28d were used to evaluate the landfill plume where it occurs in the deeper Frenchman Springs aquifer west of the original landfill.

Water supply wells are potential points of exposure for humans to contaminants in the groundwater. No residential wells completed in the landfill plume were identified, although wells hypothetically could be completed in it in the future without institutional controls (see Section 7.2.9.2).

In addition to evaluating the plume components described above, source area groundwater contamination was also characterized for FS development using the collective data from 29 monitoring wells[4] from multiple aquifers and locations. These include (1) the P1 and P2 zones (Figures 8 and 9 in the RI Report [PGG 2010]), the Hole, and the Roza aquifer at the north end of the original landfill; (2) the Interflow aquifer along the west, east, and south boundaries of the original landfill; and (3) the Outwash aquifer at the south end of the landfill[5]. Source area groundwater is distinct from an exposure standpoint because it is located within the landfill property and is neither accessible to the public nor used at the landfill.

The RI Report (PGG 2010) and RI Addendum (PGG 2012) identified contaminants of concern (COCs) that include solvents, fuel constituents, paint constituents, pesticides, landfill leachate salts, metals, nitrate, and breakdown products. Most of the organic COCs are VOCs, which are of concern due to their persistence in the environment and potential health risks. Table 1 presents the updated list of COCs identified in the RI Addendum.

2.1 ADDITIONAL HYDROGEOLOGIC CALCULATIONS

Pacific Groundwater Group (PGG) completed hydrogeologic calculations (Appendix A) to support the evaluation of possible cleanup action components and alternatives. The calculations include Hole, P1 zone, and Roza aquifer groundwater removal rates and appropriate well locations and spacing. Groundwater removal rates cited in this FS are based on these hydrogeologic calculations.

2.2 ADDITIONAL CONTAMINANT FATE AND TRANSPORT CALCULATIONS

The source calculations (Appendix A) also support contaminant fate and transport calculations (Appendix B), which PGG completed to support the evaluation of possible cleanup action components and alternatives. The fate and transport calculations include REMChlor (Falta 2007) simulation of IHS reduction over time in the Roza aquifer component of the northerly plume for several possible cleanup action components. Northerly

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[4] The 29 wells used to characterize source area groundwater are EW-1, EW-2, MW-1a, MW-2c, MW-3b, MW-5c, MW-6c, MW-7b, MW-9b, MW-10a, MW-11a, MW-16d, MW-22c, MW-23a, MW-24a, MW-25a, MW-29b, MW-30b, MW-31b, MW-32a, MW-33p2, MW-35p2, MW-37p1, MW-38p2, MW-39p2, MW-40p2, MW-41a, MW-42b, and MW-43p2.

[5] Wells used to characterize the landfill plume components were excluded from this group.

plume IHS concentrations over time cited in this FS are based on results of these fate and transport calculations. The following IHS were modeled:

- 1,2-dichloropropane (1,2-DCP)
- Vinyl chloride
- Benzene
- Methylene chloride.

3. APPLICABLE LOCAL, STATE, AND FEDERAL LAWS

Cleanup actions under MTCA must comply with applicable local, state, and federal laws, which include legally applicable requirements and relevant and appropriate requirements (similar to the applicable, relevant and appropriate requirements [ARAR][6] approach of the federal superfund law) (WAC 173-340-710). ***Legally 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, cleanup action, location, or other circumstance at a site (WAC 173-340-710(3)). ***Relevant and appropriate requirements*** are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, cleanup action, location, or other circumstance at a site, address problems or situations sufficiently similar to those encountered at the site such that their use is well-suited to the particular site (WAC 173-340-710(4)).

Potential ARARs for the Site include:

- Chemical-specific ARARs are typically health- or risk-based values that, when applied to site-specific conditions, represent cleanup standards.
- Location-specific ARARs relate to the geographical position and/or physical condition of the site and may affect the type of cleanup action selected for the site.
- Action-specific ARARs are usually technology- 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 cleanup action alternative, but specify how or to what level a selected alternative must perform. Table 2 lists the ARARs identified for each medium of concern at the Site.

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[6] Although ***ARAR*** is a specific term defined by and used in federal Superfund cleanups, this acronym is similarly used here in reference to legally applicable and relevant and appropriate requirements, as specified in WAC 173-340-710.

4. IDENTIFICATION OF INDICATOR HAZARDOUS SUBSTANCES AND DEVELOPMENT OF CLEANUP LEVELS

This section describes the identification of IHSs and the development of CULs for the Ephrata Landfill cleanup action. This project meets the criteria at WAC 173-340-703 for evaluating CULs, cleanup action components, and alternatives based on those COCs that contribute a relatively large percentage of the overall threat to human health and the environment (i.e., IHSs). The IHS approach is appropriate for this site because many COCs (1) are present at concentrations below levels that will adversely affect human health and the environment, (2) are detected infrequently, and (3) exhibit limited persistence, mobility, and degradation by-product toxicity. CULs were developed for the IHSs identified herein based on the reasonable maximum exposure expected to occur under both current and future site use conditions for groundwater (WAC 173-340-720(1)(a)) and soil (WAC 173-340-740(1)(a)). For potable groundwater, CULs were set at concentrations that would allow the groundwater to be safely used as a drinking water source (WAC 173-340-720(1)(a)). The data used for IHS identification and CUL development are summarized in Appendix C.

4.1 CONCEPTUAL SITE MODEL AND EXPOSURE PATHWAYS

The RI and Addendum (PGG 2010, 2012) addressed area geology, hydrology, and aquifer relationships, and contaminant sources and transport pathways based on groundwater movement. The COCs (Table 1) were also identified in the RI and Addendum. To develop groundwater CULs for the Site, concepts developed in the RI and Addendum were expanded by refining the details of contaminant release mechanisms, extending the transport mechanisms and exposure pathways to include vapor transport and outdoor and indoor air (adding ecological receptors), and refining the human receptors to distinguish between landfill workers and local residents. The resulting CSM thus serves as the basis for assessing potential exposure pathways and health risks to landfill workers, residents, and wildlife, as well as development of CULs.

The CSM is based on the three contaminant sources identified in the RI and summarized above (Section 2):

- Drum area – releases from the removed drums
- Original landfill – capped landfill refuse, leachate, and diffusion of volatile organic compounds (VOCs) from landfill gas
- North end soils – historic releases around the old scale and maintenance shop

Figures 3, 4, and 5, respectively, depict the CSM for each of these sources. Each part of the CSM identifies a COC source, along with the mechanisms involved in COC release and the pathways transporting COCs from the source to the media to which human and ecological receptors could potentially be exposed.

Additionally, several processes can affect the fate of COCs through attenuation (reduction) of contaminant concentrations during transport from their sources to the exposure media (PGG 2010):

- Dispersion – dilution of contaminant concentrations due to groundwater mixing
- Sorption – adhesion of contaminants to soil phase
- Volatilization – evaporation of contaminants to gas phase
- Degradation – breakdown (transformation) of contaminants

Groundwater contaminants can move into water supply wells and surface water features located within the groundwater transport pathway and create direct exposure routes for human and ecological receptors. Groundwater contaminants can also volatilize. While volatilization reduces the contaminant concentrations in groundwater, contaminant vapors migrating from shallow groundwater can mix with indoor and outdoor air and thereby potentially expose receptors to vapor contaminants through inhalation. Similarly, once a contaminant is released to soil gas, contaminant vapors can migrate upward into indoor or outdoor air or they can dissolve into groundwater and become a source of groundwater contamination.

Human and ecological receptors can also be exposed to contaminant sources through direct contact or by contact with windborne contaminant particles. People can be exposed to contaminated soil by deliberately eating it (as is sometimes done by children), by incidentally transferring soil on their hands to their mouths where they swallow it, and by inhaling dust particles that are trapped in mucous in the upper respiratory system that is then coughed up and swallowed.

The CSM indicates whether an exposure pathway is complete or incomplete[7], and major (potentially posing unacceptable health risks) or minor (posing negligible health risks). Major pathways in the CSM do not necessarily lead to unacceptable health risks; rather, the CSM identifies them as complete pathways that warrant quantitative evaluation relative to regulatory limits. For those major pathways with health risks exceeding regulatory levels, CULs were developed in accordance with the MTCA cleanup regulations (see Section 4.2, Identification of Indicator Hazardous Substances, and Section 4.4, Development of Cleanup Levels). Complete but minor exposure pathways are addressed qualitatively in this section.

4.1.1 Human Health Exposure Pathways

People can potentially be exposed to COCs present in source area groundwater and the northerly and landfill plume components via ingestion and inhalation exposure pathways, as well as to COCs present in north end soils through incidental ingestion and dermal exposure. Human health exposure pathways for landfill workers, residents, and recreational users from the three contaminant sources are shown in Figures 3, 4, and 5 and are described below for each exposure medium: groundwater, indoor air, outdoor air, and soil.

4.1.1.1 Landfill Worker Exposure Pathways

Potential exposure of landfill workers to COCs in the groundwater, indoor air, outdoor air, and soils are discussed below. The landfill is an industrial property as defined under WAC 173-340-200 and WAC 173-340-745; thus, landfill worker exposure is evaluated using MTCA Method C.

Groundwater

COCs derived from each of the three sources could be present in groundwater through direct or partial dissolution of COCs followed by transport to drinking water wells. However, no one is exposed to source area groundwater because no drinking water wells draw from it. The landfill's water supply well (33M1) (Figure 1) was sealed and completed in the Grand Ronde

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[7] A complete pathway consists of a series of direct links between source, release mechanism(s), transport mechanism, exposure media, and human and ecological receptors. For incomplete pathways, at least one of the links is missing.

aquifer (PGG 2010). The supply well was tested in 1993, 2004, and 2011, and VOCs were not detected. The 2011 test was conducted in accordance with the Washington State Department of Health (DOH) permitting requirements for potable use of the well for the new scale and maintenance shop. The DOH permitting process ensures that water supplied from a well meets drinking water standards. The supply well was not previously used for drinking. Water supply wells cannot be located within 1,000 feet of a landfill unless Ecology grants a variance (WAC 173-160-171). The Whitson well, which is within 1,000 feet of the landfill property, is now owned by the County and was converted to a monitoring well. Other than 33M1, there are no water supply wells within 1,000 feet of the Ephrata Landfill. Source area groundwater is neither used nor consumed[8], so this groundwater is therefore not a complete exposure pathway for any persons at the landfill site, including landfill workers. Although the exposure pathway for source area groundwater is not complete, IHS identification was completed to support development of CULs and cleanup action components for source removal.

Indoor Air

The old scale and maintenance shop, which were located on north end soils, were recently removed and replaced with new facilities east of the landfill property where soil is not contaminated (Figure 1). COCs could still be transported to the new facilities by groundwater following direct and partial dissolution of COCs. COCs could then volatilize into soil gas and intrude into indoor air. Indoor air is considered a complete and major exposure pathway for landfill workers and was evaluated for IHS identification (Section 4.2).

Outdoor Air

Landfill workers could hypothetically be exposed to COC vapors in outdoor air derived from the COCs in the three sources that could migrate, volatilize, and be transported to outdoor air (Figures 3, 4, and 5). However, the contribution of these sources to landfill worker exposure is considered negligible (complete but minor exposure pathway) and was therefore not evaluated for IHS identification.

Soils

Landfill workers could be exposed to COCs present in soils through inhalation of airborne particulates or direct contact; however the exposure pathways for the drum area and original landfill refuse are incomplete since the entire area was capped with a geomembrane liner and cover system that disrupts these exposure pathways. Landfill workers may access the north end soils area from time to time during ordinary landfill operation and maintenance activities. Consequently, the north end soil exposure pathway is complete for landfill workers and was evaluated quantitatively for potential human health risks (Section 4.3).

Surface Water

There are no potential exposure pathways for landfill workers via surface water. Exposure for landfill workers who may also recreate at local surface water bodies is addressed in Section 4.1.1.3, Recreational Users.

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[8] Workers involved in future cleanup efforts could be exposed to groundwater during cleanup activities, such as pump and treat. However, these exposures will be addressed under the Health and Safety Plan for those actions and in other cleanup action plans. These workers will wear appropriate personal protective equipment to limit exposure to acceptable levels.

4.1.1.2 Residents Exposure Pathways

Current and future adult and child residents of properties near the landfill that partly or fully overlie either the northerly plume or landfill plume could be exposed to groundwater COCs through the pathways described below.

Groundwater

COCs derived from each of the three sources could be present in groundwater through direct or partial dissolution of COCs followed by transport to residential drinking water wells. Adult and child residents could then be exposed to COCs during the course of their daily activities by drinking (ingesting) or inhaling (while showering) groundwater containing COCs pumped from residential wells completed in either the northerly or landfill plume. The groundwater exposure pathway is complete for residents and was evaluated for potential human health risks (Section 4.2).

Indoor Air

The indoor air exposure pathways from the three sources include dissolution and vapor partitioning of COCs to groundwater, groundwater transport of COCs to residential properties, followed by volatilization of COCs into soil gas and indoor spaces of residents' homes. Residents could be exposed to COCs by breathing vapors in indoor air.

Each northerly and landfill plume component has unique groundwater contaminant and exposure characteristics, which are summarized in Section 2, Hydrogeologic Understanding. The indoor air exposure pathways from the Roza aquifer and Whitson well components of the northerly plume and the Frenchman Springs aquifer component of the landfill plume are incomplete for residents because of hard, relatively impermeable, basalt aquitards above groundwater and the lack of VOC detections in the overlying P2 zone at well MW-44b (completed in the Roza aquifer component of the northerly plume). The indoor air exposure pathway for residents is complete for the remaining plume components, and these were evaluated for potential human health risks (Section 4.2).

Outdoor Air

COCs derived from each of the three sources could be present in outdoor air through dissolution and vapor partitioning of COCs to groundwater, groundwater transport of COCs to residential properties, followed by volatilization of COCs into soil gas and outdoor air. The exposure pathway to outdoor air from landfill sources is complete but minor for residents based on the depth of the underlying aquifers, the thickness of overlying aquitards[9], and expected high levels of attenuation. Therefore, this pathway was not evaluated quantitatively.

Soils

Residents could be exposed to COCs present in soils through inhalation of airborne particulates or direct contact. The exposure pathways for the drum area and original landfill refuse are incomplete since the original landfill, including the drum area, was capped with a geomembrane liner and cover system that disrupts these exposure pathways. The exposure pathway to north end soils is incomplete for residents since public access is restricted (Figure 5). Consequently, this exposure pathway was not evaluated quantitatively.

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[9] Aquitards are low-permeability units that inhibit vertical movement of groundwater and vapors.

Surface Water

There are no potential exposure pathways for residents to COCs from the three sources via surface water. Exposure for residents who may also recreate at local surface water bodies is addressed in Section 4.1.1.3, Recreational Users.

4.1.1.3 Recreational Users

There are no potential exposure pathways for recreational users to COCs from the three sources via groundwater, indoor air, outdoor air, and soils due to the lack of public access to areas where exposure may occur. Recreational use of surface water is addressed below.

Surface Water

COCs derived from each of the three sources could potentially be present in surface water through dissolution and vapor partitioning of COCs to groundwater, followed by groundwater transport of COCs to local surface water bodies. People could therefore potentially be exposed to contaminants through recreational use of these local surface water bodies, such as Neva Lake.

Neva Lake is the closest surface water feature downgradient of the landfill property (approximately 0.3 mile south) (PGG 2010). Arsenic concentrations were above background in the first sample collected in August 2009 but below background in the second sample collected in February 2010 (Appendix D). Additionally, VOCs were not detected in either of two RI samples collected in August 2009 and February 2010 from Neva Lake (PGG 2010). The exposure pathway to surface water (Neva Lake) is complete but minor. No other potentially contaminated surface water was identified. This pathway was therefore not evaluated quantitatively.

4.1.2 Ecological Receptors

Interim actions have modified or eliminated some ecological exposure pathways. Capping the original landfill eliminated the potential exposure of terrestrial wildlife to contaminants now under the cap. Additionally, current industrial activities in that area discourage use by wildlife. However, ecological receptors could still be exposed to contaminated outdoor air, north end soils, and surface water.

Outdoor Air

COCs derived from each of the three sources could be present in outdoor air through dissolution and vapor partitioning of COCs to groundwater, groundwater transport of COCs, followed by volatilization of COCs into soil gas and outdoor air. Terrestrial receptors could be exposed to COCs by inhaling vapors in outdoor air. The original landfill, including the drum area, is capped with a geomembrane liner and cover system that disrupts what might otherwise be a terrestrial ecological outdoor air exposure pathway. Consequently, the outdoor air exposure pathway for terrestrial receptors to COCs in the original landfill, including the drum area, is incomplete.

Soils

As for outdoor air, the original landfill cap disrupts what might otherwise be a terrestrial ecological soil exposure pathway for that area. However, the exposure pathway for terrestrial receptors to north end soils is potentially complete. Although the north end soils are located near undeveloped land, the landfill is an industrial property with low habitat quality. Nonetheless, to make a conservative estimate of possible wildlife exposure to north end soils, a simplified terrestrial ecological evaluation (WAC 173-340-7492(2)(a)(ii) and MTCA

Table 749-1) was completed assuming the area is of high habitat quality and likely to attract wildlife. Based on the simplified terrestrial evaluation, substantial wildlife exposure to the north end soils is unlikely (Table 3). Other than releases in the immediate vicinity of the removed drums, there is no record of use or disposal of bioaccumulative chemicals (e.g., pesticides, polychlorinated biphenyls [PCBs], dioxins/furans) at the landfill. Consequently, the soils exposure pathway is considered complete but minor and was not further evaluated.

Surface Water

As mentioned, COCs derived from each of the three sources could potentially be present in surface water; however, Neva Lake, the surface water body closest to the landfill, is considered a complete but minor exposure pathway for terrestrial and aquatic life and was not evaluated quantitatively.

4.2 IDENTIFICATION OF INDICATOR HAZARDOUS SUBSTANCES IN GROUNDWATER

This section describes the identification of IHSs in groundwater for both source area groundwater and plume components. Specific RI monitoring wells used to characterize each plume component are identified in Section 2, Hydrogeologic Understanding, and the data used are summarized in Appendix C.

The Site meets the criteria for evaluating CULs and cleanup action components and alternatives based on those groundwater COCs that contribute a relatively large percentage of the overall threat to human health and the environment (i.e., IHSs). Other COCs will be managed along with the IHSs, although detailed calculations were generally not performed for the other COCs to support this FS. The IHS approach developed for the Site is consistent with WAC 173-340-703 because many COCs (1) are present at concentrations below levels that will adversely affect human health and the environment, (2) are detected infrequently, and (3) exhibit limited persistence, mobility, and degradation by-product toxicity.

For adjacent residential properties, each northerly and landfill plume component has unique groundwater contaminant and exposure characteristics, which are summarized in Section 2, Hydrogeologic Understanding. Human health exposure pathways were therefore evaluated separately for each plume component to identify IHSs (and develop CULs). As discussed in Section 4.1.1.2, IHS identification did not include the indoor air (groundwater vapor intrusion) exposure pathways from the Roza aquifer and Whitson well components of the northerly plume and the Frenchman Springs aquifer component of the landfill plume because they are incomplete.

IHSs were also identified for source area groundwater. As stated in Section 2, Hydrogeologic Understanding, source area groundwater is distinct from an exposure standpoint because it is neither accessible to the public nor used at the landfill (i.e., an incomplete exposure pathway).

Based on rules at WAC 173-340-703, and as exemplified in the Mica Landfill cleanup action plan (CAP) (Ecology 2001), the following process was used to identify IHSs:

- For each COC, the lowest applicable standard was determined from groundwater maximum contaminant levels (MCLs, 40 Code of Federal Regulations [CFR] 141.61) and MTCA Method B standard formula values[10] (SFVs) per WAC 173-340-720(4)(b) and 705.

- Standards based on groundwater MCLs were adjusted downward if needed so that the individual COC excess cancer risk and hazard quotient were less than or equal to 1×10^{-5} and 1.0, respectively, per WAC 173-340-705(5).
- MTCA Method B SFVs were obtained from the Cleanup Levels and Risk Calculation (CLARC) Database (Ecology 2011). Where COC SFVs were dropped from the CLARC Database in the April 2011 update, toxicity values were obtained, if available, from Tier 3 sources in the U.S. Environmental Protection Agency's (EPA's) hierarchy and used to calculate SFVs using MTCA Method B standard equations 720-1 and 720-2 (Appendix C).
- If no applicable standards were available from the CLARC Database or calculated from Tier 3 sources, the COCs were not evaluated further for possible identification as IHSs.
- A COC was selected as an IHS if its reasonable maximum exposure point concentration exceeded its lowest applicable standard and its frequency of detection exceeded 5 percent (Appendix C).

Reasonable maximum exposure point concentrations for individual plume components and source area groundwater were calculated using ProUCL (EPA 2010) as 95 percent upper confidence limits on the mean concentrations (95th UCLs), or maximum measured concentrations for small sample sizes ($n \leq 5$) (Appendix C).

Table 4 summarizes the identification of IHSs for source area groundwater and the individual plume components. Thirteen COCs exceeding their lowest applicable standards in source area groundwater were identified as IHSs. Only five of these COCs exceeded standards in one or more of the northerly and landfill plume components. The Roza aquifer component of the northerly plume has five IHSs (1,2-DCP, benzene, dissolved manganese, methylene chloride, and vinyl chloride), the most of any plume component. Two IHSs (1,2-DCP and vinyl chloride) were identified for the Whitson well component of the northerly plume. No COC concentrations in the Interflow aquifer or saturated alluvium components of the northerly plume exceeded applicable standards, so no IHSs were identified for those components. No COCs exceeded standards in the Frenchman Springs or Outwash aquifer components of the landfill plume.

Table 5 summarizes identification of IHSs for indoor air exposure in the new scale and maintenance shop east of the landfill property (Figure 1). Reasonable maximum exposure point concentrations in shallow groundwater were calculated using collective groundwater monitoring data from wells MW-1a and MW-26a (Figure 2). No COCs exceeded standards for this exposure pathway.

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[10] For plume components with complete residential indoor air exposure pathways, groundwater screening levels generated from MTCA Method B air SFVs (per Ecology 2009) were also used (Appendix C).

4.3 EVALUATION OF NORTH END SOILS

Since the original landfill was capped in 2008, the north end soil area is the only remaining location with a complete soil exposure pathway. North end soils were evaluated for potential human health risks and to calculate soil COC concentrations protective of groundwater (i.e., concentrations that will not cause an exceedance of groundwater CULs). RI data used for this evaluation are summarized in Appendix C.

Table 6 summarizes the north end soils human health risk evaluation. To evaluate the risk for landfill worker exposure, modified MTCA Method C equations 745-4 and 745-5 in WAC 173-340-745 were used to calculate protective soil concentrations, because they address the incidental soil ingestion and dermal exposure pathways identified in the CSM (Figure 5). The toxic mechanism approach, as described below for groundwater CUL development, was also used in the soil evaluation. Table 6 shows there are no exceedances of regulatory limits for individual COCs, for total excess cancer risk, or for noncarcinogenic toxic effects (hazard quotients and hazard index). Consequently, CULs were not developed for north end soils.

Table 7 summarizes a preliminary evaluation of the potential for north end soil IHS concentrations to cause exceedances of groundwater CULs. The Fixed Parameter Three-phase Partitioning Model (WAC 173-340-747(4)) was used to calculate soil IHS concentrations that would result in groundwater concentrations equal to the groundwater CULs from Table 8. Soil 95th UCLs were compared to the calculated soil IHS concentrations for protection of groundwater. For four IHSs, soil 95th UCLs exceeded the calculated soil COC concentrations, suggesting that north end soils may have the potential to cause an exceedance of some groundwater CULs. Consequently, the north end soils are addressed in the development of cleanup action components and alternatives.

4.4 DEVELOPMENT OF GROUNDWATER CLEANUP LEVELS

Table 8 shows CULs for the source area groundwater and the individual plume components. Plume component CULs were developed to reflect potential exposure of residents to contaminated groundwater from plume components. Source area CULs were developed based on the lack of access to or use of source area groundwater.

The lowest applicable standards calculated for the identification of IHSs were used as CULs for source area groundwater. Plume component CULs were developed based on exposure from drinking and showering with contaminated groundwater as follows (Parametrix 2011a):

- Plume component CUL values were initially set equal to source area groundwater CUL values for those IHSs identified for both the source area groundwater and a plume component.
- Downward adjustments were made to individual CULs, if needed, to account for overall risk (WAC 173-340-705(4)).
- Noncarcinogenic toxic effects (hazard indexes) based on CULs reflect additive effects of chemicals with similar chronic effects on individual human organ systems (toxic mechanisms; WAC 173-340-708(5)(b)).

CULs for source area groundwater do not reflect downward adjustments, nor were toxic mechanisms evaluated for noncarcinogenic toxic effects, because there is no exposure to source area groundwater.

The CULs in Table 8 are considered preliminary because final CULs will be established in the CAP for the Site, to be prepared by Ecology.

5. CLEANUP STANDARDS

Cleanup standards under the MTCA cleanup regulations consist of the following (WAC 173-340-700(3)):

- CULs for hazardous substances present at the Site
- The location where the CULs must be met (POC)
- Other regulatory requirements applicable to the Site (ARARs)

Setting cleanup standards also involves specifying restoration timeframes (WAC 173-340-700(7)). Restoration time frames described in this FS are the time intervals needed to meet CULs at and beyond the POC for the cleanup action alternatives (Section 7).

Cleanup standards for the Site are evaluated below based on criteria in WAC 173-340-700 through 173-340-760 and the CULs in Table 8. Development of CULs is described in Section 4, and ARARs are discussed in Section 3. Although cleanup standards will be confirmed in the CAP, those described in this FS serve as a basis for evaluating the alternatives (Section 7). This section focuses on identification of groundwater and soil POCs for the Site.

5.1 GROUNDWATER POINT OF COMPLIANCE

As with other landfills managed under MTCA, it is not practicable to meet groundwater CULs throughout the Site within a reasonable restoration timeframe (WAC 173-340-720(8)(c))[11]. Cleanup action alternatives that would meet groundwater CULs at the original landfill boundary, such as excavating the original landfill, would not be technically feasible (WAC 173-340-350(8)(b)(ii)), would be disproportionately costly (WAC 173-340-350(8)(b)(i)), and might not meet the minimum requirements specified in WAC 173-340-360(2), such as protection of human health and the environment.

To identify a groundwater POC at which groundwater CULs could be met within a reasonable restoration timeframe, the fate and transport of IHSs in the northerly plume was modeled (Appendix B).

Hydrogeologic calculation and groundwater modeling results suggest that, for the northerly plume, it may be technically feasible to meet groundwater CULs at the POC and all areas outside the POC within about 20 to over 71 years. The east and west margins of original landfill refuse extend nearly to the east and west landfill property lines (Figure 6). To the south, it should be feasible to meet groundwater CULs at an east-west line across the landfill property between the original landfill and new landfill (Figure 6). Such a southern POC would maintain separation between compliance monitoring wells for the original landfill and ongoing solid waste monitoring activities at the new landfill cell. The landfill property line to the east, north, and west and an east-west line between the original and new landfills is therefore proposed as the groundwater POC[12].

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[11] See Ecology (2007) at 4, which describes landfills as prime examples of where conditional POCs are appropriate.

[12] While technically a conditional POC under MTCA, since there is only one groundwater POC, it is referred to as a POC in this FS.

This POC is consistent with MTCA cleanup regulations, is protective of human health and the environment, and will support selection of a cleanup action that is not disproportionately costly (WAC 173-340-720(8)(c) and WAC 173-340-360(e)(i)).

5.2 SOIL POINT OF COMPLIANCE

For soil CULs based on human exposure via direct contact or other exposure pathways where contact with the soil is required to complete the pathway, WAC 173-340-740(6) defines the standard soil POC as all soils throughout the site from the ground surface to 15 feet below the ground surface. This represents a reasonable estimate of the depth of soil that could be excavated and distributed at the soil surface as a result of site development activities. This also corresponds to the POC for terrestrial ecological receptors. The standard soil POC is generally applicable throughout the Site with the following exceptions:

- Original landfill: Since the original landfill is capped with a geomembrane cover system, the depth of the geomembrane liner below ground surface is the appropriate soil POC for the original landfill. That depth is 24 inches on the top of the original landfill and 26 inches on the side slopes. The geomembrane cover system is designed in part to prevent animals and plant roots from contacting refuse.
- North end soils: The top of bedrock is less than 15 feet below the ground surface in places based on boring and test pit logs in the north end soil area (PGG 2009). Disturbance of bedrock underlying the north end soils by people or animals is unlikely. The soil POC is therefore proposed as the north end soil area from ground surface to the shallower of top of bedrock or 15 feet below ground surface. The horizontal extent of a POC for NES is shown on Figure 6.

As with soil at other landfills managed under MTCA, it is not practicable to meet the soil CUL throughout the site within a reasonable restoration timeframe (WAC 173-340-720(8)(c))[13] due to the refuse contained within the original landfill. Cleanup action alternatives that would meet soil CULs in and beneath the original landfill, which would require excavating the original landfill, would not be technically feasible (WAC 173-340-350(8)(b)(ii)), would be disproportionately costly (WAC 173-340-350(8)(b)(i)), and might not meet the minimum requirements specified in WAC 173-340-360(2), such as protection of human health and the environment.

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[13] See Ecology (2007) at 4, which describes landfills as prime examples of where conditional POCs are appropriate.

6. CLEANUP ACTION TECHNOLOGIES AND COMPONENTS

Development of cleanup action alternatives started with an overview of relevant groundwater and soil cleanup technologies (Section 6.1). Retained technologies (i.e., those potentially viable for the Site) were then used to develop cleanup action components based on COC- and Site-specific information (Section 6.2).

6.1 CLEANUP ACTION TECHNOLOGIES

Cleanup action technologies were evaluated for the Site to identify potentially applicable technologies (Parametrix 2011b). Site-specific factors were considered in the screening of these technologies: the nature of Site COCs, environmental media impacted (basalt bedrock, soil, and groundwater), and types of exposures to be addressed. Cleanup action technologies not applicable to Site conditions and Site COCs, such as the excavation and disposal of any contaminated solid waste materials and soil located beneath the original landfill cover, were excluded from further consideration for this Site. Tables 9 and 10 list the cleanup action technologies screened for the Site for groundwater and north end soils, respectively.

In addition to cleanup action technologies that treat contaminated media, institutional controls were also evaluated for both soil and groundwater. Although institutional controls provide no reduction of toxicity, volume, or mobility of contaminants, they can reduce or eliminate exposure pathways and resultant potential risk.

The following screening criteria were used to determine applicable cleanup action technologies for the Site (WAC 173-340-350(8)(b)):

- Technical feasibility/effectiveness. The ability of the technology to function effectively and achieve meaningful progress toward protecting human health and the environment based on site-specific characteristics, including the nature and extent of COCs, waste/source type and locations, site hydrogeology, and time required to achieve CULs.
- Implementability. Administrative issues related to the technology, including 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.

Retained cleanup action technologies are identified in Table 9 for groundwater and Table 10 for north end soils. Use of these technologies as cleanup action components are provided in Section 6.2.

6.2 CLEANUP ACTION COMPONENTS

The cleanup action components described below were developed from the retained cleanup action technologies and Site hydrogeologic and contaminant fate and transport data developed in support of this FS. Various combinations of components were used to develop the cleanup action alternatives described in Section 7.2.

Some of the cleanup action components described below are specifically designed to remove residual source, thus accelerating decay of the source (“source removal components”). In general, source removal components are considered more permanent under MTCA and contribute to more rapid attainment of environmental restoration in the absence of control measures. Source removal components noted in evaluation of alternatives in Section 7.3.2.

Table 11 summarizes the evaluation of cleanup action components. Some components were evaluated in terms of IHS reduction over time in the northerly plume (Appendix A). The restoration times are summarized by IHS for those components. For the source removal components, and initial removal rate of organic COCs was calculated (Appendix H). The initial removal rates are shown in Table 11. Some components are for groundwater treatment or disposal, which support source removal components. Individual component costs were evaluated on the basis of present worth for a 30-year time interval. Although not noted in Table 11, some components are mutually dependent, some mutually exclusive. Component compatibility is addressed in Section 6.3, Cleanup Action Component Combinations and Compatibility.

6.2.1 Natural Attenuation

The RI Report (PGG 2010) established that contaminant decay (i.e., destruction) is significant at the Site. Having removed the drums, which were a significant source of groundwater contamination, natural attenuation, including decay, will continue to reduce groundwater COC concentrations over time regardless of whether other cleanup actions are implemented. Natural attenuation will continue after cessation of active cleanup action components.

Natural attenuation is considered a component of all cleanup action alternatives, although the degree of reliance upon natural attenuation differs between alternatives. The initial COC removal rate for natural attenuation (Table 11; rate developed in Appendix A) is based on estimated reductions of COC mass flux in the northerly plume between the source area and groundwater POC (property boundary) under current conditions.

6.2.2 Manual LNAPL Removal

LNAPL has been observed in the P1 zone by the drum area (Figure 2). It has been observed to migrate into wells MW-34p1 and MW-36p1 (in the P1 zone) when they are drawn down by pumping and when water levels are naturally (seasonally) lower. LNAPL has not been detected elsewhere in the P1 zone and it has not observed in Site aquifers. The area of LNAPL occurrence in the P1 zone is hereafter referred to as the LNAPL area.

Manual LNAPL removal would decrease contaminant mass. LNAPL can be collected and removed with oleophilic absorbent socks placed in the and this is one way to reduce source contaminant mass in the P1 zone, thus reducing source mass.

The absorbent socks must be manually checked and removed when saturated with LNAPL. Based on previous interim actions (Appendix E), socks should be checked weekly during groundwater extraction. The estimated LNAPL removal rate from the two wells in 2010 was 5 to 10 gallons over an 8-month period (March through October); however, this rate diminished substantially in subsequent extraction periods.

The LNAPL, spent socks, and personal protective equipment would be held in onsite drums for disposal. Grant County would then manage the waste using the Hazardous Waste Handling and Disposal Services Contract Number 03505 (State Hazardous Waste Contract). LNAPL management would likely be necessary for the duration of groundwater extraction from the LNAPL area.

6.2.3 LNAPL Separation and Disposal

Mixed-phase (i.e., groundwater and LNAPL) liquid extraction from the LNAPL area would require *ex-situ* separation of LNAPL from groundwater, either prior to groundwater evaporation or as an early step in the groundwater treatment train (Figure 7). Oil-water separation would generate two waste streams, settled solids and LNAPL. Water would be routed to the next treatment step. Based on expected solids precipitation and previously documented LNAPL generation rates (Appendix E), annual dangerous waste generation for this process is estimated at about 250 gallons of solids, LNAPL, and personal protective equipment.

An LNAPL separation system would include an oil-water separator (5 gallons per minute [gpm] capacity), an effluent pump to discharge water to an evaporation pond or next treatment step, sludge and LNAPL pumps to move the respective waste streams into containers for disposal, and an air compressor to operate the sludge and LNAPL pumps. The system would be located in a small building (if water is discharged to an evaporation pond) or in the treatment system building (if water is treated before disposal).

Anticipated operation, maintenance, and monitoring activities and costs would include:

- Pump maintenance
- Pump performance evaluation
- Pump replacement (5-year pump life is assumed)
- Effluent sampling as needed for evaporation pond compliance monitoring or treatment system performance monitoring
- Electricity costs
- System monitoring (leaks, LNAPL generation, discharge rates, etc.)

The relatively small quantities of dangerous waste generated by this process would likely be managed under the State Hazardous Waste Contract. LNAPL removal activities would be needed for the duration of mixed-phase pumping from the P1 zone. Upon completion of cleanup action activities, the extraction pumps would be removed and disposed, the wellhead completions would be demolished, and the three extraction wells would be decommissioned in accordance with Chapter 173-160 WAC.

6.2.4 Seasonal Pumping from the Hole and P1 Zone

Seasonal (March through November) groundwater extraction from the Hole (well EW-1) and the P1 zone in the vicinity of the former drum cache area, around wells MW-34p1 and MW-36p1, would decrease contaminant source mass and produce an upward vertical gradient, thus reducing contaminant migration into underlying aquifers, which transport contaminants off site.

Wells EW-1, MW-34p1, and MW-36p1 would be fitted with pitless adapters to allow subsurface discharge through a buried pipe (no aboveground piping). The extracted groundwater would be discharged to an evaporation pond or treatment system.

Pump rates from about 1.4 to 1.9 gpm total for the three wells (annual total up to 545,000 gallons) are estimated for the seasonal pumping approach based on aquifer and zone transmissivities and thicknesses (Appendix A). A piston pump system would be appropriate for the estimated pump rates. Electric pumps are assumed for cost estimating, although pneumatic pumps might be a viable alternative. To avoid pumping LNAPL during extraction of groundwater from the P1 zone, pump rates would be monitored and adjusted to maintain about 2 feet of groundwater above the pump intake. Seasonal pumping activities would likely be necessary for the entire restoration timeframe.

Anticipated operation, maintenance, and monitoring activities and costs would include:

- Pump maintenance
- Pump performance evaluation
- Pump replacement (5-year pump life is assumed)
- Annual flushing and evacuation of discharge lines (freeze prevention)
- Effluent sampling as needed for evaporation pond compliance monitoring or treatment system performance monitoring
- Electricity costs
- System monitoring (leaks, LNAPL generation, drawdown, discharge rates, etc.)

Upon completion of cleanup action activities, the extraction pumps would be removed and disposed, the wellhead completions would be demolished, and the three extraction wells would be decommissioned in accordance with Chapter 173-160 WAC.

6.2.5 Continuous Pumping from the Hole and P1 Zone

Continuous groundwater extraction from the Hole and LNAPL area would remove source mass and substantially reduce potential chemical transport from the source area (i.e., P1 zone or the Hole) to underlying aquifers (at least partially dewater the target zones). The (partial) dewatering would reduce contact between groundwater and residual contamination remaining within the P1 zone or the Hole, and it would create a vadose zone within which vapor extraction (from the P1 zone) could be performed (Section 6.2.7).

In addition to existing well EW-1, three new wells were assumed for continuous pumping from the Hole. Similarly, for the LNAPL area, continuous pumping would require three new wells in addition to existing wells MW-34p1 and MW-36p1.

Extraction wellheads would be completed with pitless adapters to allow discharge to flow directly to buried piping (no aboveground piping). Groundwater would be discharged to an evaporation pond or treatment system.

The estimated long-term P1 zone extraction rate is 0.5 gpm (250,000 gallon per year [gpy]) (Appendix A). The initial discharge rate to dewater the Hole is estimated at 4 gpm, or 390,000 gallons over a 40- to 70-day interval (Appendix A). Initial dewatering of the Hole would be followed by either cyclic recharge and dewatering or a reduced discharge rate to maintain the lowered groundwater level (estimated ambient groundwater flow through the Hole is 46,000 gpy) (Appendix A). The estimated combined initial discharge rate (initial Hole dewatering and long-term P1 zone extraction) is 4.5 gpm (640,000 gallons in the first year) (Appendix A). The estimated sustained rate (P1 zone plus the ambient groundwater flow rate through the Hole) would be about 300,000 gpy (Appendix A). Piston pumps would be appropriate for the estimated discharge rates. Pumping rates would be monitored and adjusted to maintain about 2 feet of groundwater above the pump intakes in the P1 zone. Pumping activities would likely need to be conducted for the entire restoration timeframe.

Anticipated operation, maintenance, and monitoring activities and costs would include:

- Pump maintenance
- Pump performance evaluation
- Pump replacement (5-year pump life is assumed)
- Effluent sampling as needed for evaporation pond compliance monitoring or treatment system performance monitoring
- Electricity costs
- System monitoring (leaks, LNAPL generation, drawdown, discharge rates, etc.)

Upon completion of cleanup action activities, the extraction pumps would be removed and disposed, the wellhead completions would be demolished, and the three extraction wells would be decommissioned in accordance with Chapter 173-160 WAC.

6.2.6 Hydraulic Capture of the Northerly Plume in the Roza Aquifer

Significant volumes of contaminated groundwater could be extracted from the Roza aquifer high-T zone near the north landfill property boundary (Figure 2). PGG estimated it could be possible to hydraulically capture the northerly plume in the Roza aquifer at the northern landfill property boundary within about 1 year (Appendix A) by pumping about 6 gpm from two new extraction wells installed in the Roza aquifer high-T zone. Hydraulic capture of the northerly plume at the north landfill property line (hereafter referred to as northerly plume capture) would stop migration in the Roza aquifer north of the landfill. Extraction wellheads would be completed with pitless adapters to allow discharge to flow directly to buried piping (no aboveground piping). Groundwater would be discharged to an evaporation pond or treatment system.

Northerly plume capture would be compatible with concurrent groundwater extraction from the Hole and the P1 zone. Northerly plume capture, without concurrent groundwater extraction from the Hole and the P1 zone would effectively stop Roza aquifer contaminant migration north of the landfill, but would not directly remove source mass from the P1 Zone or the Hole.

Anticipated operation, maintenance, and monitoring activities and costs would include:

- Pump maintenance
- Pump performance evaluation
- Pump replacement (5-year pump life is assumed)
- Effluent sampling as needed for evaporation pond compliance monitoring or treatment system performance monitoring
- Electricity costs
- System monitoring (leaks, drawdown, discharge rates, etc.)

Upon completion of cleanup action activities, the extraction pumps would be removed and disposed, the wellhead completions would be demolished, and the three extraction wells would be decommissioned in accordance with Chapter 173-160 WAC.

6.2.7 Soil Vapor Extraction

A soil vapor extraction (SVE) system could be used to reduce contaminant mass in the LNAPL area if the P1 zone groundwater level is lowered. An SVE system is assumed to require about six wells spaced about 50 feet apart. SVE wells would be screened for the full thickness of the P1 zone, which averages about 4 feet. Well discharge piping would be connected and the combined discharge routed underground to a small building housing a water knockout tank, blower, and associated instrumentation and controls. A 300 cubic-feet-per-minute blower operating at about an 80-inch water column vacuum was assumed for estimating costs. Residual water (condensate) from the system would be evaporated.

Although the SVE system described above is representative for the LNAPL area in question and sufficient for cost estimation, SVE removal rate calculations are sensitive to variables that are not well understood for the LNAPL area. As a gross estimate, it was assumed that half of the LNAPL mass could be removed with SVE, although the actual proportion could differ significantly higher or lower. SVE is not universally successful, and further testing and engineering is needed to evaluate SVE viability for the Ephrata Landfill. For purposes of this FS, estimated contaminant removal rates for SVE should be considered less reliable than contaminant removal rates estimated for groundwater extraction.

Typical SVE operation, maintenance, and monitoring activities and costs would include:

- Typical equipment maintenance
- One vacuum pump replacement
- Monthly air samples and analyses
- Part-time operations staff
- Electricity costs

SVE is estimated to remove contaminants from the LNAPL area to the extent feasible with this method in about 5 years.

6.2.8 Pumped Groundwater Treatment

Treatment of pumped groundwater (*ex-situ* treatment) would be needed to discharge extracted water to either the City of Ephrata Water Reclamation Facility (WRF) or to the ground (infiltration basin). The impacts of the added capacity on the WRF would be infeasible for the City to estimate and the costs of upgrades would be substantial; therefore, discharge to the ground (infiltration; Section 6.2.10) is the basis for FS cost estimates. In either case, *ex-situ* groundwater treatment would need to satisfy the conditions of a State Waste Discharge Permit, either indirectly for discharge to the WRF under its permit, or directly for discharge to the ground. To meet the stringent discharge requirements of a State Waste Discharge Permit (Chapters 173-216 and 173-200 WAC), a multiple-stage treatment train would be needed (Figure 7). Such a treatment train would consist of:

1. Equalization tank. A 20,000-gallon equalization tank would provide a full day’s worth of storage, allowing treatment system maintenance without cessation of groundwater pumping
2. Oil-water separation. Solids and non-aqueous-phase liquids (e.g., LNAPL) would be separated from groundwater to avoid fouling downstream treatment equipment. The oil-water separation would generate two waste streams: settled solids and LNAPL.

Based on estimated solids precipitation and past LNAPL generation (Appendix E), annual generation is estimated at about 250 gallons, which would be managed as dangerous waste.

3. Clarification. An inclined plate clarifier with a chemical dosing system would precipitate and reduce dissolved metals and hardness concentrations to avoid fouling the downstream treatment equipment. Lime precipitation with polymer would be planned for the chemical dosing processes. The clarifier would generate settled solids. Based on a typical sludge generation rate of 5 percent of influent flow, about 0.6 gpm, or 315,000 gpy, of sludge would be discharged to an evaporation pond.
4. Air stripping. An air stripper would be needed to remove VOCs prior to removal of the total dissolved solids. An air stripper is essentially a stacked tray system in a shroud with an air blower. Water cascades over the trays as ambient air is blown through the shroud. Water spreads on the trays, creating surface area for evaporation and advection of VOCs to the passing air. Air stripper exhausts are often equipped with carbon filters to reduce VOC emissions to the atmosphere. For the estimated flows, a six-tray system with about 240 cubic feet per minute air flow would be appropriate.
5. Greensand pressure filter. A vertical greensand pressure filter would remove iron and manganese to prevent fouling of the downstream reverse osmosis unit. Chlorine dosing prior to the greensand filtration would activate and regenerate the filter media for removal of iron and manganese. A greensand pressure filter would need to be backwashed regularly with relatively clean water, which could be supplied from the reverse osmosis unit permeate flow.
6. Reverse osmosis. Reverse osmosis would reduce the hardness and total dissolved solids to below discharge limits. A reverse osmosis unit contains membranes that remove contaminants. For the estimated groundwater discharge rates, an 18-membrane system would be appropriate. Sodium bisulfite would be added upstream of the reverse osmosis unit to remove residual chlorine. Antiscalant chemicals would also be added upstream to increase the solubility of constituents that would otherwise tend to deposit as scale on the membranes (e.g., calcium carbonate, calcium sulfate). Membranes could be maintained with a clean-in-place system consisting of a pump, mixing tank with heater, and associated controls. The reverse osmosis unit would generate concentrated brine which would be discharged to an evaporation pond. The brine generation rate is typically about 30 percent of the influent flow. Based on the estimated groundwater discharge for northerly plume capture and continuous pumping from the Hole and P1 zone, brine generation would be about 3.5 gpm, or 1,840,000 gpy.
7. Granular activated carbon. Liquid-phase granular activated carbon (GAC) would provide a final polishing step to remove any remaining organic compounds. For the estimated flows, two 250-pound GAC units would be appropriate.

Bench-scale treatability testing would be recommended to evaluate waste generation rates, chemical dosing rates, efficacy of the individual treatment components, and efficacy of the overall treatment train. Accurate estimates of treatment results are not feasible for multiple chemicals and processes.

Representative treatment system operation, maintenance, and monitoring activities and costs would include:

- Typical equipment maintenance
- Pump and blower replacement (5-year life expectancy assumed)
- Compliance monitoring, including annual waste characterization samples from the separation systems and effluent characterization
- Annual replacement of membranes for the reverse osmosis system
- GAC replacement (estimated 50 treatment-day GAC life for upstream unit)
- Operations staff
- Electricity costs

The relatively small quantities of dangerous waste generated through groundwater treatment could be managed under the State Hazardous Waste Contract. Treatment would be needed for the duration of groundwater pumping, an estimated 30 years.

Unless treated groundwater is discharged to the WRF, regulatory compliance for this cleanup action component would include compliance with substantive requirements of applicable air emission regulations (Chapter 173-460 WAC) and application for a State Waste Discharge Permit.

A building to house the treatment system would be needed for security and for protection of costly equipment from the elements. A building of about 4,000 sf would allow proper spacing between pieces of equipment for operation and maintenance access. A fully insulated, pre-engineered metal building on a concrete floor with office space and a control room is typical. Building temperature would need to be maintained between 40 and 90°F for treatment purposes. Utilities would include electricity, communications, potable water, and sanitary sewer.

6.2.9 Evaporation

An evaporation pond could be used to dispose of contaminated groundwater, with or without pretreatment. Pond size would depend on how much groundwater is pumped and whether other disposal options are used if groundwater is pretreated. Evaporation ponds under consideration vary by alternative and range from about 1 acre of total lined area (seasonal pumping) to 9 acres (northerly plume capture and continuous pumping from the source area).

Regardless of size, an evaporation pond system would consist of:

- Conveyance piping from wells or a pretreatment train
- Excavation and placement of a soil berm to form a pond subgrade
- A double-liner system, including a leak-detection system
- Access roads
- Fencing

Although groundwater contaminant concentrations are not expected to exceed LDR regulatory levels for discharges from the Roza aquifer, Hole, and P1 zone, pretreatment system residuals (sludge) could be concentrated enough to trigger LDR requirements. LDR pond design criteria are sufficient for a pond handling contaminated water with concentrations below LDR thresholds. The evaporation pond would be designed and operated consistent with most stringent regulations at *WAC 173-350-330 Surface Impoundments and Tanks* and *40 CFR PART 264 - Standards For Owners And Operators Of Hazardous Waste Treatment, Storage, And Disposal Facilities, Subpart K – Surface Impoundments*. These regulations include applicable requirements for pond location, design, operation, monitoring, inspection, leak response and repair, closure, post-closure care and other requirements.

Evaporation in Ephrata is estimated to require 1 surface acre per million gpy of net evaporation based on precipitation and pan evaporation data from the Western Regional Climate Center (WRCC 2012a,b). Total lined area generally needs to be significantly larger than this evaporation rate to account for pond side slopes and freeboard. Although not included in the cost assumptions for this FS, it may be feasible to increase evaporation rates and reduce evaporation pond size for a given groundwater discharge through use of discharge distribution manifold or spray system.

VOC air emissions estimated for about 4.15 million gpy (discharge from northerly plume capture, P1 long-term pumping, and Hole dewatering) (Appendix A) are expected to exceed *de minimis* values for several VOCs but are below small quantity emission rates (SQER) for all VOCs.

An evaporation pond should be located close to areas where groundwater will be pumped or to *ex situ* treatment systems to limit transmission pipe installation and maintenance costs. The recently County purchased Whitson property would be suitable (Figure 1).

An evaporation pond would need to remain in service concurrent with groundwater pumping actions.

6.2.10 Infiltration

Extracted groundwater treated to state groundwater quality standards could be disposed of by infiltration under a State Waste Discharge Permit (Chapters 173-216 and 173-200 WAC).

An infiltration basin system would include:

- Conveyance piping from the treatment train discharge
- A prepared surface area of about 3,600 sf (based on estimated discharge and infiltration rates)
- Berms about 2 feet high around the basin to contain peak groundwater discharge during significant precipitation events
- Access roads
- Fencing

An infiltration basin could be located in an area identified by PGG as suitable (Appendix F), on a County-owned parcel adjacent to and east of the landfill property where the high permeable Outwash formation is near the surface.

An infiltration basin would need to remain in service concurrent with associated groundwater treatment actions.

6.2.11 Whitson Well Modification

Grant County purchased the property located to the northeast and adjacent to the landfill (former Whitson parcel) (Figure 1) in April 2012. The water supply well (Whitson well), located near the north property line (Figure 2), was an open borehole approximately 294 feet deep. VOCs were detected in this well, with two measured at concentrations above CULs. Therefore, it was concluded that the well provided a conduit for COCs from upper aquifers (such as the Roza aquifer) to migrate to lower aquifers. The well has been modified (August 2012) by sealing the lower portions of the well (130 to 294 feet) to prevent vertical migration of contaminants to deeper aquifers, and a new monitoring well was constructed in the Interflow aquifer in accordance with Chapter 173-160 WAC.

6.2.12 North End Soils Capping and Removal

North end soils were evaluated under MTCA Method C for direct exposure (industrial) and Method B for possible contamination of groundwater (Section 4.3). Possible exposure of terrestrial ecological receptors was also evaluated (Section 4.1.2). Although estimated potential risk to workers was below regulatory thresholds and exposure to terrestrial ecological receptors unlikely, north end soils were estimated to be a potential source of groundwater contamination based on the Fixed Parameter Three-phase Partitioning Model (WAC 173-340-747(4)). Potential groundwater concentration increases were not quantified.. Grant County plans to extend Neva Lake Road across the north end of the Ephrata Landfill that would cross the north end soil area (Figure 6).

The north end soil surface area (Figure 2) includes about 60,000 square feet (sf) of contaminated soils and 12,000 sf of soils containing some refuse, for a total of 72,000 sf (about 1.65 acres). The thickness of the north end contaminated soils varies from 5 feet to over 20 feet (with a typical thickness of about 6 feet).

The potential for COCs in north end soils to contaminate underlying groundwater could be eliminated by soil removal or significantly reduced by installing an impermeable cap. Capping would eliminate percolation of direct precipitation through north end soils; however, the relative contributions of percolation and lateral advection of groundwater are not known. Groundwater was observed above bedrock in contact with the lower portion of the north end soils at some locations (PGG 2010). Percolation could be significant, so capping options are evaluated later in this section for comparison with excavation. The following four options based on different combinations of excavation and capping were evaluated.

1. North end soils would be completely removed. This option would involve removing about 27,000 cubic yards (cy) of contaminated soils from the area, temporary stockpiling of the removed soil, analytical testing to evaluate whether stockpiled material is subject to LDR (requiring offsite management) or acceptable for deposition in the new landfill, offsite haul and disposal of unsuitable material, onsite haul of suitable material, and backfilling with clean soil.
2. North end soils would be capped in place, with limited excavation at the planned road alignment to provide clean soils for future work in the road prism. This option would involve removing approximately 1,200 cy of soil from the future road alignment to a width of 34 feet and to an average depth of 3 feet below the existing grade, temporary stockpiling of the removed soil, analytical testing to evaluate whether stockpiled material is subject to LDR (requiring offsite management) or acceptable for deposition in the new landfill, offsite haul and disposal of unsuitable material,

deposition of suitable material at the toe of the existing landfill cover system south of the north end soil area, minor grading to provide drainage for a capping system, and installation of a capping system similar to the original landfill cover system over the 72,000-sf area.

3. North end soils would be capped in place, with complete excavation at the planned road alignment. This option would involve removing approximately 3,800 cy of soil from the road alignment (34-foot corridor) to bedrock, temporary stockpiling of the removed soil, analytical testing to evaluate whether stockpiled material is subject to LDR (requiring offsite management) or acceptable for deposition in the new landfill, offsite haul and disposal of unsuitable material, deposition of suitable material at the toe of the existing landfill cover system south of the north end soil area, minor grading to provide drainage for a capping system, and installation of a capping system similar to the original landfill cover system over about 62,000 sf (area of north end soils not removed). No cap would be installed within the road alignment since the potentially contaminated soil in that area would be removed.
4. North end soils would be completely removed within the planned road prism and north of the road, with capping south of the road. This option would involve removing about 11,000 cy of soil from the road alignment north, temporary stockpiling of the removed soil, analytical testing to evaluate whether stockpiled material is subject to LDR (requiring offsite management) or acceptable for deposition in the new landfill, offsite haul and disposal of unsuitable material, deposition of suitable material at the toe of the existing landfill cover system south of the north end soil area, minor grading to provide drainage for a capping system, and installation of a capping system similar to the original landfill cover system over about 55,000 sf south of the planned road.

Excavation would potentially be a permanent solution for north end soils. Operations and maintenance for capping systems are equivalent to those for the closed original landfill.

6.3 CLEANUP ACTION COMPONENT COMBINATIONS AND COMPATIBILITY

Certain cleanup action components described above rely on one another to varying degrees, while some components are mutually exclusive. For instance, groundwater volumes generated by northerly plume capture would require either large-scale evaporation or treatment to groundwater standards and infiltration, but not both. Large-scale evaporation and treatment are mutually exclusive, since they are options for managing the same groundwater. In contrast, medium-scale evaporation would be used to dewater treatment residuals. As another example, SVE from the LNAPL area would rely on the establishment of a vadose zone through continuous P1 zone groundwater drawdown. SVE therefore depends on continuous pumping of the P1 zone. North end soil components would be compatible with any of the groundwater components. Table 12 summarizes which cleanup action components are mutually exclusive, compatible, or mutually dependent.

7. CLEANUP ACTION ALTERNATIVES

This section presents the cleanup action alternatives developed for the Site, which are based on combinations of the cleanup action components described in Section 6.2. Alternatives are evaluated and compared relative to MTCA cleanup regulations in terms of COC reduction in the northerly plume and COC removal from the source area. The preferred cleanup action alternative for the Site is also described. Cleanup objectives are first summarized below.

7.1 CLEANUP OBJECTIVES

Cleanup objectives for the Site are based on MTCA requirements; an evaluation of the data collected during the RI (PGG 2010, 2012) and summarized in Section 2, Hydrogeologic Understanding; and cleanup standards (Section 5).

7.1.1 MTCA Requirements

The MTCA cleanup regulations require that all cleanup actions meet certain minimum requirements (WAC 173-340-360).

Threshold requirements (WAC 173-340-360(2)(a)) are:

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

Other requirements (WAC 173-340-360(2)(b)) for alternatives meeting the above threshold requirements are:

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

Where it is not practicable to achieve groundwater CULs at the standard POC within a reasonable restoration timeframe, contaminant source treatment or removal, or groundwater containment is nonetheless required (WAC 173-340-360(2)(c) to the maximum extent practicable.

Cleanup action alternatives shall prevent or minimize present and future releases and migration of hazardous substances in the environment.

Cleanup actions shall not rely primarily on dilution and dispersion unless the incremental costs of any active remedial measures grossly exceed the incremental degree of benefits.

7.1.2 Groundwater Cleanup Objectives

Following are Site cleanup objectives for contaminated groundwater:

- Reduce or eliminate human exposure through ingestion of groundwater containing COCs at concentrations that exceed CULs in the northerly plume.

- Prevent further migration of COCs in concentrations exceeding CULs to drinking water sources through source removal and/or containment.

7.1.3 Soil Cleanup Objective

Following is the Site cleanup objective for contaminated soil:

- Ensure that contaminants in north end soils do not increase groundwater COC concentrations above CULs.

Risks to landfill workers were calculated to be below MTCA modified Method C limits (Section 4.3). Substantial wildlife exposure to north end soils was found to be unlikely (Section 4.1.2). Consequently, no further action is needed with respect to wildlife or worker exposure to soils.

7.2 CLEANUP ACTION ALTERNATIVES

The following eight cleanup action alternatives were developed based on MTCA requirements for cleanup action selection (WAC 173-340-360), the nature and extent of contamination at the Site, and the cleanup action components (Section 6.2) and their compatibility with one another (Section 6.3):

1. Monitored natural attenuation (MNA) and compliance monitoring
2. Seasonal groundwater extraction from the Hole and P1 zone and evaporation
3. Continuous groundwater extraction from the Hole and P1 zone and evaporation
4. Continuous groundwater extraction from the P1 zone, evaporation, and SVE
5. Northerly plume capture and evaporation
6. Northerly plume capture, seasonal groundwater extraction from the Hole and P1 zone, and evaporation
7. Northerly plume capture, continuous groundwater extraction from the Hole and P1 zone, evaporation, and SVE
8. Northerly plume capture, continuous groundwater extraction from the Hole and P1 zone, treatment, infiltration, and SVE

Compliance monitoring and institutional controls, needed for every alternative, are described generally in Sections 7.2.9.1 and 7.2.9.2, respectively. Natural attenuation processes will continue during the implementation of active measures under any of the alternatives. The natural attenuation process is part of every alternative in this sense. Alternative 1 explores the viability of natural attenuation combined with minimal active measures. Monitoring wells common to all alternatives are shown in Figure 8, and additional monitoring wells for Alternatives 5, 6, 7, and 8 are shown in the figures associated with those alternatives.

7.2.1 Alternative 1 – Monitored Natural Attenuation and Compliance Monitoring

Alternative 1 would consist of the following cleanup action components:

- Natural attenuation
- Manual LNAPL removal
- Institutional controls
- Compliance monitoring

This alternative was developed to evaluate whether natural attenuation processes following removal of the drums in 2008 could potentially meet the threshold requirements at WAC 173-340-360(2) within a reasonable timeframe.

Natural attenuation was only evaluated for the northerly plume because no COCs exceed CULs in the landfill plume components (Section 4.2).

Northerly plume attenuation was simulated for this alternative, and restoration timeframe would be over 71 years (Table 13; Table 3 in Appendix B). Vinyl chloride is the COC that drives the restoration time frame in every alternative (Table 11; Table 3 in Appendix B). An initial COC removal rate of 200 kg/yr was estimated as the current rate of COC destruction between the drum area and the groundwater POC. Many COCs that are not IHS disappear completely from groundwater between the drum area and the POC.

Manual LNAPL removal (absorbent socks) would continue under this alternative at an estimated removal rate of 5 to 10 gallons annually. This corresponds to an initial source area COC removal rate of about 6 kilograms per year (kg/yr). The total initial removal rate of organic COCs for Alternative 1 is 206 kg/yr (Table 13).

North end soils would not be removed or capped under this alternative. Groundwater monitoring results would be used to evaluate whether north end soil contamination might be increasing groundwater COC concentrations. Additional measures, such as capping or soil removal, would be evaluated if groundwater COC concentration increases are observed.

7.2.2 Alternative 2 – Seasonal Groundwater Extraction from the Hole and P1 Zone and Evaporation

Alternative 2 would consist of the following cleanup action components:

- Natural attenuation
- Manual LNAPL removal
- Seasonal pumping from the Hole and LNAPL area
- Evaporation of pumped groundwater
- North end soils capping
- Institutional controls
- Compliance monitoring

This alternative was developed to evaluate longer-term continuation of seasonal groundwater pumping from the Hole and LNAPL area combined with capping the north end soils. Figure 9 shows the extraction wells, which are existing, and possible location of a small evaporation pond for this alternative.

Seasonal pumping from the Hole and LNAPL area would resume, and manual LNAPL removal from P1 zone wells would continue under this alternative. Well EW-1 was pumped at a rate of about 1 gpm and well MW-34p1 at a rate of about 0.1 gpm at different times from 2009 to 2011 as an interim action, and LNAPL was removed manually from wells MW-34p1 and MW-36p1. An estimated combined pumping rate of 1.4 to 1.9 gpm could be achieved through pumping system optimization (Appendix A). At the above pump rates and average groundwater concentrations for these areas, the initial source area organic COC removal rate would be about 276 kg/yr (Table 13).

An evaporation pond would be used to dispose of pumped groundwater. VOC air emissions might exceed *de minimis* values for several VOCs but would be below SQER for all VOCs.

Although not simulated specifically for this alternative, the restoration time frame for Alternative 2 is assumed to be similar to that estimated for Alternative 1 (over 71 years for vinyl chloride).

Placing a cap similar in construction to the original landfill cover system over north end soils would eliminate percolation and reduce or eliminate the opportunity for COC dissolution to groundwater. North end soils occur over bedrock that is thought to be the bottom of the P1 zone. Groundwater was observed above bedrock at some locations, so some P1 zone groundwater advection through north end soils may occur. However, the soil samples upon which the soil-to-groundwater calculations were based (Section 4.3, Appendix C) were collected above the water table, suggesting that percolation could be a transport mechanism. Capping would stop percolation.

7.2.3 Alternative 3 – Continuous Groundwater Extraction from the Hole and P1 Zone and Evaporation

Alternative 3 would consist of the following cleanup action components:

- Natural attenuation
- LNAPL separation and disposal
- Continuous pumping of the Hole and P1 zone
- Evaporation of pumped groundwater
- North end soils removal within county road corridor, capping of remaining North end soils (clean road corridor)
- Institutional controls
- Compliance monitoring

This alternative was developed to evaluate whether Hole dewatering and long-term drawdown of the LNAPL area, combined with north end soils removal within a planned County road corridor and capping elsewhere, could reduce restoration timeframes. Figure 10 shows the extraction wells and possible location of a small evaporation pond for this alternative.

New extraction wells (EW-3, EW-4, EW-5, EW-6, EW-7, and EW-8) would allow dewatering of the Hole and increased groundwater removal from the LNAPL area compared to what would be achievable with Alternative 2, further reducing groundwater contact with COCs and increasing COC removal from the source area. The initial source area COC removal rate would be about 381 kg/yr (Table 13).

Pumped groundwater could be evaporated. Although the pond would need to be slightly larger than that for Alternative 2, VOC emissions would still be below SQER.

Northerly plume attenuation was simulated for this alternative (continuous P1 zone pumping), and restoration timeframes 34 years (Table 13; Table 3 in Appendix B).

North end soils would be removed to bedrock within the corridor limits of a planned Neva Lake Road extension, and the corridor would be backfilled with clean fill. Remaining north end soils would be capped as described for Alternative 2. North end soils removal from the road corridor would be one way to accommodate ordinary utilities and attendant maintenance or modification within the road corridor while preventing future contact with north end soils.

7.2.4 Alternative 4 – Continuous Groundwater Extraction from the P1 Zone, Evaporation, and Soil Vapor Extraction

Alternative 4 would consist of the following cleanup action components:

- Natural attenuation
- LNAPL separation and disposal
- Continuous pumping of the P1 zone
- SVE
- Evaporation of SVE condensate and groundwater
- Institutional controls
- Compliance monitoring

This alternative was developed to evaluate whether SVE as the primary source reduction component would be sufficient to achieve cleanup standards in a reasonable restoration timeframe. P1 zone groundwater drawdown is necessary to produce a vadose zone for vapor extraction and would contribute to source removal. Figure 11 shows the layout of Alternative 4. Three new extraction wells (EW-6, EW-7, and EW-8) would be needed for P1 zone drawdown. The initial organic COC removal rate would be about 922 kg/yr (Table 13), although that estimate is considerably more uncertain than alternative estimates based only on groundwater removal.

The 34 year restoration time estimated for this alternative (Table 13; Table 3 in Appendix B) is based on estimates for continuous pumping of the P1 zone. SVE should result in greater source removal over a given time interval than was simulated for continuous pumping from the LNAPL area alone; however, the amount of additional source removal over continuous pumping from the LNAPL area alone depends on the effectiveness of SVE. The combined effect of SVE and continuous pumping from the LNAPL area on plume attenuation was not simulated. As for the initial COC removal rate estimated above, estimated northerly plume COC reductions resulting from SVE are subject to considerably more uncertainty than for groundwater-based estimates.

A small SVE building to house equipment would need to be located near the P1 zone extraction area. SVE condensate would be evaporated along with groundwater. The evaporation pond size would be similar to that for Alternative 2.

North end soils would be managed the same as for Alternative 1 under this alternative.

7.2.5 Alternative 5 – Northerly Plume Capture and Evaporation

Alternative 5 would consist of the following cleanup action components:

- Natural attenuation
- Manual LNAPL removal
- Northerly plume capture
- Evaporation of pumped groundwater
- Institutional controls
- Compliance monitoring

This alternative was developed to evaluate whether northerly plume capture near the north landfill property boundary could reduce restoration timeframes compared to continuous pumping from the Hole and LNAPL area and SVE. A medium-scale evaporation pond would be needed for groundwater disposal. The initial organic COC removal rate would be about 206 kg/yr (Table 13).

The estimated restoration time frame associated with northerly plume capture is 20 years (Table 13; Table 3 in Appendix B). However, northerly plume capture would need to continue until contaminant sources are depleted by natural attenuation in this alternative.

Figure 12 shows the layout of Alternative 5. Northerly plume capture would require pumping from two new wells (EW-9 and EW-10) in the Roza aquifer high-T zone that extends under the western part of the north landfill property line (Figure 12). PGG has estimated the northerly plume could be hydraulically captured within about 1 year of pumping at a total discharge rate of 6 gpm from the new wells (Appendix A). Northerly plume capture should greatly curtail, if not stop, COC migration north of the landfill property line.

North end soils would be managed the same as for Alternative 1 under this alternative.

7.2.6 Alternative 6 – Northerly Plume Capture, Seasonal Groundwater Extraction from the Hole and P1 Zone, and Evaporation

Alternative 6 would consist of the following cleanup action components:

- Natural attenuation
- Manual LNAPL removal
- Seasonal pumping of the Hole and P1 zone
- Northerly plume capture
- Evaporation of pumped groundwater
- Institutional controls
- Compliance monitoring

This alternative was developed to evaluate the results of northerly plume capture combined with limited source reduction through seasonal groundwater extraction from the Hole and P1 zone and manual LNAPL removal. The initial organic COC removal rate would be about 268 kg/yr (Table 13). Figure 13 shows the layout of Alternative 6.

The estimated restoration time frame associated with northerly plume capture is 20 years (Table 13; Table 3 in Appendix B). However, northerly plume capture would need to continue until contaminant sources are depleted by natural attenuation and source removal components in this alternative.

Groundwater evaporation requirements would be slightly lower than for Alternative 7, which includes continuous pumping from the Hole and LNAPL area and SVE.

North end soils would be managed the same as for Alternative 1 under this alternative.

The source removal components of this option are seasonal pumping of the Hole and P1 zone, and NES removal.

7.2.7 Alternative 7 – Northerly Plume Capture, Continuous Groundwater Extraction from the Hole and P1 Zone, Evaporation, and Soil Vapor Extraction

Alternative 7 would consist of the following cleanup action components:

- Natural attenuation
- LNAPL separation and disposal
- Continuous pumping of the Hole and P1 Zone
- Northerly plume capture
- SVE
- Evaporation of pumped groundwater
- North end soils removal from county road corridor north, capping of remaining north end soils (cap/removal hybrid)
- Institutional controls
- Compliance monitoring

This alternative was developed to evaluate northerly plume capture, continuous pumping from the Hole and LNAPL area, SVE, and a combination of partial north end soils removal and capping the remaining north end soils. Large-scale evaporation would be needed for pumped groundwater and SVE condensate disposal. The initial organic COC removal rate would be about 1,004 kg/yr (Table 13), although that estimate is considerably more uncertain than estimates for alternatives based only on groundwater removal.

The estimated restoration time frame associated with northerly plume capture is 20 years (Table 13; Table 3 in Appendix B). However, northerly plume capture would need to continue until contaminant sources are depleted by natural attenuation and source removal components in this alternative.

Figure 14 shows the components associated with Alternative 7. The evaporation pond, about 5 surface acres, could be built on County-owned parcels adjacent to the landfill to the east and northeast.

North end soils would be removed from the Neva Lake Road corridor toward the north under this alternative. Excavated material would be contoured for drainage along the toe of the original landfill and capped, as would the remaining north end soils south of the road corridor.

The source removal components of this option are continuous pumping of the Hole and LNAPL area and partial north end soils removal.

7.2.8 Alternative 8 – Northerly Plume Capture, Continuous Groundwater Extraction from the Hole and P1 Zone, Treatment, Infiltration, and Soil Vapor Extraction

Alternative 8 would consist of the following cleanup action components:

- Natural attenuation
- LNAPL separation and disposal
- Continuous pumping of the Hole and P1 zone
- Northerly plume capture

- Pumped groundwater treatment
- SVE
- Evaporation of treatment residuals
- North end soils removal
- Institutional controls
- Compliance monitoring

This alternative was developed to evaluate discharge to the ground as the primary groundwater disposal option. Medium-scale evaporation would be used to dewater treatment residuals. For discharge to the ground, extracted groundwater would need to be treated to meet State groundwater quality criteria (Chapter 173-200 WAC). In addition, complete north end soils removal was evaluated. Alternative 8 is similar to Alternative 7, except for treatment and discharge to the ground (replaces large-scale evaporation) and complete north end soils removal (replaces hybrid approach). The initial COC removal rate would be about 1,083 kg/yr (Table 13), although that estimate is considerably more uncertain than alternative estimates based only on groundwater removal.

The estimated restoration time frame associated with northerly plume capture is 20 years (Table 13; Table 3 in Appendix B). However, northerly plume capture would need to continue until contaminant sources are depleted by natural attenuation and source removal components in this alternative.

Figure 15 shows the components associated with Alternative 8. Treatment facilities, a medium-scale evaporation pond (needed to evaporate water from treatment system residuals), and an infiltration basin could be located on County-owned parcels adjacent to the landfill to the east and northeast. Similar to Alternative 7, an SVE system would be located near the P1 zone extraction area, but SVE condensate could be discharged to the groundwater treatment system.

Figure 7 is a planning-level process flow diagram of the treatment system needed to make extracted groundwater comply with State groundwater quality criteria. Oil/water separation, clarification, greensand prefiltration backwash, and reverse osmosis brine would generate aqueous waste streams from which water would be evaporated and the solid residuals disposed of.

Treatment system capacity was assumed to be about 11 gpm for the purposes of evaluating this alternative. This capacity is based on the combined estimated discharge rates from northerly plume capture and continuous pumping of the Hole and P1 zone.

Complete north end soils removal would eliminate the possibility of future groundwater recontamination. The source removal components of this option are continuous pumping of the Hole and LNAPL area, and north end soils removal.

7.2.9 Common Requirements

Compliance monitoring and institutional controls would be needed for any cleanup action alternative.

7.2.9.1 Compliance Monitoring

Groundwater compliance monitoring is expected to be the key element of an overall compliance monitoring program. The MTCA cleanup regulations describe three types of compliance monitoring (WAC 173-340-410):

1. Protection monitoring
2. Performance monitoring
3. Confirmational monitoring

Although a groundwater compliance monitoring plan will be developed after the CAP is finalized, anticipated groundwater protection, performance, and confirmational monitoring activities are described below and provide the basis for cost estimates in this FS.

As part of a compliance monitoring program for the Site, different combinations of existing and new wells would be either gauged for water levels only or gauged and sampled as summarized in Table 14. Figure 8 shows the monitoring well locations that are common to all of the alternatives.

Figures 9 through 15 show additional new monitoring wells associated with Alternatives 2 through 8, respectively. The new monitoring wells are needed for the following reasons:

- Two well clusters, each with a well in the P2 zone, Roza aquifer, and Interflow aquifer (three wells per cluster). The first cluster, located at the northeast corner of the former Whitson parcel, comprises MW-57p2 and MW-58b (new wells) and MW-56c (the former Whitson well that was recently modified to monitor the Interflow aquifer). The second cluster (MW-59p2, MW-60b, and MW-61c), located at the southeast corner of the former Whitson property, would provide additional data along the eastern portion of the northerly plume.
- For the northerly plume capture, Hole dewatering, and long-term P1 pumping cleanup action components, two new wells would be installed north of MW-3b (MW-62p2, MW-63b) and four east of MW-3b (MW-64p2, MW-65b, MW-66p2, MW-67b) at two locations in the low-T zone along the northern landfill property line to monitor the POC in the P2 zone and Roza aquifer (six new monitoring wells).

All wells would be gauged for depth-to-water and, in the P1 zone, LNAPL measurements. In addition to gauging, samples would be analyzed as described below. Table 14 indicates whether a well would be used for gauging only or for gauging and sampling.

Sample analysis would include field parameters (pH, specific conductivity, dissolved oxygen, temperature, and reduction/oxidation potential), inorganics (arsenic, barium, cadmium, chromium, iron, manganese, and lead), VOCs (EPA Method 8260), and conventional compounds (nitrate, calcium, magnesium, potassium, sodium, ammonia, total organic carbon, sulfate, alkalinity, and total dissolved solids). Some field parameters and conventional compounds indicate the level and quality of biodegradation. Dissolved inorganics analysis indicates whether reducing conditions, which mobilize various metals, are present. VOC analysis measures the IHS concentrations and the by-products of biodegradation (e.g., dichloroethenes, vinyl chloride).

Gauging and sampling frequency would depend on groundwater concentrations and LNAPL occurrence, constituent concentration trends, and biodegradation indicators. Five years of quarterly monitoring and sampling of the wells listed in Table 14 was assumed for cost estimation. Five years of quarterly data would provide a seasonal record of constituent concentrations for the planned new wells. Monitoring and sampling frequency could potentially be reduced if data trends are relatively stable after 5 years, so semi-annual monitoring and sampling was assumed after year 5. Extraction wells (EW-# in Table 14) would be monitored monthly to optimize and monitor performance (e.g., maintain appropriate drawdown, assess radius of influence, and evaluate LNAPL accumulation).

The compliance monitoring plan will address specific reporting requirements. The following reports are representative of what may be required for this type of project:

- Groundwater compliance monitoring and well maintenance plan – Describes the long-term groundwater monitoring program for the Site to comply with MTCA requirements (Chapter 173-340 WAC). The groundwater monitoring required by the solid waste permit (Chapter 173-351 WAC) would not be included in this plan.
- Annual groundwater monitoring report – Describes the groundwater monitoring results for activities conducted the previous year. Any modifications to the groundwater monitoring program would be recommended in the annual reports. The groundwater monitoring required by the solid waste permit would not be included in these reports.
- Annual cleanup action activity report – Describes the cleanup action activities conducted the previous year and associated monitoring results from those activities. This report would include required regulatory reporting for the various cleanup action components implemented at the Site.
- Annual dangerous waste report – Documents the previous year’s dangerous waste generation and disposal, as required in Chapter 173-303 WAC.
- Periodic (5-year) review report – Provides an overall assessment of the activities conducted at the Site during the previous 5 years, as well as any recommendations for modifications to the groundwater monitoring and cleanup action activities.

7.2.9.2 Institutional Controls

The cleanup action components comprising the alternatives and discussed in Section 6 are engineered controls, which would be “designed and constructed prevent or limit the movement of, or exposure to, hazardous substances” (WAC 173-340-200), while institutional controls are measures to “limit or prohibit activities that may interfere with the integrity of an interim action or a cleanup action or result in exposure to hazardous substances at the site” (WAC 173-340-200). Institutional controls that can be undertaken at cleanup sites are described in the MTCA regulations (WAC 173-340-440). Institutional controls are required when CULs are established using MTCA Method B and if hazardous substances remain at a site, or if CULs are established using MTCA Method C. Institutional controls are also required if a conditional POC is established. All of the above circumstances apply at this Site.

Current institutional controls for the Site include the 1000-foot restriction for construction of domestic supply wells near a solid waste facility (WAC 173-160-171(3)(b)(iv)) (Figure 1), landfill closure requirements (Chapter 173-304 WAC), and partial fencing and signage around the landfill property.

Future institutional controls could include deed restrictions and an environmental or restrictive covenant on County properties affected by contamination from the Site, and these would be enforceable upon property transfer or sale. Future controls could also include additional fencing and signage.

Except for the Ackerblade parcel abutting the landfill property to the north (Figure 8), the County owns the properties beneath which groundwater COC concentrations exceed CULs. There are no water supply wells currently completed in this area, but part of area is outside the 1000 foot area within which drinking water well construction is already prohibited (Chapter 173-160 WAC). Restrictive covenants prohibiting well completion within the Roza and deeper aquifers beneath the northerly plume are recommended.

Other specific future institutional controls could be addressed in the CAP (WAC 173-380(1)(a)(vi)) or an engineering design report (WAC 173-340-400(4)(a)). Items to be presented or addressed in these reports may include:

- Site map with selected cleanup action components identified
- Existing engineered and institutional controls
- Engineered and/or institutional controls required by the selected cleanup action
- Activities at the Site that could result in disturbance of the selected cleanup action
- Institutional controls and procedures to be implemented on Site, including deed restrictions and environmental covenants
- Time table for establishing engineered and institutional controls or procedures
- Federal, state, or local entities responsible for implementation, maintenance, and enforcement of selected engineered and institutional controls
- Actions that may require permitting or other approval by the above entities
- Procedures for prohibiting certain Site activities that may affect the selected cleanup action and procedures for reporting improper or unauthorized uses or activities
- Procedures for measuring protectiveness for each implemented engineered and institutional control.

7.3 CLEANUP ACTION ALTERNATIVES EVALUATION

This section presents the evaluation of the eight cleanup action alternatives described in Section 7.2. These alternatives are compared to the cleanup objectives presented in Section 7.1 (Section 7.3.1), and they are evaluated based on contaminant reduction and control, as well as cost (Section 7.3.2 and 7.3.3, respectively). The preferred alternative is also identified (Section 7.4).

7.3.1 Comparison of Alternatives to Cleanup Objectives

The eight alternatives were compared to the cleanup objectives described in Section 7.1. The respective comparisons to threshold requirements, other requirements, groundwater cleanup objectives, and soil cleanup objectives are summarized in Table 15. All of the alternatives meet the cleanup objectives, although through different means and over different timeframes.

7.3.1.1 Comparison to Threshold Requirements

Threshold requirements (WAC 173-340-360(2)(a)) are protection of human health and the environment, compliance with cleanup standards, compliance with ARARs, and provision for compliance monitoring. The comparison focuses on northerly plume groundwater, which is the only medium outside the groundwater POC in which COC concentrations are known to exceed CULs.

Protection of human health and the environment would be achieved by each alternative through varied combinations of source removal and containment, protection monitoring, institutional controls, and natural attenuation. Groundwater COC concentrations in the Roza aquifer component of the northerly plume will likely continue to exceed CULs for some time for any of the alternatives. No water supply wells are known to draw from this plume component, and the Roza aquifer is not ordinarily targeted for water supply. Nonetheless, restrictive covenants prohibiting completion of water supply wells within the Roza and deeper aquifers beneath the northerly plume are recommended as part of any alternative (Section 7.2.9.2).

Compliance with cleanup standards depends partly on contaminant containment and partly on the determination of a reasonable restoration timeframe. Alternatives that include SVE (Alternatives 4, 7, and 8) provide comparatively high contaminant reduction in the source area, but plume restoration timeframes are still estimated 20 to 34 years. Although northerly plume capture (Alternatives 5, 6, 7, and 8) is estimated to result in the attainment of groundwater CULs at and beyond the POC within 20 years, northerly plume capture itself provides relatively low COC removal; thus, northerly plume capture beyond 20 years may be required if source contaminants are still present at levels that can continue to contribute to plume concentrations above CULs (Table 11) and must be maintained until the source is sufficiently depleted. Consequently, alternatives with more direct source removal are favored.

Similar to compliance with cleanup standards, compliance with ARARs depends partly on contaminant containment and partly on restoration timeframe.

All the alternatives provide for compliance monitoring, as described in Section 7.2.9.1.

7.3.1.2 Comparison to Other Requirements

Other requirements (WAC 173-340-360(2)(b)) are use of permanent solutions to the extent practicable, provision for a reasonable restoration timeframe, and consideration of public concerns.

Since the Site includes the Ephrata Landfill, a permanent solution is not feasible (Section 5.1). The drums, free liquid presumed to have leaked from the drums, and highly contaminated soil, collectively considered to be a significant source of groundwater contamination, were removed in 2008. The comparison of permanence is therefore essentially a comparison of the degree of additional contaminant removal achievable with each alternative.

Table 15 provides a descriptive comparison of the alternatives in terms of contaminant removal and control (based on estimates of initial organic COC removal rates presented in Table 13). The SVE alternatives (Alternatives 4, 7, and 8) provide comparatively high contaminant removal. Contaminant removal is comparatively low for Alternatives 1 and 5, in which natural attenuation would be the main source of contaminant removal. Although northerly plume capture is predicted to reduce the time required for COCs to meet CULs at the groundwater POC, the associated contaminant removal is estimated to be relatively low due to the lower concentrations of COCs in the Roza aquifer compared to the P1 zone (Table 11).

Restoration timeframes are shown in Table 11 and 13 and discussed above.

Consideration of public concerns is being addressed through the administration of a public participation program by Ecology.

7.3.1.3 Comparison to Groundwater Cleanup Objectives

The groundwater cleanup objectives (Section 7.1.2) are met to varying degrees under each alternative.

Comparatively low contaminant removal is achieved with Alternatives 1 and 5, which rely mainly on natural attenuation. Comparatively high contaminant removal is achieved with Alternatives 4, 7, and 8, which include SVE. Moderate contaminant removal is achieved through source area groundwater extraction with Alternatives 2, 3, and 6. Alternatives 5, 6, 7, and 8 provide comparatively high contaminant containment by reducing COC migration beyond the POC through northerly plume capture.

Human exposure would be prevented by institutional controls (i.e., restrictive covenants) recommended on water supply well installation in the Roza aquifer component of the northerly plume and lower aquifers with every alternative. Although northerly plume capture (Alternatives 5, 6, 7, and 8) is estimated to reduce northerly plume COC concentrations to below CULs within 20 years, it is an engineered control, is not efficient at source removal, and is not a permanent solution. Thus, northerly plume capture beyond 20 years may be required if source contaminants are still present at levels that can continue to contribute to plume concentrations above CULs.

7.3.1.4 Comparison to Soil Cleanup Objective

The soil cleanup objective (Section 7.1.3), ensuring that north end soils contaminants will not increase groundwater COC concentrations above CULs, would be achieved with all the alternatives. Soil removal could be considered the most permanent solution; however, it is unclear whether any further action is needed to protect groundwater. The Fixed Parameter Three-phase Partitioning Model results (Section 4.3, Table 7) may over-predict possible groundwater concentrations attributable to soil contamination. Monitoring (Alternatives 1, 4, 5, and 6) would show if groundwater contamination from north end soils were a threat, and actions need to be taken. Capping north end soils (Alternatives 2, 3, and 7) would prevent percolation, although as for removal, it is unclear whether any further action is needed.

7.3.2 Alternative Performance and Costs

The cleanup action alternatives described in Section 7.2 were further evaluated based on initial COC removal, when groundwater CULs would be met at the POC and beyond, and cost. The cost (present worth in 2012 dollars) per unit of initial organic COC removal (kg/yr) metric provides a basis upon which to evaluate and compare alternatives. It is the estimated initial (first-year) COC removal rate divided by the present worth of the alternative. Tables 15 and 16 summarize this comparison. Appendix G contains detailed cost estimates and Appendix H contains the initial organic COC removal rate estimates. The evaluation of each alternative is summarized below.

Alternative 1 – Monitored Natural Attenuation and Compliance Monitoring

Alternative 1, although protective, would require the longest restoration timeframes for natural attenuation processes to deplete COC concentrations below CULs in the northerly plume. The restoration timeframe would be over 71 years with this alternative (Tables 13; Table 3 in Appendix B). The evaluation of this alternative provides a sense of the timeframes over which natural attenuation processes occur. This is important, because natural attenuation is a component of all alternatives, regardless of which active cleanup measures are implemented. Alternative 1, at an estimated present worth (cost) of $2,386,000, is the least costly among the alternatives (Table 16). Although the present worth cost is the lowest among the alternatives, Alterative 1 has a moderate contaminant removal unit cost at $11,584/kg/yr (Table 13).

Alternative 2 – Seasonal Groundwater Extraction from the Hole and LNAPL Area and Evaporation

Alternative 2, although similar to Alternative 1 in other respects, includes additional source removal through seasonal pumping from the Hole and LNAPL area. Although not quantitatively estimated, it is reasonable to expect that restoration timeframes would be somewhat shorter than for Alternative 1. North end soils capping and attendant prevention of possible groundwater contamination is not expected to significantly reduce restoration timeframes in the Roza aquifer component of the northerly plume. The present worth of Alternative 2 ($3,926,000) is substantially higher than Alternative 1, yet the unit cost of COC removal is comparatively moderate at $14,224/kg/yr (Table 13).

Alternative 3 – Continuous Groundwater Extraction from the Hole and LNAPL Area and Evaporation

Alternative 3 is similar to Alternative 2, but with continuous pumping from the Hole and LNAPL area instead of seasonal pumping. Although continuous pumping would require additional extraction points and the evaporation pond would need to be larger than for Alternative 2, the estimated initial COC removal would be substantially higher. This alternative was estimated to reduce northerly plume IHS concentrations significantly over 34 years (Table 13; Table 3 in Appendix B). Removing north end soils from the planned Neva Lake Road corridor and capping the remaining north end soils is not expected to significantly reduce restoration timeframes. The present worth of Alternative 3 ($5,091,000) is higher than Alternative 2, yet the unit cost of COC removal is lower ($13,373/kg/yr) due to more contaminant removal (Table 13).

Alternative 4 – Continuous Groundwater Extraction from the LNAPL Area, Evaporation, and Soil Vapor Extraction

Alternative 4 shows the potential for significantly increased contaminant removal with SVE. Continuous pumping from the P1 zone to create a vadose zone for SVE implementation accounts for about 145 kg/yr of the initial COC removal (Table 11). The initial removal rate for SVE is estimated at 577 kg/yr (Table 11). As mentioned in Section 6.2.7, SVE performance is sensitive to variables that have not been determined for this site. The 34 year estimated restoration time frame results from continuous pumping of the P1 zone (Tables 11 & 13; Table 3 in Appendix B). Alternative 4 is the lowest cost alternative that includes SVE. The present worth of Alternative 4 ($5,309,000) is slightly higher than Alternative 3, yet the unit cost of COC removal ($5,759/kg/yr) is the lowest among the alternatives (Table 13).

Alternative 5 – Northerly Plume Capture and Evaporation

Alternative 5 shows the effect of hydraulic containment of the northerly plume. Hydraulic containment is estimated to result in a 20 restoration timeframe (Table 13; Table 3 in Appendix B), although the initial organic COC removal rate with this alternative is comparatively low (206 kg/yr) (Table 13). Alternative 5 is the lowest cost alternative that includes northerly plume capture. The present worth of Alternative 5 ($5,997,000) is higher than Alternative 4, and the unit cost of COC removal ($29,115/kg/yr) is the highest among the alternatives by a substantial margin (Table 13).

Since this alternative does not include source removal components, maintenance of environmental restoration depends on long-term continuation of northerly plume capture and natural depletion of the source. Simulations (Appendix B) suggest that northerly plume capture would likely be required for 71 years or more before the source is likely to be depleted enough to allow cessation of active measures.

Alternative 6 – Northerly Plume Capture, Seasonal Groundwater Extraction from the Hole and LNAPL Area, and Evaporation

Alternative 6 is similar to Alternative 5, but with the addition of seasonal pumping from the Hole and P1 zone and evaporation. Although higher than that of Alternative 5, the initial COC removal rate (268 kg/yr) is moderate in comparison to the other alternatives (Table 13). The present worth of Alternative 6 is $6,617,000 and the unit cost of COC removal ($24,719/kg/yr) is the second highest among the alternatives (Table 13).

Alternative 7 – Northerly Plume Capture, Continuous Groundwater Extraction from the Hole and LNAPL Area, Evaporation, and Soil Vapor Extraction

Alternative 7 combines northerly plume capture and continuous groundwater extraction from the Hole and P1 zone with SVE. The estimated restoration time frame of 20 years (Table 13) is based on northerly plume capture, which would need to continue until the contaminant source is sufficiently depleted. Removing north end soils from the planned Neva Lake Road corridor northward and capping the remaining north end soils is not expected to significantly reduce restoration timeframes, although about 81 kg of COCs would be removed on a one-time basis as a result (Table 11). The present worth of Alternative 7 ($8,549,000) is the second highest of the eight alternatives, yet the initial organic COC removal (1,004 kg) is similar to that of Alternative 4 (922 kg) (Table 13). The unit cost of COC removal for Alternative 7 ($8,511/kg/yr) is the second lowest among the alternatives (Table 13).

Alternative 8 – Northerly Plume Capture, Continuous Groundwater Extraction from the Hole and LNAPL Area, Treatment, Infiltration, and Soil Vapor Extraction

Alternative 8 is similar to Alternative 7, but with pumped groundwater treatment and infiltration replacing large-scale evaporation. North end soils would be completely removed for this alternative, providing a one-time COC removal of 160 kg compared to 81 kg removal with the hybrid approach in Alternative 7 (Table 11). That is the only difference in COC removal between Alternatives 7 and 8. In fact, any north end soil component could be implemented under any alternative, so the apparent difference in COC removal is arbitrary. Although treatment and infiltration is a technically feasible alternative to large-scale evaporation, the treatment system present worth cost of $7,580,000 (Table 11) is disproportionately expensive. Treatment neither reduces restoration timeframes nor increases COC removal rates compared to large-scale evaporation. Evaporation would not be fully avoided, because medium-scale evaporation would be needed to manage treatment by-products. The present worth of Alternative 8 is $15,460,000 and the unit cost of COC removal is $14,270/kg/yr (Table 13).

7.3.3 Disproportionate Cost Analysis

MTCA (WAC 173-340-360(3)(e)) provides for comparative evaluation of incremental degree of benefits achieved by each alternative to incremental cost, or disproportionate cost analysis. The alternatives were compared on this basis, as summarized in Table 16.

Alternatives 1 through 4 are numbered in order of increasing permanence. The incremental costs of Alternatives 2 and 3, respectively, are associated with incremental increases in contaminant reduction primarily due to increased source area groundwater removal.

The incremental cost of Alternative 4 ($218,000) is the least among the alternatives (Table 16), yet SVE provides a substantial increase in the initial organic COC removal rate from 381 kg/yr under Alternative 3 to 922 kg/yr under Alternative 4 (Tables 13 & 16). Additionally, Alternative 4 is the lowest cost alternative that includes SVE.

Alternative 5 is the lowest cost alternative that includes northerly plume capture. The incremental cost is $688,000 (Table 16). Although the restoration time frame estimated for northerly plume capture is 20 years, the initial organic COC removal rate (206 kg/yr) is substantially less than Alternative 4 (922 kg/yr) (Table 13). This option thus favors near-term reductions in northerly plume component concentrations and delays permanent source reductions relative to other alternatives that include source removal components.

The incremental cost of Alternative 6 ($620,000) (Table 16) is accompanied by a higher COC removal rate than for Alternative 5; however, the difference in initial COC removal rates is not compelling, since both removal rates are near the low end of the range for the alternatives analyzed (Table 13).

The incremental cost of Alternative 7 is $1,932,000 compared to Alternative 6 (Table 16). The incremental cost of Alternative 7 compared to Alternatives 4 and 5, the lowest-cost alternatives that include SVE and northerly plume capture, respectively, are $3,240,000 (61 percent higher), and $2,552,000 (43 percent higher), respectively.

Alternative 7, like the other alternatives, does not provide a permanent solution. Furthermore, northerly plume capture will need to continue longer than 20 years, until source contaminants have been reduced to levels that will not cause exceedances of CULs.

For the above reasons, Alternative 7 is disproportionately costly, particularly in comparison to Alternative 4, which provides a similar degree of permanence (source reductions through SVE).

Alternatives 7 and 8 differ primarily in the *ex-situ* groundwater management approach; the initial COC removal rate difference results from pairing different north end soil components with the different alternatives. Contaminant removal and containment are equal for Alternatives 7 and 8, yet the incremental cost of Alternative 8 ($6,911,000) is 81 percent higher than Alternative 7 (Table 16) due to the high costs associated with treatment and infiltration of extracted groundwater. The cost of Alternative 8 is patently disproportionate compared to Alternative 7.

7.4 PREFERRED CLEANUP ACTION ALTERNATIVE

Alternative 4, which includes continuous groundwater extraction from the LNAPL area, evaporation, and SVE, is recommended as the preferred cleanup action for Ephrata Landfill for the following reasons:

1. The comparatively high COC removal rates associated SVE correspond with a comparatively high degree of permanence.
2. Cleanup would remain focused on the most highly contaminated area of the Site, namely the LNAPL area, which is closely associated with the drum area.
3. It provides the lowest unit cost of source removal among the alternatives.

4. The estimated 34 year restoration timeframe for groundwater in the northerly plume components, while not the lowest among the alternatives, is less than for natural attenuation or seasonal pumping from the Hole and P1 zone.
5. The cost ($5,309,000) is not disproportionate compared to the benefits.

Alternative 4 is therefore recommended as the basis for the CAP and engineering design of the final cleanup action for Ephrata Landfill.

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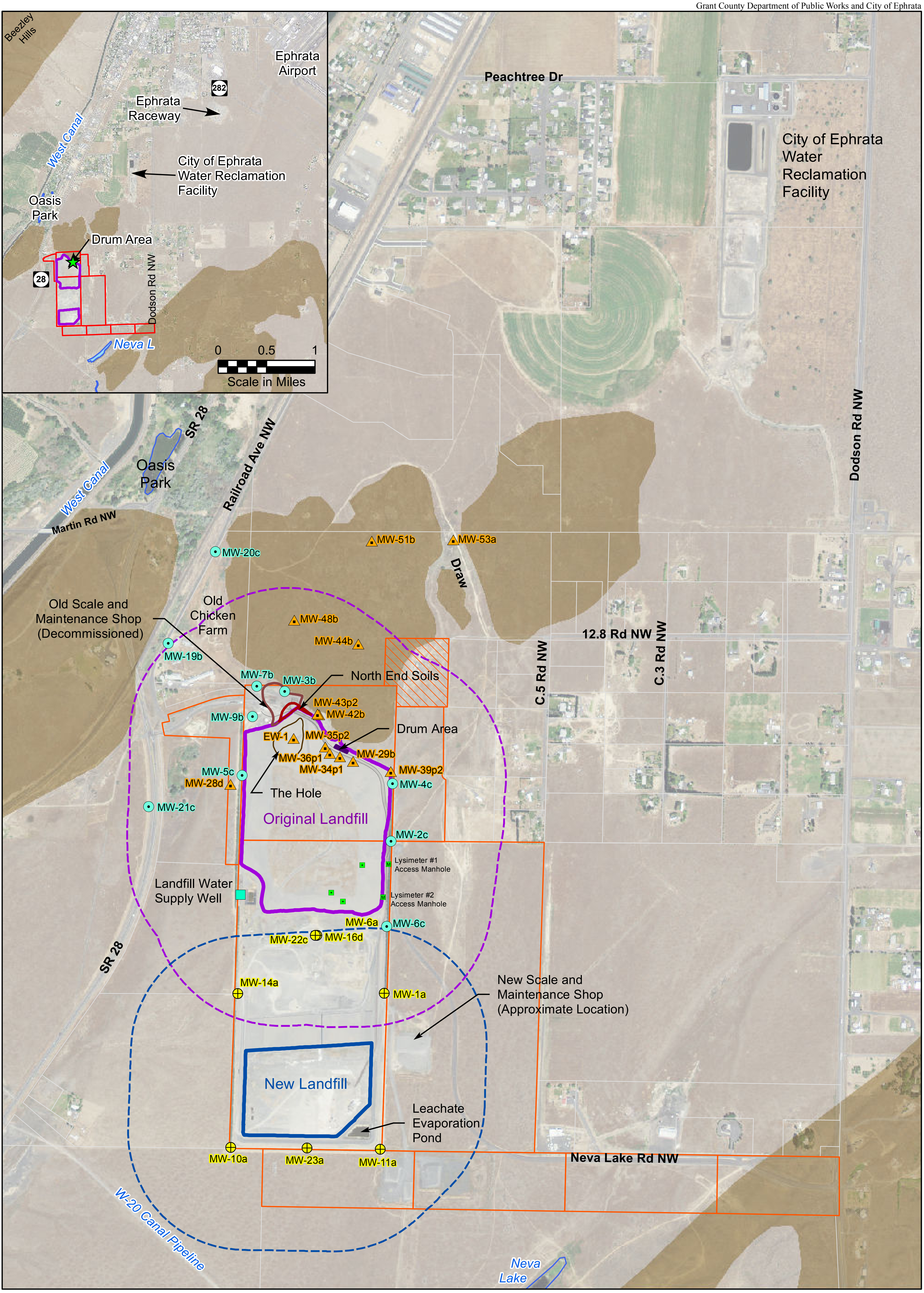
FIGURES



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Parametrix
PgG

N

0 400 800
Scale in Feet
2011 NAIP Orthophoto

- ▲ Existing RI Monitoring Well
- ⊙ Original Landfill Monitoring Well
- ⊕ New Landfill Monitoring Well
- 🟩 Landfill Water Supply Well
- ▪ Lysimeter
- ▪ Access Manhole
- ▭ Basalt Outcrop

Note: Colors of shaded well IDs correspond to type of monitoring well.

- ▭ Original Landfill
- ▭ New Landfill
- ▭ 1000' Buffer on Original Landfill
- ▭ 1000' Buffer on New Landfill
- ▭ County-owned Parcel
- ▨ Former Whitson Property

North End Soils
- ▭ Estimated Area of Refuse Not Capped
- ▭ Estimated Area of Uncapped Contaminated Soils

Figure 1
Ephrata Landfill
Site Map

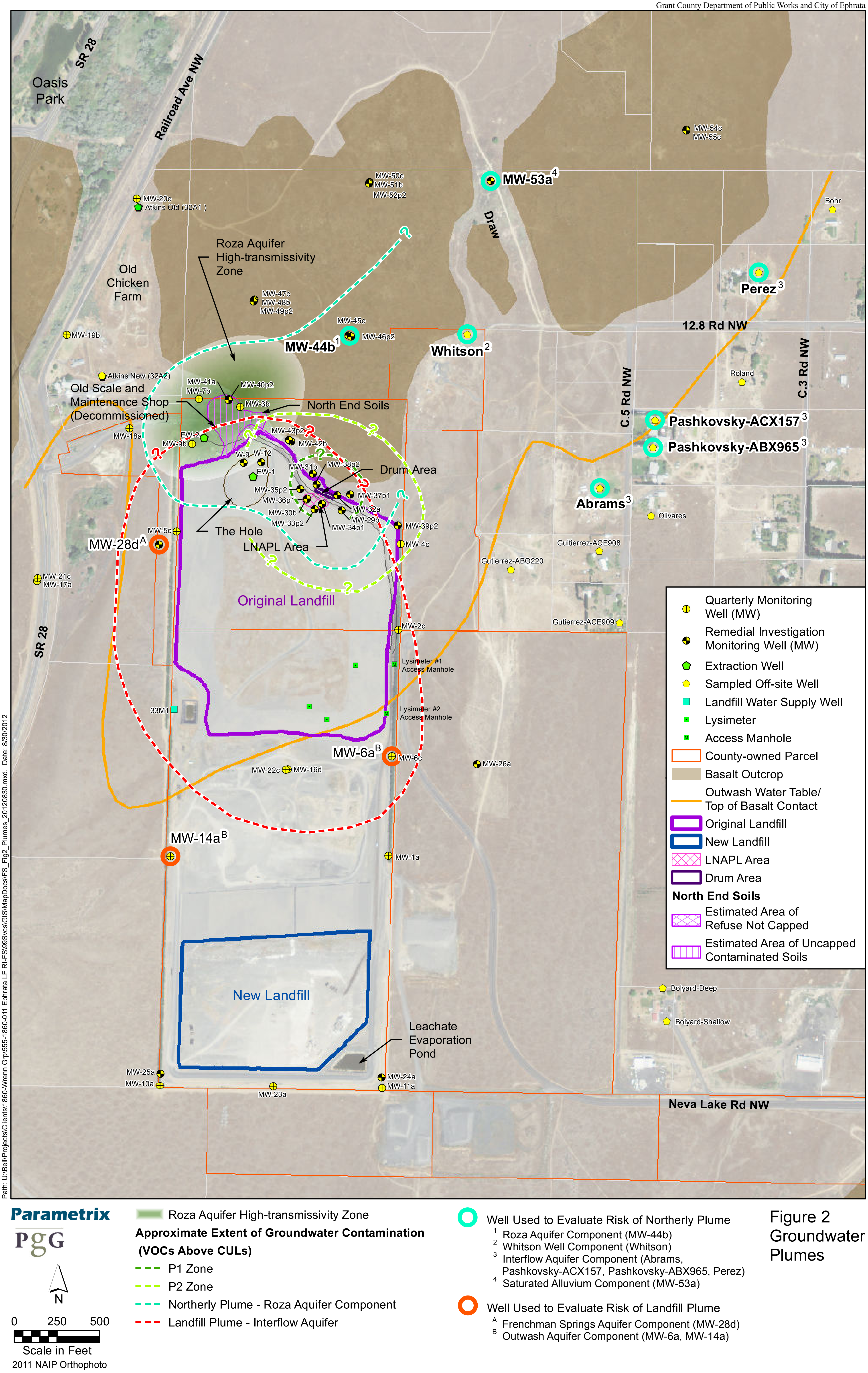
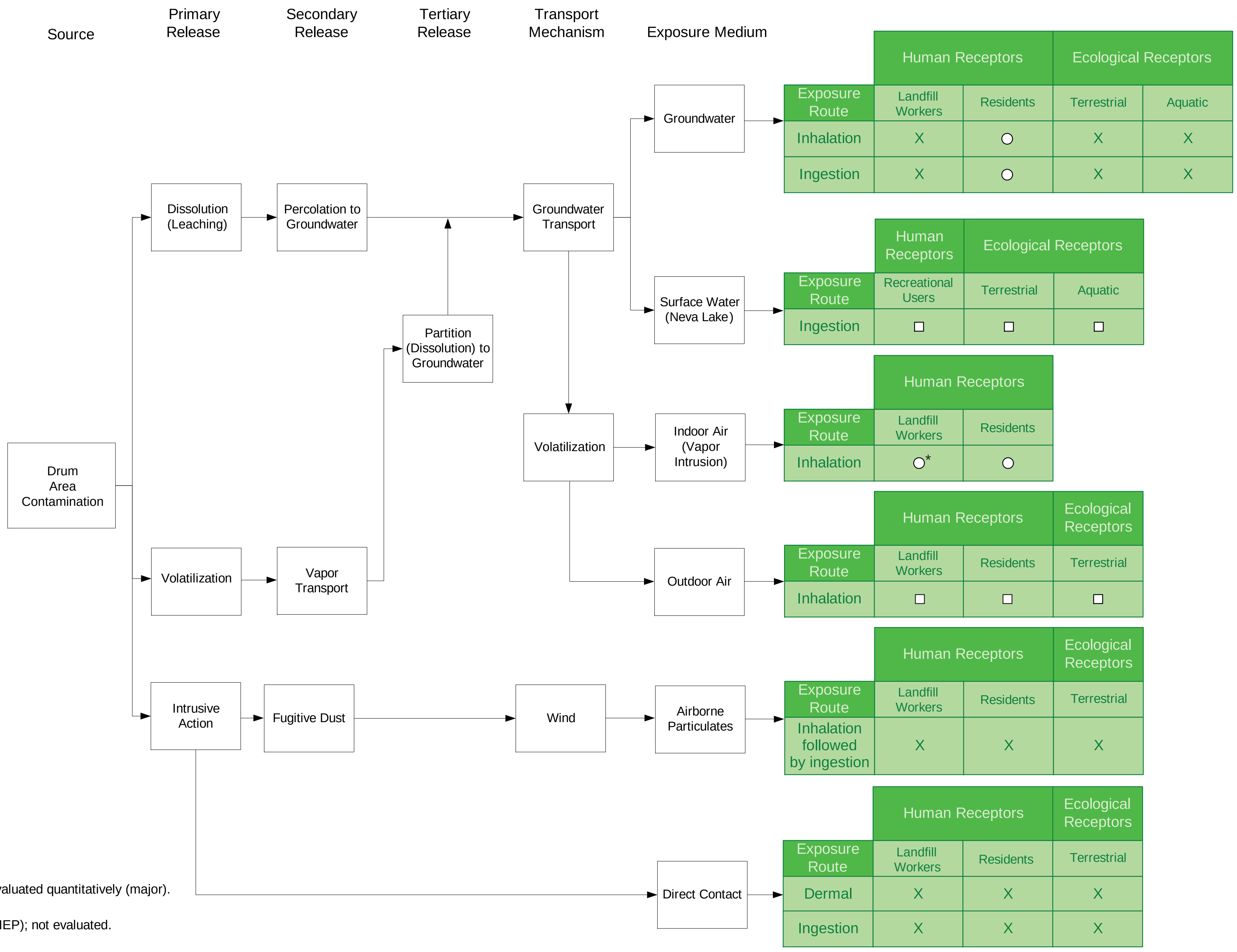


Figure 2
Groundwater Plumes



Groundwater

	Human Receptors		Ecological Receptors	
Exposure Route	Landfill Workers	Residents	Terrestrial	Aquatic
Inhalation	X	○	X	X
Ingestion	X	○	X	X

Surface Water (Neva Lake)

	Human Receptors	Ecological Receptors	
Exposure Route	Recreational Users	Terrestrial	Aquatic
Ingestion	☐	☐	☐

Indoor Air (Vapor Intrusion)

	Human Receptors	
Exposure Route	Landfill Workers	Residents
Inhalation	○*	○

Outdoor Air

	Human Receptors		Ecological Receptors
Exposure Route	Landfill Workers	Residents	Terrestrial
Inhalation	☐	☐	☐

Airborne Particulates

	Human Receptors		Ecological Receptors
Exposure Route	Landfill Workers	Residents	Terrestrial
Inhalation followed by ingestion	X	X	X

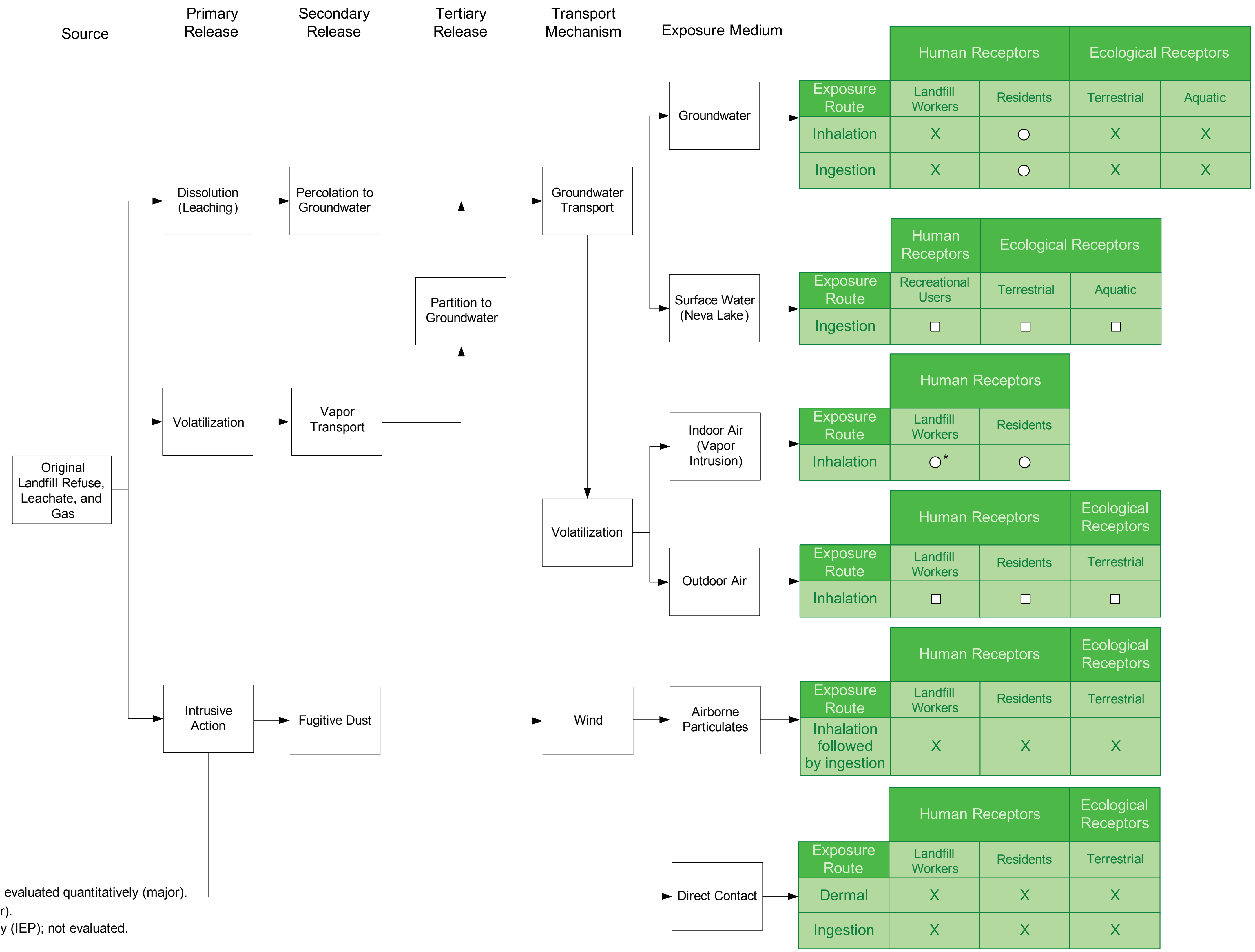
Direct Contact

	Human Receptors		Ecological Receptors
Exposure Route	Landfill Workers	Residents	Terrestrial
Dermal	X	X	X
Ingestion	X	X	X

○ Complete exposure pathway; evaluated quantitatively (major).
☐ Evaluated qualitatively (minor).
X Incomplete exposure pathway (IEP); not evaluated.

*From groundwater at the new scale and maintenance shop location.

Figure 3
Conceptual Site Model for Drum Area Contamination at the Ephrata Landfill



Groundwater:

	Human Receptors		Ecological Receptors	
Exposure Route	Landfill Workers	Residents	Terrestrial	Aquatic
Inhalation	X	○	X	X
Ingestion	X	○	X	X

Surface Water (Neva Lake):

	Human Receptors	Ecological Receptors	
Exposure Route	Recreational Users	Terrestrial	Aquatic
Ingestion	☐	☐	☐

Indoor Air (Vapor Intrusion):

	Human Receptors	
Exposure Route	Landfill Workers	Residents
Inhalation	○*	○

Outdoor Air:

	Human Receptors		Ecological Receptors
Exposure Route	Landfill Workers	Residents	Terrestrial
Inhalation	☐	☐	☐

Airborne Particulates:

	Human Receptors		Ecological Receptors
Exposure Route	Landfill Workers	Residents	Terrestrial
Inhalation followed by ingestion	X	X	X

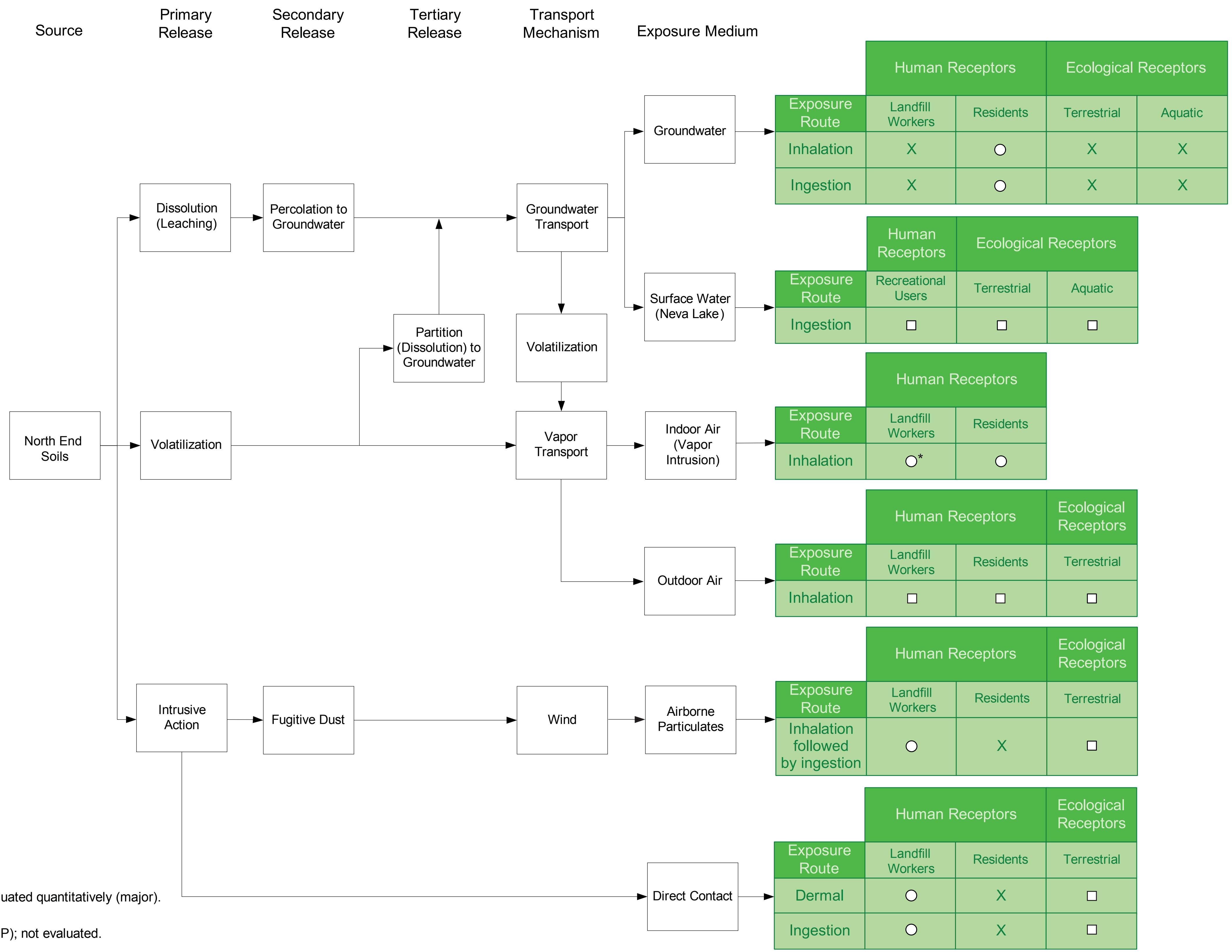
Direct Contact:

	Human Receptors		Ecological Receptors
Exposure Route	Landfill Workers	Residents	Terrestrial
Dermal	X	X	X
Ingestion	X	X	X

○ Complete exposure pathway; evaluated quantitatively (major).
☐ Evaluated qualitatively (minor).
X Incomplete exposure pathway (IEP); not evaluated.

*From groundwater at the new scale and maintenance shop location.

Figure 4
Conceptual Site Model for the Original Landfill Refuse, Leachate, and Gas at the Ephrata Landfill



Groundwater:

	Human Receptors		Ecological Receptors	
Exposure Route	Landfill Workers	Residents	Terrestrial	Aquatic
Inhalation	X	○	X	X
Ingestion	X	○	X	X

Surface Water (Neva Lake):

	Human Receptors	Ecological Receptors	
Exposure Route	Recreational Users	Terrestrial	Aquatic
Ingestion	☐	☐	☐

Indoor Air (Vapor Intrusion):

	Human Receptors	
Exposure Route	Landfill Workers	Residents
Inhalation	○*	○

Outdoor Air:

	Human Receptors		Ecological Receptors
Exposure Route	Landfill Workers	Residents	Terrestrial
Inhalation	☐	☐	☐

Airborne Particulates:

	Human Receptors		Ecological Receptors
Exposure Route	Landfill Workers	Residents	Terrestrial
Inhalation followed by ingestion	○	X	☐

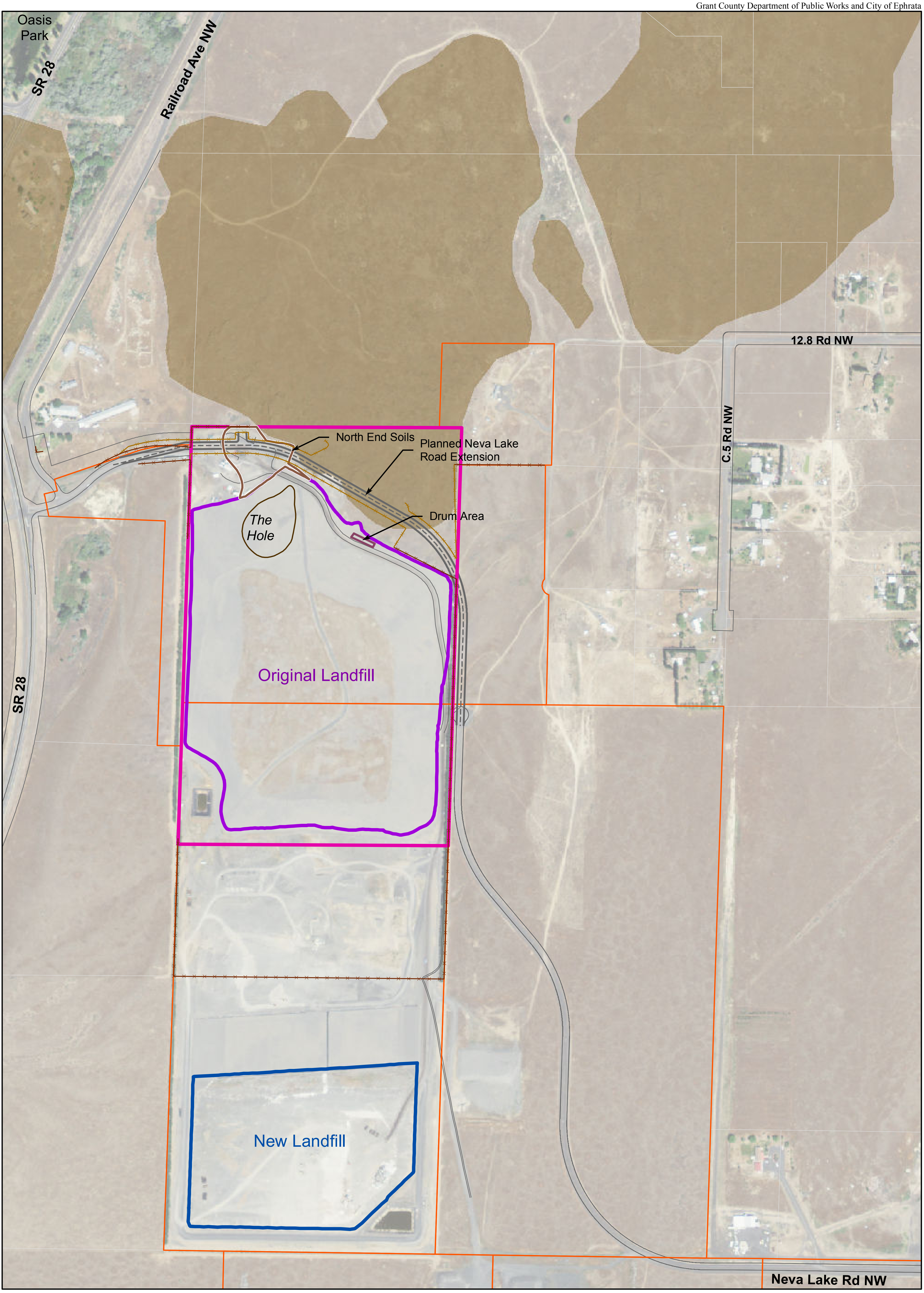
Direct Contact:

	Human Receptors		Ecological Receptors
Exposure Route	Landfill Workers	Residents	Terrestrial
Dermal	○	X	☐
Ingestion	○	X	☐

○ Complete exposure pathway; evaluated quantitatively (major).
☐ Evaluated qualitatively (minor).
X Incomplete exposure pathway (IEP); not evaluated.

*From groundwater at the new scale and maintenance shop location.

Figure 5
Conceptual Site Model for North End Soils at the Ephrata Landfill

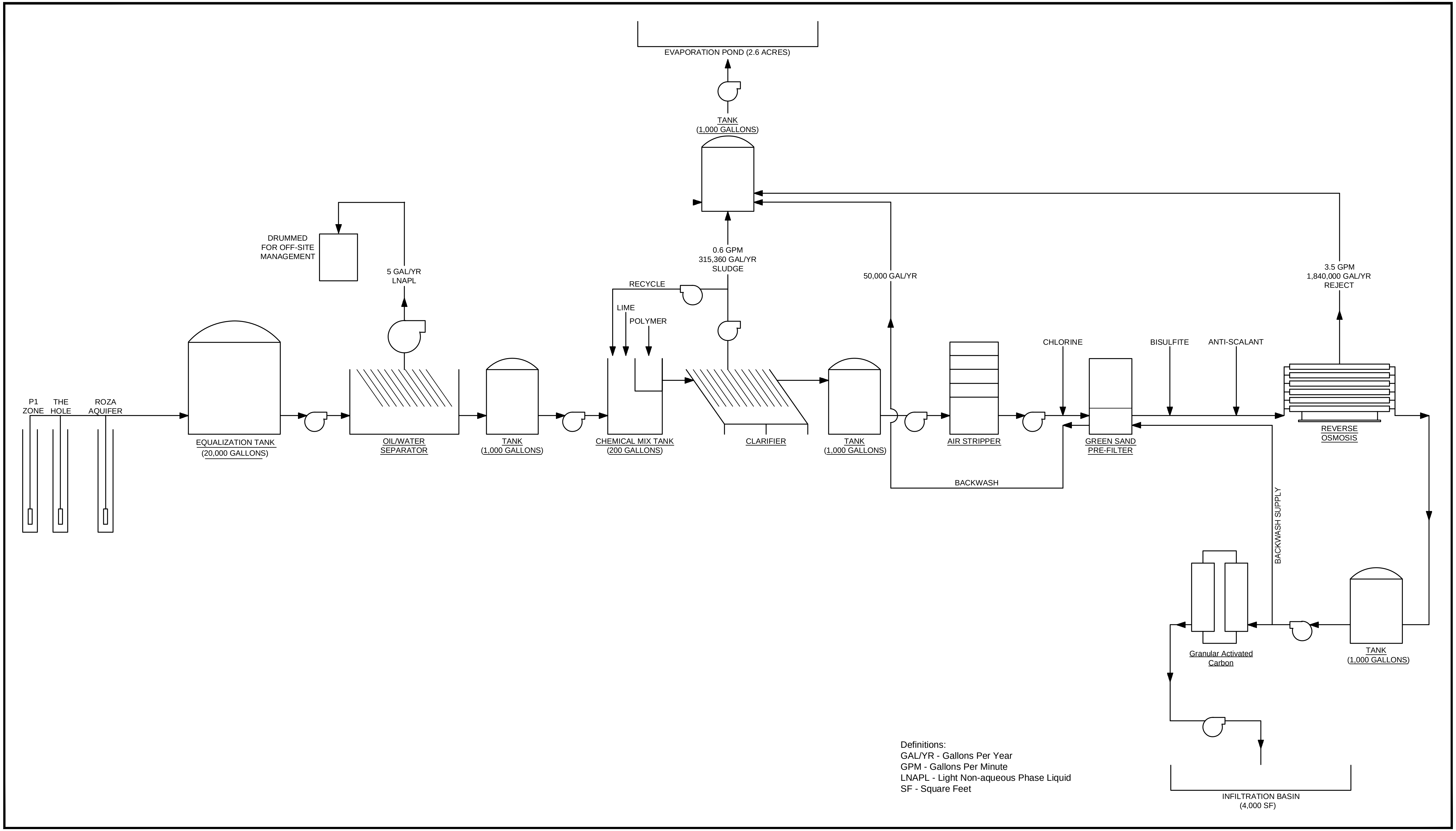


Path: U:\Bell\Projects\Clients\1860-Wrenn Grp\555-1860-011 Ephrata LF RI-FS\99Svcs\GIS\MapDocs\FS_Fig6_POCs_20120830.mxd. Date: 8/30/2012

Parametrix

PgG

Figure 6
Ephrata Landfill
Groundwater
and Soil Points
of Compliance



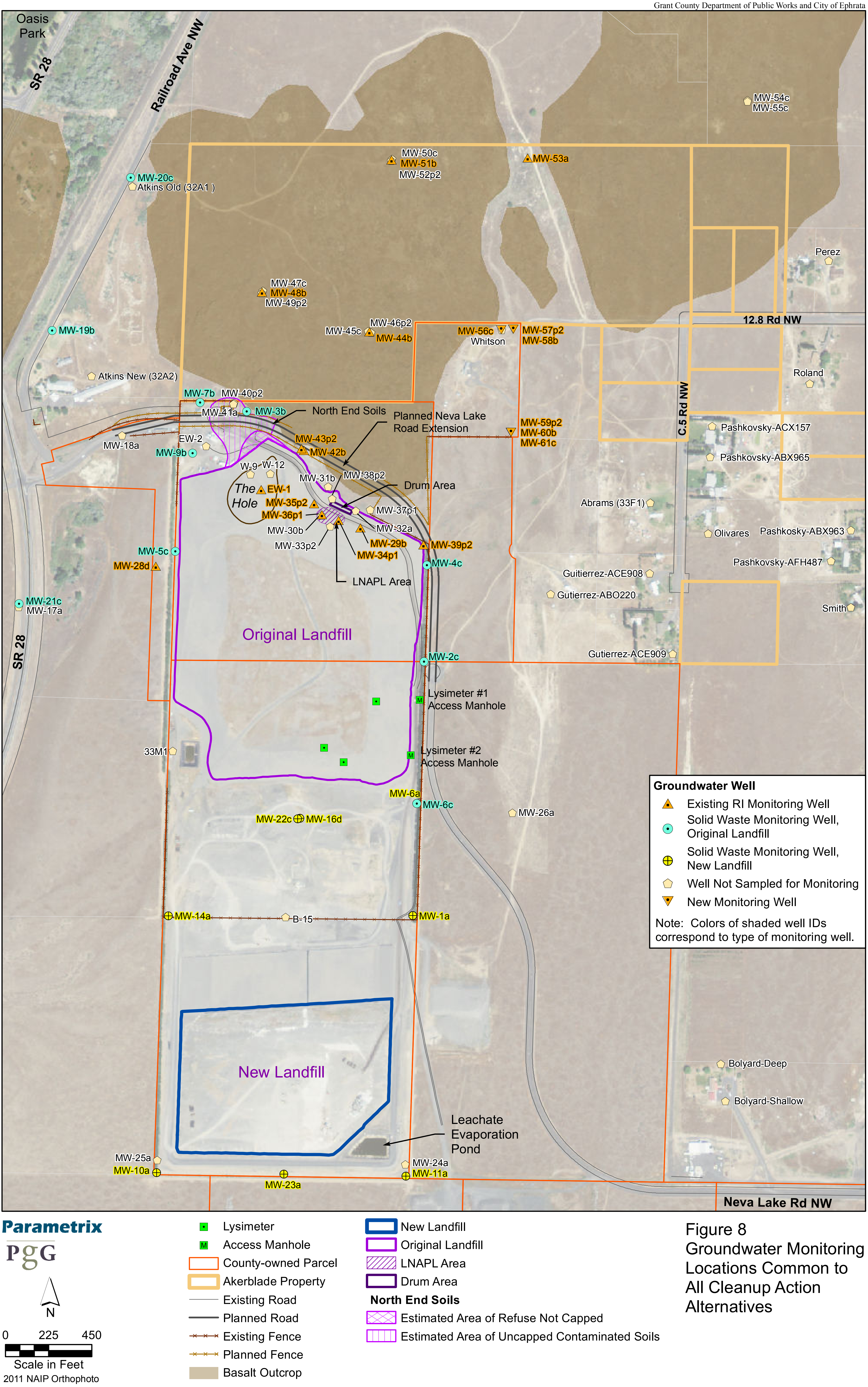
Definitions:
GAL/YR - Gallons Per Year
GPM - Gallons Per Minute
LNAPL - Light Non-aqueous Phase Liquid
SF - Square Feet

Parametrix DATE: August 30, 2012 FILE: BR1860011P06T01C-F01

0
SCALE IN FEET

Note:
Dimensions and capacities are based on planning-level engineering for FS purposes and are approximate.

Figure 7
Pumped Groundwater Treatment System Process Flow Diagram for the Ephrata Landfill



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Parametrix
PGG

Figure 8
Groundwater Monitoring Locations Common to All Cleanup Action Alternatives

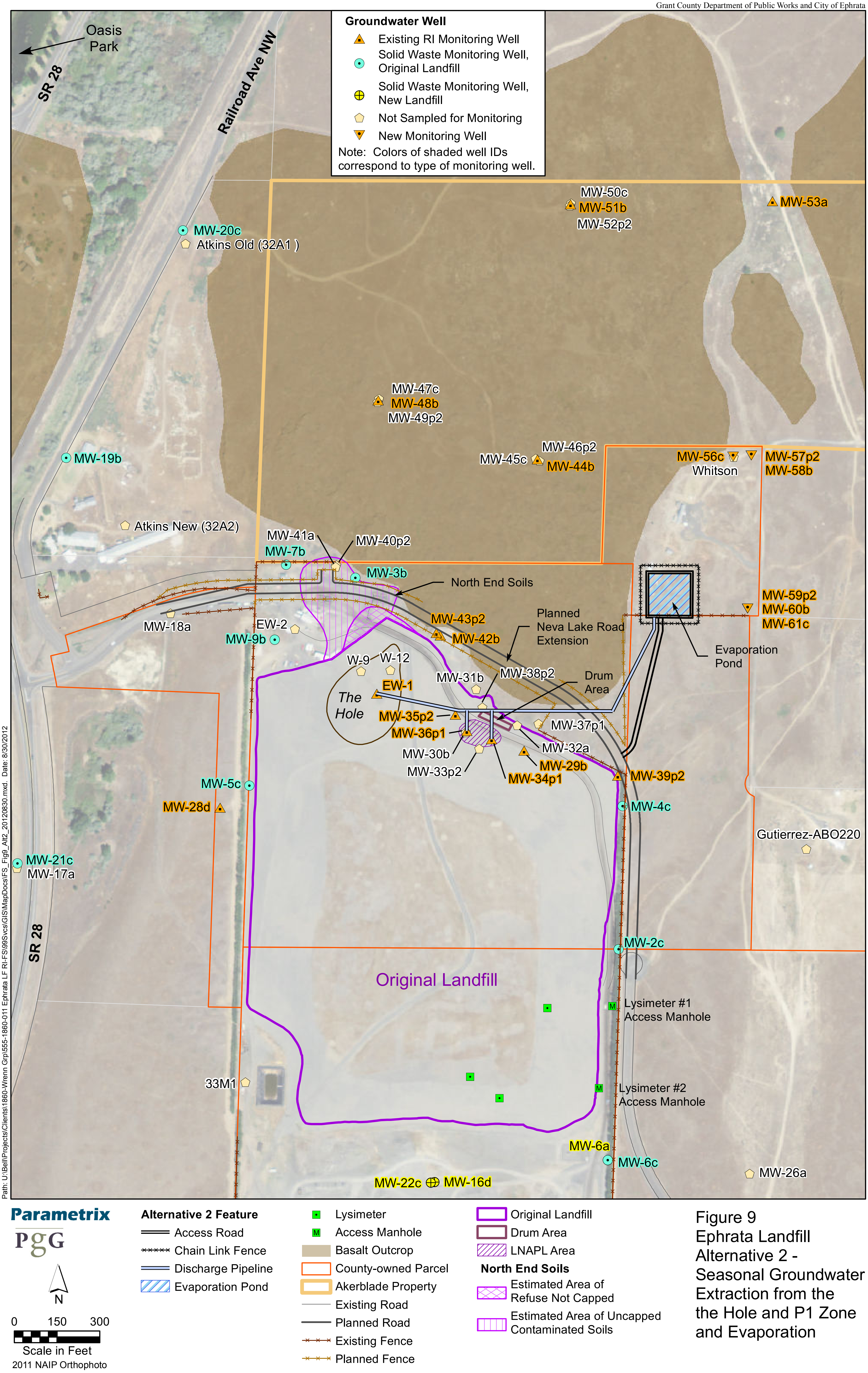


Figure 9
Ephrata Landfill
Alternative 2 -
Seasonal Groundwater
Extraction from the
the Hole and P1 Zone
and Evaporation

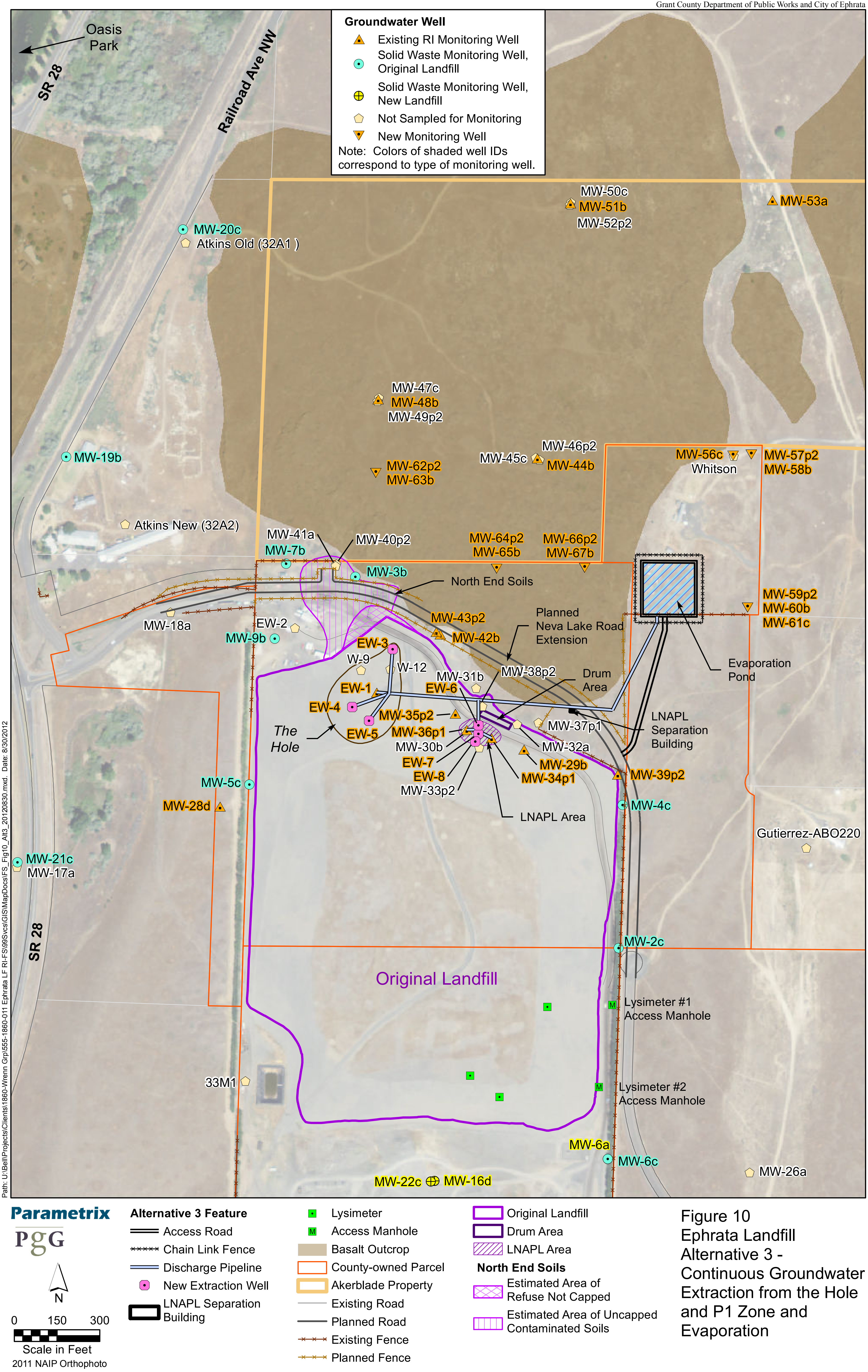
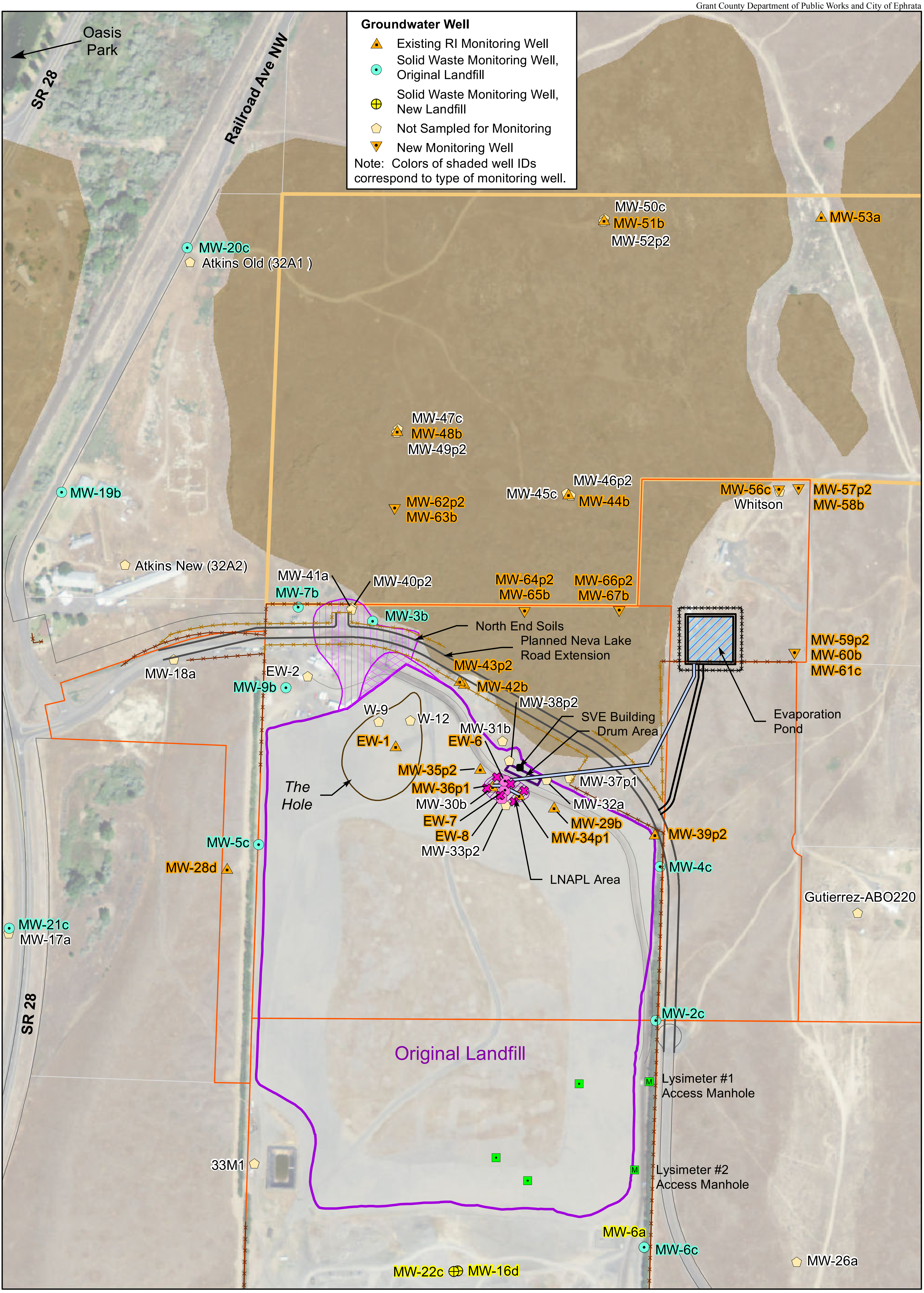


Figure 10
Ephrata Landfill
Alternative 3 -
Continuous Groundwater
Extraction from the Hole
and P1 Zone and
Evaporation

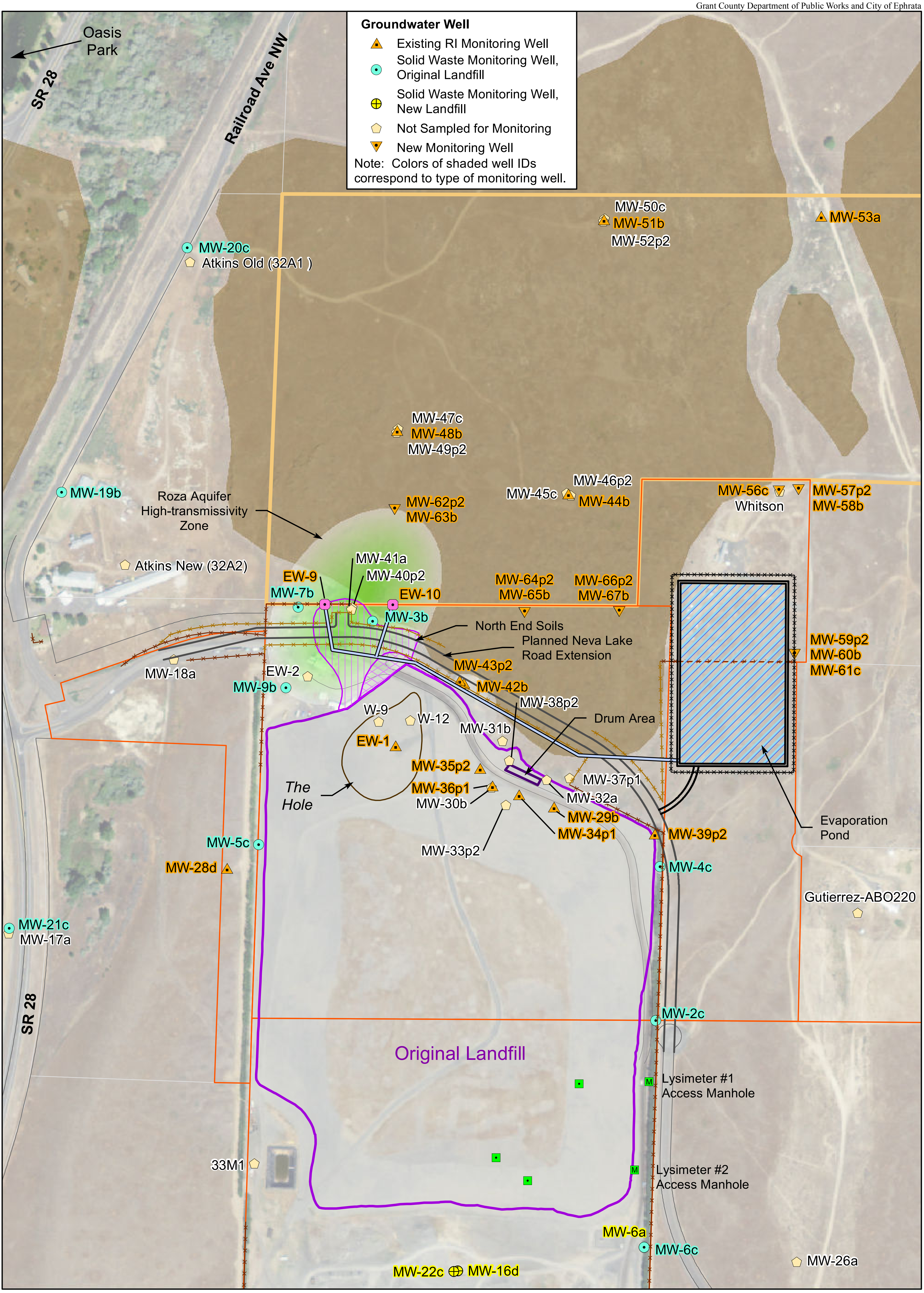


Parametrix
PGG

Alternative 4 Feature
- Access Road
- Chain Link Fence
- Discharge Pipeline
- New Extraction Well
- SVE Well
- Evaporation Pond
- SVE Building
- Lysimeter
- Access Manhole
- Basalt Outcrop
- County-owned Parcel
- Akerblade Property
- Existing Road
- Planned Road
- Existing Fence
- Planned Fence
- Original Landfill
- Drum Area
- LNAPL Area

North End Soils
- Estimated Area of Refuse Not Capped
- Estimated Area of Uncapped Contaminated Soils

Figure 11
Ephrata Landfill
Alternative 4 -
Continuous Groundwater Extraction from the P1 Zone, Evaporation, and Soil Vapor Extraction



Parametrix

PGG

N

0 150 300
Scale in Feet
2011 NAIP Orthophoto

Alternative 5 Feature
Access Road
Chain Link Fence
Discharge Pipeline
New Extraction Well
Evaporation Pond

Lysimeter
Access Manhole
Basalt Outcrop
County-owned Parcel
Akerblade Property
Existing Road
Planned Road
Existing Fence
Planned Fence

Original Landfill
Drum Area
Roza Aquifer High-transmissivity Zone
North End Soils
Estimated Area of Refuse Not Capped
Estimated Area of Uncapped Contaminated Soils

Figure 12
Ephrata Landfill Alternative 5 - Northerly Plume Capture and Evaporation

Path: U:\Bell\Projects\Clients\1860-Wrenn Grp\555-1860-011 Ephrata LF RI-FS\99Svcs\GIS\MapDocs\FS_Fig12_Alt5_20120830.mxd Date: 8/30/2012

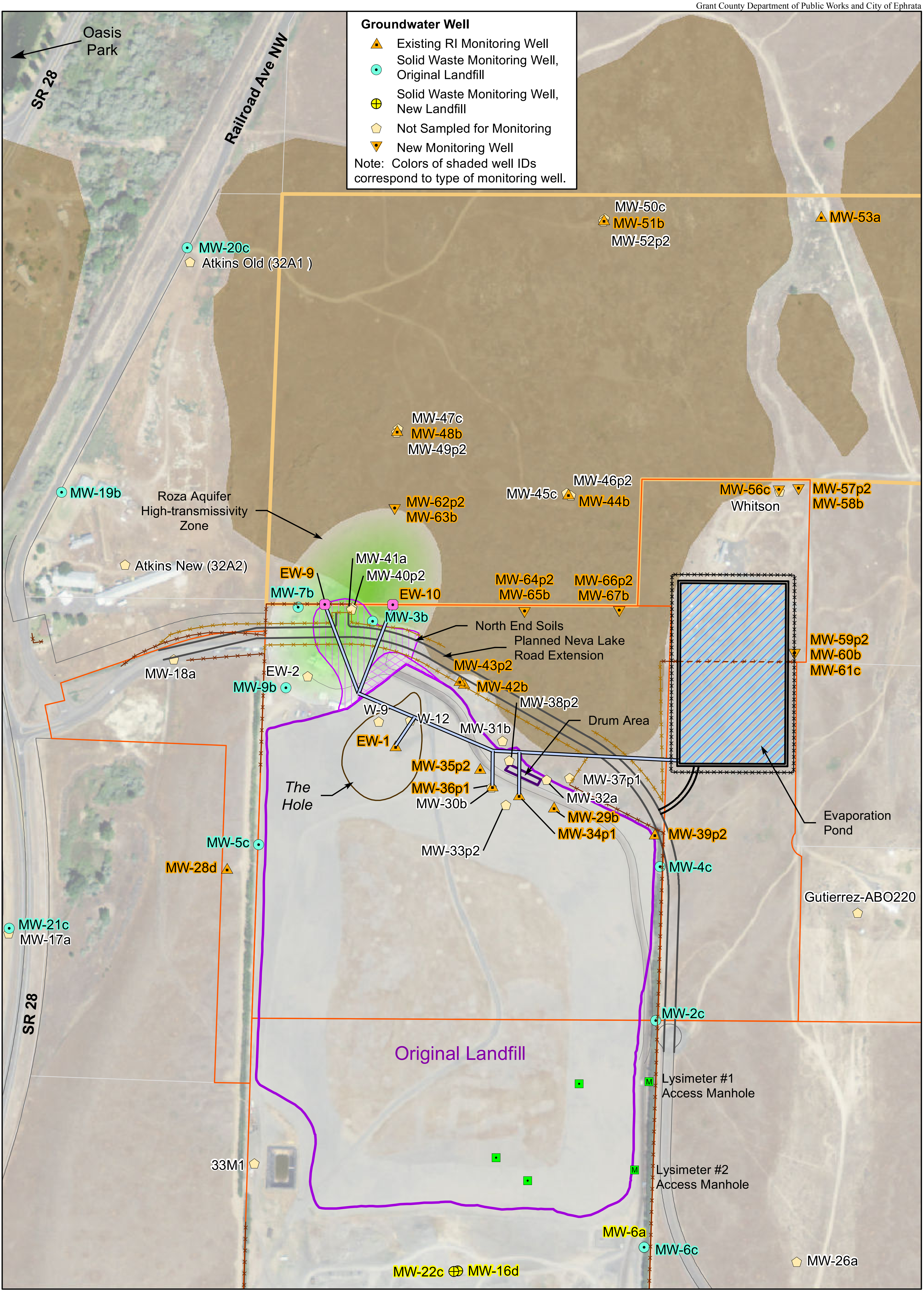


Figure 13
Ephrata Landfill
Alternative 6 -
Northerly Plume Capture,
Seasonal Groundwater
Extraction from the Hole
and P1 Zone, and
Evaporation

Path: U:\Bell\Projects\Clients\1860-Wrenn Grp\555-1860-011 Ephrata LF RI-FS\99Svcs\GIS\MapDocs\FS_Fig13_Alt6_20120830.mxd. Date: 8/30/2012

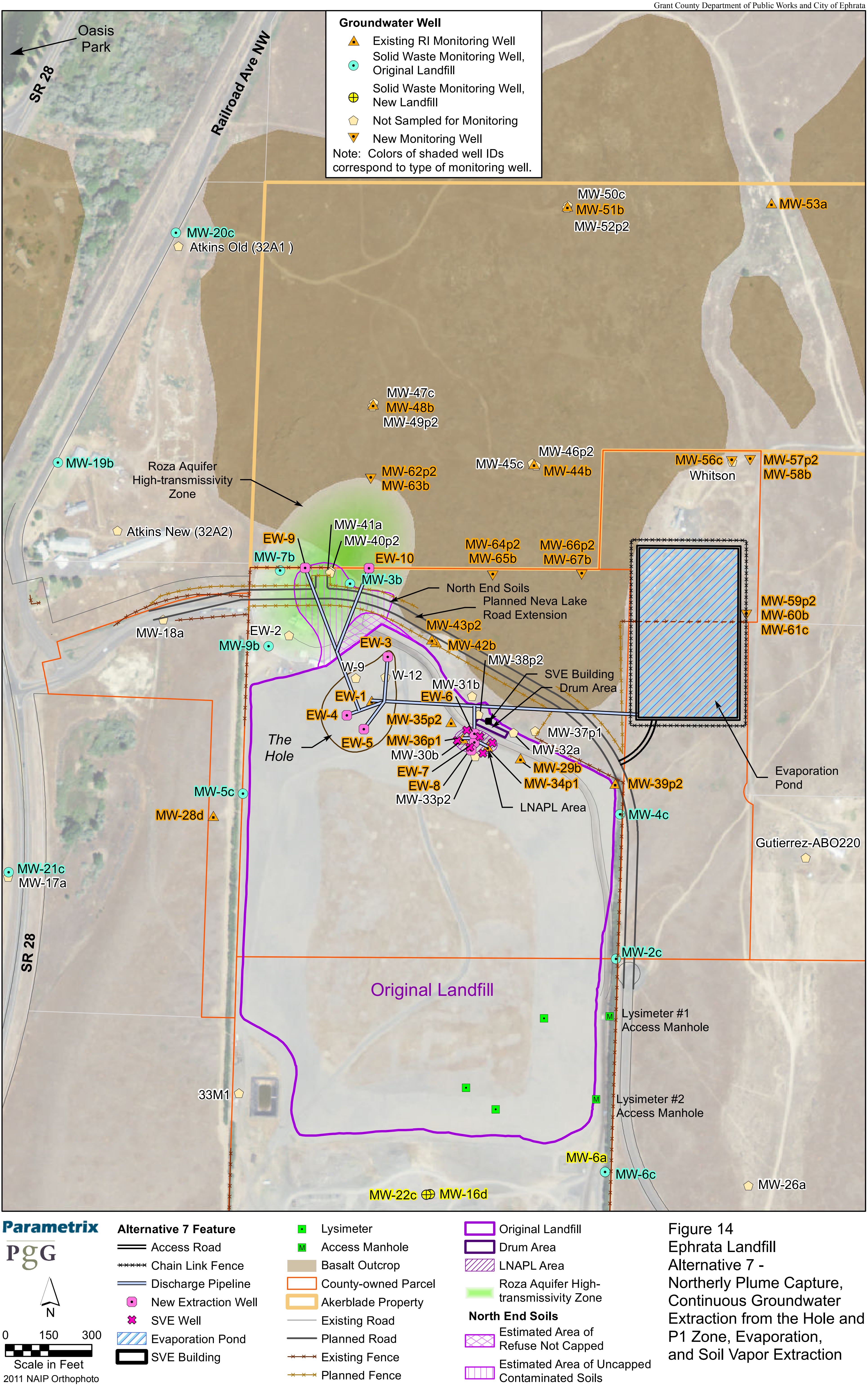


Figure 14
Ephrata Landfill
Alternative 7 -
Northerly Plume Capture,
Continuous Groundwater
Extraction from the Hole and
P1 Zone, Evaporation,
and Soil Vapor Extraction

Path: U:\Bell\Projects\Clients\1860-Wrenn Grp\555-1860-011 Ephrata LF RI-FS\99Svcs\GIS\MapDocs\FS_Fig14_Alt7_20120830.mxd. Date: 8/30/2012

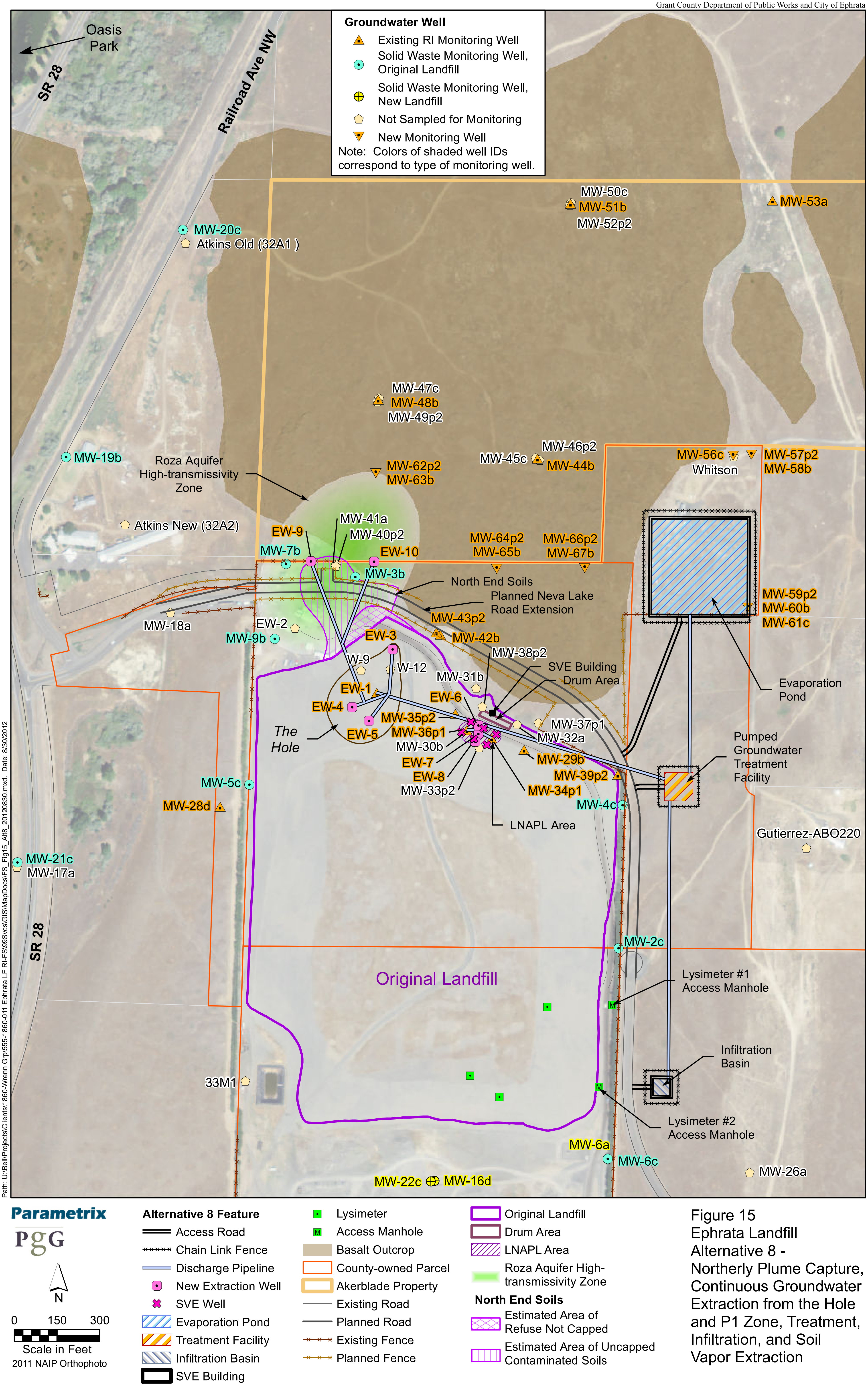


Figure 15
Ephrata Landfill
Alternative 8 -
Northerly Plume Capture,
Continuous Groundwater
Extraction from the Hole
and P1 Zone, Treatment,
Infiltration, and Soil
Vapor Extraction

TABLES

Table 1. Updated COCs for the Ephrata Landfill

Original COCs			Additional COCs	
Inorganics	**Metals**	**Organics**	**Organics**	**Organics w/o Screening Levels**
Chloride	Arsenic	1,1-Dichloroethane	1,1,1-Trichloroethane	n-Butylbenzene
Nitrate	Iron	1,2-Dichloroethane (EDC)	1,1,2-Trichloroethane	sec-Butylbenzene
Sulfate	Manganese	Chloroethane	2-Butanone	1,2,4-Trimethylbenzene
Total Dissolved Solids		Tetrachloroethene (PCE)	4-Methyl-2-Pentanone (MIBK)	1,3-Dichlorobenzene
		Trichloroethene (TCE)	Acetone	2-Hexanone
		1,1-Dichloroethene	Chloroform	4-Isopropyltoluene
		cis-1,2-Dichloroethene	Naphthalene	Bromobenzene
		Vinyl Chloride	1,3,5-Trimethylbenzene	
		Chloromethane	2-Methylphenol	
		Methylene Chloride	4-Methylphenol	
		1,2-Dichloropropane		
		Benzene		
		Toluene		
		Ethylbenzene		
		o-Xylene		
		Xylene Isomers, M+P		
		Bis(2-ethylhexyl)phthalate		

Source: PGG (2012).

Definition:

COC – contaminant of concern.

Table 2. Potential Applicable or Relevant and Appropriate Requirements

ARAR	Description	Applicability
Soil		
MTCA (WAC 173-340-740 and -173-340-747)	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 Site soil.
Groundwater		
EPA Underground Injection Control Regulations (40 CFR 144 and 146)	Regulates injection into underground sources of drinking water by specific classes of injection wells.	These regulations are relevant to the use of any cleanup technology involving injection into a drinking water aquifer.
Safe Drinking Water Act, Primary Drinking Water Regulations (40 CFR 141)	Protects the quality of public drinking water supplies through regulation of chemical parameters and constituent concentrations as MCLs.	MCLs are potentially relevant and appropriate where groundwater is a potential source of drinking water.
MTCA (WAC 173-340-720)	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 Site groundwater.
State Water Code and Water Rights (Chapters 173-150 and 173-154 WAC)	Establishes rights of well owners to have adequate water supplies and establishes a permit program for groundwater withdrawal.	These regulations are applicable 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.	These criteria are potentially relevant and appropriate to ambient surface water quality in, and point-source discharges to, surface water should cleanup activities result in a release to surface water.
Clean Water Act, NPDES (40 CFR 122-125) and Washington State NPDES Permit Program (WAC 173-220).	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, National Toxics Rule (40 CFR 131.36)	Provides numeric criteria for priority toxic pollutants in point-source discharges to surface water.	This rule is potentially applicable to point-source discharges to surface water and landfill stormwater ditches should cleanup activities result in a release to surface water.
Clean Water Act, Pretreatment Regulations (40 CFR Part 503.5)	Limits pollutants in wastewater discharges to sanitary sewer systems to protect publicly owned treatment works from accepting wastewater that would damage their system or cause them to exceed their NPDES permit discharge limits.	These regulations are potentially applicable to the discharge of treated groundwater to the City of Ephrata WRF.
Stormwater Permit Program (40 CFR 122.26)	Requires use of BMPs and appropriate monitoring 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 cleanup action components at the Site.
MTCA (WAC 173-340-730)	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 Site if cleanup activities result in a release to surface water.
Stormwater Management (Chapter 173-220 WAC)	Requires use of BMPs and appropriate monitoring 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 cleanup action components at the Site.
Washington State Water Quality Standards for Surface Waters (Chapter 173-201A WAC)	Protects freshwater aquatic life by specifying protection criteria by surface water segment. 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.	Substantive requirements of this regulation are potentially applicable for cleanup action components affecting surface water.
Air		
National Ambient Air Quality Standards (40 CFR 50.6 and 50.12)	Provides acceptable ambient air quality levels for particulate matter and lead.	These standards are applicable to earth-moving activities, as well as treatment processes that may include mixing or other processes resulting in potential releases of particulates or lead.
National Emission Standards for Hazardous Air Pollutants (40 CFR 261)	Establishes specific emissions levels allowed for toxic air pollutants.	These standards are applicable to cleanup technologies that may emit toxic pollutants to the air.
Washington Clean Air Act and Implementing Regulations (Chapters 173-400, 173-460, 173-490 WAC)	Chapter 173-400 WAC: Requires air emissions at the Site boundary to fall below the acceptable source impact limit. Also requires control of fugitive dust emissions during construction and defines general emission discharge treatment requirements. Chapter 173-460 WAC: Requires systemic control of new sources emitting air pollutants. Chapter 173-490 WAC: Sets emission standards and source control for volatile organic compounds.	These regulations are applicable for air stripping and sparging cleanup technologies.
MTCA (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 Site if cleanup activities result in a release to air.

Table 2. Potential Applicable or Relevant and Appropriate Requirements (continued)

ARAR	Description	Applicability
Miscellaneous		
Endangered Species Act (50 CFR 17 and 402)	Require that federal agencies consider the effects of their proposed actions on federally listed species. Requires consultation between the agency proposing the action and the U.S. Fish and Wildlife Service or National Oceanic and Atmospheric Administration Fisheries, as appropriate. Requires preparation of a biological assessment to address the potential effects to listed species in the area and methods to minimize those effects.	The ESA is potentially applicable to cleanup actions at the Site because federally listed species could possibly use the area. Therefore, they could potentially be affected by cleanup actions conducted at the Site.
Native American Graves Protection and Repatriation Act (43 CFR 10)	Protects 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 cleanup actions at the Site because it is possible that the disturbance of Native American materials could occur as a result of work in subsurface excavations at the Site. Such materials are not known to be present at the Site, but could be inadvertently uncovered during soil removal.
National Historic Preservation Act (36 CFR 60, 63, and 800)	Requires 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 Site. No such historic sites are known to be present in the area.
RCRA – Identification and Listing of Hazardous Waste (40 CFR 261-265, 270, and 271)	Defines those solid wastes that are subject to regulation as hazardous wastes, and lists specific chemical and industry-source wastes.	This Act is 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.	These restrictions are applicable if cleanup 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.	These standards are applicable if cleanup activities generate and include the management of non-hazardous wastes.
Department of Transportation of Hazardous Wastes (49 CFR 105-180)	Establishes specific U.S. Department of Transportation rules and technical guidelines for the off-site transport of hazardous materials.	These rules and guidelines are applicable to cleanup activities that involve the off-site transportation of hazardous waste.
SEPA (Chapter 192-11 WAC)	Requires a review of potential damage that occurs to the environment as a result of man's activities.	A SEPA checklist may be required prior to construction of a cleanup action component at the site.
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 Site. The area of contamination policy allows contaminated media to be consolidated within the same area of a site without triggering RCRA or Washington dangerous waste regulations.
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.	These standards apply to closure of a solid waste landfill, including capping, installation of a gas system, and environmental monitoring. Future site actions will comply with these regulations regardless of the cleanup action 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 non-hazardous wastes and are potentially relevant and appropriate to cleanup action components 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 Site.
Grant County Municipal Code (Title 13 – Water and Sewer)	Provides local standards for water supply and sanitary sewer.	This code is applicable if cleanup activities require a water supply or discharges to the sanitary sewer.
Grant County Municipal Code (Title 14 – Building and Construction)	Provides local standards for all building and construction activities, including stormwater management, building construction, and grading.	Plan reviews and building permits are not required, but planned facilities must meet substantive requirements of applicable codes.
Grant County Municipal Code (Title 24 – Environment)	Requires a review of potential damage that occurs to the environment as a result of man's activities in accordance with SEPA requirements.	A SEPA checklist may be required prior to construction of a cleanup action component.

Definitions:
BMP – best management practice.
CFR – Code of Federal Regulations.
MCL – maximum contaminant level.
NPDES – National Pollutant Discharge Elimination System.
RCRA – Resource Conservation and Recovery Act.
SEPA – State Environmental Policy Act.

Table 3. Completed Table 749-1 Representing the Simplified Terrestrial Ecological Evaluation – Exposure Analysis Procedure under WAC 173-340-7492(2)(a)(ii)

	Site Characteristics	Assigned Points
1)	Number of points corresponding to the approximately 2 acres of uncapped contaminated soils (north end soils) at the scale and maintenance shop area.	8
2)	Is this an industrial or commercial property? See WAC 173-340-7490(3)(c). If yes, enter a score of 3. If no, enter a score of 1.	3
3)	Enter a score for the habitat quality of the Site (High = 1, Intermediate = 2, Low = 3)	1[1]
4)	Is the undeveloped land likely to attract wildlife? If yes, enter a score of 1. If no, enter a score of 2.	1[1]
5)	Are there any of the following soil contaminants present: DDE, DDD, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, benzene hexachloride, toxaphene, hexachlorobenzene, pentachlorophenol, pentachlorobenzene? If yes, enter a score of 1. If no, enter a score of 4.	4[2]
6)	Add the numbers on lines 2 through 5 and enter this number. If this number is larger than the number on line 1, the simplified terrestrial ecological evaluation may be ended under WAC 173-340-7492(2)(a)(ii).	9

[1] The most conservative value was assigned because the area has not been evaluated by an experienced field biologist.

[2] There is no record of use or disposal of bioaccumulative chemicals (e.g., pesticides, polychlorinated biphenyls [PCBs], dioxins/furans) at the landfill site.

Table 4. Identification of COCs as Groundwater Indicator Hazardous Substances for the Ephrata Landfill RI/FS

															Northerly Plume Components[7]								Landfill Plume Components[7]			
			MTCA Method B – Groundwater[2]		MTCA Method B – Indoor Air[2,3]		Groundwater ARARs			Standard[4,5]		Source Area Groundwater (GW Only)[6]			Roza (GW Only)		Whitson (GW Only)		Interflow (GW / Air)		Alluvium (GW / Air)		Frenchman Springs (GW Only)		Outwash (GW / Air)	
COC[1]	CAS #	Units	Non-cancer SFV	Cancer SFV	Non-cancer SFV	Cancer SFV	Federal Primary MCL	Federal MCL Goal	State Primary MCL	Ground-water Only	Ground-water / Air	95th UCL	FOD (%)	IHS?	Cmax	IHS?	Cmax	IHS?	Cmax	IHS?	Cmax	IHS?	Cmax	IHS?	95th UCL[8]	IHS?
1,1,1-Trichloroethane	71-55-6	µg/L	16,000	NR	5,515	NR	200	200	200	200	200	**229**	**10.4**	**YES**	ND	NO	ND	NO	ND	NO	0.4	NO	ND	NO	ND	NO
1,1,2-Trichloroethane	79-00-5	µg/L	32	0.77	IEP	IEP	5	3	5	5	IEP	35	2.2	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
1,1-Dichloroethane	75-34-3	µg/L	1,600	NR	1,150	11	NR	NR	NR	1,600	11	293	64.8	NO	64	NO	7.5	NO	2.1	NO	1.4	NO	0.4	NO	ND	NO
1,1-Dichloroethene	75-35-4	µg/L	400	RND	130	RND	7	7	7	7	7	**40**	**46.9**	**YES**	0.86	NO	0.2	NO	ND	NO	ND	NO	ND	NO	0.066	NO
1,2-Dichloroethane (EDC)	107-06-2	µg/L	160	0.48	RND	4.2	5	0	5	4.8	4.8	**31**	**37.4**	**YES**	3.8	NO	0.7	NO	0.2	NO	ND	NO	ND	NO	ND	NO
1,2-Dichloropropane	78-87-5	µg/L	NR	1.2	28	3.7	5	0	5	5	5	**103**	**47.8**	**YES**	**36**	**YES**	**5.3**	**YES**	2.9	NO	0.4	NO	0.4	NO	ND	NO
1,3,5-Trimethylbenzene	108-67-8	µg/L	80	NR	IEP	IEP	NR	NR	NR	80	IEP	10	7.7	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
2-Butanone	78-93-3	µg/L	4,800	NR	IEP	IEP	NR	NR	NR	4,800	IEP	338	2.2	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
2-Methylphenol (o-cresol)[9]	95-48-7	µg/L	400	NR	IEP	IEP	NR	NR	NR	400	IEP	205	9.1	NO	NT	NO	NT	NO	NT	NO	NT	NO	NT	NO	ND	NO
4-Methyl-2-pentanone (MIBK)	108-10-1	µg/L	640	NR	IEP	IEP	NR	NR	NR	640	IEP	137	3.3	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
4-Methylphenol (p-cresol)[9]	106-44-5	µg/L	40	NR	IEP	IEP	NR	NR	NR	40	IEP				NT	NO	NT	NO	NT	NO	NT	NO	NT	NO	ND	NO
Acetone	67-64-1	µg/L	7,200	NR	NR	NR	NR	NR	NR	7,200	7,200	1,205	22.0	NO	12	NO	6	NO	ND	NO	ND	NO	ND	NO	6.2	NO
Arsenic[10]	7440-38-2	µg/L	4.8	0.058	IEP	IEP	10	0	10	0.58	IEP	0	90.6	NO	0	NO	0	NO	0	NO	0	NO	0	NO	0	NO
Benzene	71-43-2	µg/L	32	0.80	IEP	IEP	5	0	5	5	IEP	**16**	**33.5**	**YES**	**39**	**YES**	1	NO	ND	NO	ND	NO	ND	NO	ND	NO
Bis(2-ethylhexyl)phthalate	117-81-7	µg/L	320	6.3	NR	NR	6	0	6	6	6	2.9	14.3	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO	3.6	NO
Chloroform	67-66-3	µg/L	80	1.4	IEP	IEP	80	0	80	14	IEP	**17**	**17.0**	**YES**	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
Chloromethane[11]	74-87-3	µg/L	NR	3.4	IEP	IEP	NR	NR	NR	3.4	IEP	0.3	1.1	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
cis-1,2-Dichloroethene	156-59-2	µg/L	16	NR	RND	NR	70	70	70	16	16	**76**	**62.1**	**YES**	8.2	NO	3.2	NO	0.8	NO	0.053	NO	2.1	NO	ND	NO
Ethylbenzene	100-41-4	µg/L	800	NR	IEP	IEP	700	700	700	700	IEP	52	12.1	NO	2.1	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
Iron, dissolved[10]	7439-89-6	µg/L	11,000	NR	IEP	IEP	NR	NR	NR	11,000	IEP	4,610	38.4	NO	770	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
Manganese, dissolved[10]	7439-96-5	µg/L	2,200	NR	IEP	IEP	NR	NR	NR	2,200	IEP	**5,776**	**69.6**	**YES**	**3,088**	**YES**	ND	NO	ND	NO	0	NO	0	NO	0	NO
Methylene chloride	75-09-2	µg/L	480	5.8	RND	94	5	0	5	5	5	**15**	**30.2**	**YES**	**14**	**YES**	1	NO	ND	NO	ND	NO	ND	NO	0.5	NO
Naphthalene	91-20-3	µg/L	160	NR	IEP	IEP	NR	NR	NR	160	IEP	6.1	5.5	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
Nitrate as nitrogen[10]	14797-55-8	mg/L as N	RND	RND	NR	NR	10	10	10	10	10	3.1	76.6	NO	ND	NO	1.71	NO	5.86	NO	0	NO	0	NO	0.57	NO
o-Xylene	95-47-6	µg/L	1,600	NR	IEP	IEP	NR	NR	NR	1,600	IEP	137	17.0	NO	0.7	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO
Tetrachloroethene (PCE)	127-18-4	µg/L	48	21	43	23	5	0	5	5	5	3.7	73.2	NO	ND	NO	0.5	NO	ND	NO	0.15	NO	2.4	NO	0.152	NO
Toluene	108-88-3	µg/L	640	NR	IEP	IEP	1,000	1,000	1,000	640	IEP	**1,155**	**18.1**	**YES**	0.4	NO	ND	NO	ND	NO	ND	NO	0.4	NO	ND	NO
Trichloroethene (TCE)	79-01-6	µg/L	4.0	0.54	3.8	1.6	5	0	5	4.0	3.8	**8.2**	**69.1**	**YES**	0.1	NO	0.4	NO	ND	NO	0.083	NO	0.4	NO	0.127	NO
Vinyl Chloride	75-01-4	µg/L	24	0.029	IEP	IEP	2	0	2	0.29	IEP	**90**	**48.5**	**YES**	**2.5**	**YES**	**5.1**	**YES**	ND	NO	ND	NO	0.028	NO	ND	NO
Xylene M+P	1330-20-7	µg/L	1,600	NR	IEP	IEP	10,000	10,000	10,000	1,600	IEP	262	10.4	NO	0.6	NO	ND	NO	ND	NO	ND	NO	ND	NO	ND	NO

Table 4. Identification of COCs as Groundwater Indicator Hazardous Substances for the Ephrata Landfill RI/FS (continued)

Definitions:
95th UCL – 95% upper confidence limit on the mean concentration as calculated by ProUCL.
ARAR – applicable or relevant and appropriate requirement.
Cmax – maximum concentration, used to identify IHS when sample size was insufficient (n ≤ 5) to calculate a 95th UCL.
COC – contaminant of concern.
FOD – frequency of detection (as a percent).
GW – groundwater.
IEP – incomplete exposure pathway. For plume components, chemical was not detected in wells with a complete indoor air pathway (MW-53a [Alluvium component]; Abrams, Pashkovsky-ACX157, Pashkovsky-ABX965, and Perez [Interflow component]; and MW-14a and MW-6a [Outwash component]). For source area groundwater, landfill worker exposure to indoor air is limited to the new scale and maintenance facility and is evaluated in Table 5.
IHS – indicator hazardous substance (95th UCL [Cmax if n ≤ 5] > Standard and FOD > 5%).
MCL – maximum contaminant level.
ND – non-detect.
NR – Not Researched (CLARC Database).
NT – Not tested (not part of routine RI groundwater analysis since generally not detected or considered a COC [PGG 2012]).
RND – Researched – No Data (CLARC Database).
SFV – standard formula value.

[1] Three COCs (chloride, sulfate, and total dissolved solids) were not included in this table (secondary contaminants with MCLs for taste/smell only). The following COCs did not have any applicable standards and were excluded from the calculations: 1,2,4-trimethylbenzene, 1,3-dichlorobenzene, 2-hexanone, 4-isopropyltoluene, bromobenzene, chloroethane (ethyl chloride), n-butylbenzene, and sec-butylbenzene. Bolded COCs are IHSs.

[2] See Appendix C regarding MTCA Method B SFVs that were dropped from the CLARC Database in the April 2011 update.

[3] MTCA Method B indoor air SFVs are groundwater values derived from MTCA Method B air SFVs (or other applicable toxicity values) using the method described in Appendix C.

[4] Standards were calculated following the methodology in WAC 173-340-705 and Figure 3 in Ecology's *Focus on Developing Ground Water Cleanup Standards under the Model Toxics Control Act* (April 2005). Groundwater-only standards were calculated for COCs detected in plume components with incomplete indoor air exposure pathways. Groundwater/Air standards were calculated for COCs detected in plume components with complete indoor air exposure pathways (Section 4.1.1.2). Federal MCL Goals (MCLGs) for noncarcinogens did not affect the calculation of standards.

[5] For source area groundwater IHSs, standards are also CULs.

[6] Source area groundwater includes collective data from 29 monitoring wells in portions of the P1 and P2 zones, the Hole, Roza aquifer, Interflow Aquifer, and Outwash aquifer near sources of site contamination. Source area groundwater is distinct from an exposure standpoint because it is neither accessible to residents nor used at the landfill.

[7] For the northerly and landfill plume components, Cmax values, 95th UCLs, and FODs were calculated for COCs measured in groundwater sampled from the wells identified in Appendix C. FOD is not included since it did not affect IHS identification for any plume component COCs.

[8] For the Outwash plume component, Cmax is reported for bis(2-ethylhexyl)phthalate and methylene chloride, which had insufficient sample sizes (n ≤ 5) to calculate 95th UCLs.

[9] 2-Methylphenol and 4-methylphenol were included in the IHS identification process based on detections in groundwater samples collected in September 2010 from two source area wells (MW-35p2 and MW-38p2).

[10] Site background concentrations for dissolved arsenic (14.7 µg/L), dissolved iron (50 µg/L), dissolved manganese (32 µg/L), and nitrate as nitrogen (4.1 mg/L) were subtracted from Cmax values and 95th UCLs. Values below background were set to 0.

[11] Maximum concentration was used to identify IHS when the 95th UCL could not be calculated by ProUCL (zero variance).

Table 5. Identification of Groundwater Indicator Hazardous Substances for Landfill Worker Exposure to Indoor Air from Volatile COCs Detected in Shallow Groundwater under the New Scale and Maintenance Shop

			MTCA Method C – Indoor Air[2]			Shallow Groundwater		
COC[1]	**CAS #**	**Units**	**Non-cancer SV**	**Cancer SV**	**Standard[3]**	**95th UCL**	**FOD (%)**	**IHS?**
Acetone[4]	67-64-1	µg/L	NR	NR	---	5.3	7	NO
Bis(2-ethylhexyl)phthalate[4]	117-81-7	µg/L	NR	NR	---	5.3	25	NO
Tetrachloroethene (PCE)	127-18-4	µg/L	134	327	134	0.114	50	NO
Toluene[4]	108-88-3	µg/L	49,006	NR	49,006	1.2	7	NO

Definitions:

95th UCL – 95% upper confidence limit on the mean concentration as calculated by ProUCL.
COC – contaminant of concern.
FOD – frequency of detection (as a percent).
IHS – indicator hazardous substance (95th UCL [Cmax if n ≤ 5] > Standard and FOD > 5%).
NR – Not Researched (CLARC Database).
SFV – standard formula value.
SV – screening value.
SVOC – semi-volatile organic compound.
VOC – volatile organic compound.
--- not calculated

[1] COCs included in this table are those VOCs and SVOCs detected in shallow groundwater under the new maintenance facilities, using collective data from wells MW-1a and MW-26a.

[2] MTCA Method C indoor air SVs are groundwater values derived from MTCA Method B air SFVs (or other applicable toxicity values) using the method described in Appendix C.

[3] Standards were calculated following the methodology in WAC 173-340-705 and Figure 3 in Ecology (2005). Since landfill work exposure to groundwater is an incomplete pathway, groundwater-based standards were not included in the calculations.

[4] Maximum concentration was used to identify IHS when the sample size was insufficient (n ≤ 5) to calculate a 95th UCL or a 95th UCL could not be calculated (zero variance).

Table 6. Modified MTCA Method C Evaluation of Total Excess Cancer Risk and Hazard Quotients for Landfill Worker Exposure to North End Soils

EXCESS CANCER RISK

Chemical[1]	Modified MTCA Method C C_{soil} (mg/kg)[2]	95th UCL Soil Value (mg/kg)[3]	Comparison to C_{soil} Value (Risk)	Exceeds Regulatory Limit (Risk > 1E-05)?
1,2-Dichloropropane	1,515	0.0038	2.51E-11	No
1,4-Dichlorobenzene	10,101	0.539	5.34E-10	No
Arsenic, Total	33.3	7.28	2.18E-06	No
Benzene	1,355	0.147	1.08E-09	No
Tetrachloroethene (PCE)	25,974	2.52	9.71E-10	No
Trichloroethene (TCE)	1,176	0.351	2.99E-09	No
Vinyl Chloride	49.7	0.28	5.64E-08	No
Total Excess Cancer Risk			**2.25E-06**	**No**

HAZARD QUOTIENT

Chemical[1]	Modified MTCA Method C C_{soil} (mg/kg)[2]	95th UCL Soil Value (mg/kg)[3]	Comparison to C_{soil} Value (HQ)	Toxic Effect-specific Hazard Quotients[4]								Exceeds Regulatory Limit (HQ > 1)?
				Hemo-toxicity	Cardiovascular Toxicity	Neuro-toxicity	Nephro-toxicity	Hepato-toxicity	Immunological Toxicity	Respiratory Toxicity	Reproductive Toxicity	
Arsenic, Total	400	7.28	0.018	0.018		0.018					0.018	No
Benzene	7,950	0.147	0.000018	0.000018		0.000018			0.000018			No
cis-1,2-Dichloroethene	3,975	1.36	0.00034	0.00034				0.00034				No
Ethylbenzene	145,455	0.228	0.0000016				0.0000016					No
Iron, Total	933,333	59,215	0.063	0.063	0.063		0.063	0.063		0.063		No
Manganese, Total[5]	186,667	252	0.0014			0.0014					0.0014	No
Nitrate	2,133,333	25.0	0.000012	0.000012								No
Nitrite[6]	133,333	0.404	0.0000030	0.0000030								No
o-Xylene	290,909	0.93	0.0000032			0.0000032						No
Tetrachloroethene (PCE)	8,727	2.52	0.00029				0.00029	0.00029				No
Toluene	116,364	0.724	0.0000062			0.0000062	0.0000062					No
Trichloroethene (TCE)	727	0.351	0.00048		0.00048	0.00048	0.00048	0.00048	0.00048		0.00048	No
Vinyl Chloride	5,963	0.28	0.000047			0.000047		0.000047	0.000047		0.000047	No
Xylene Isomers, M+P	290,909	1.75	0.0000060			0.0000060						No
Hazard Index				0.082	0.064	0.020	0.064	0.065	0.00055	0.063	0.020	No

Definitions:

95th UCL = 95% upper confidence limit on the mean concentration as calculated by ProUCL.

COC = contaminant of concern

Risk = total excess cancer risk (the upper bound the estimated excess cancer risk associated with exposure to multiple hazardous substances and multiple exposure pathways).

HQ = hazard quotient (the ratio of the dose of a single hazardous substance over a specified time period to a reference dose for that hazardous substance derived for a similar exposure period).

[1] Samples collected from north end soils were analyzed for COCs identified in the original work plan (PGG 2010), as summarized in Appendix C Tables C-1 and C-10. Chloride and sulfate are not included in these tables (no reference dose or cancer potency factor for calculating C_{soil} values). 1,1-Dichloroethane, 1,1-dichloroethene, 1,2-dichloroethane (EDC), chloroethane, chloromethane, and methylene chloride are not included in these tables (all non-detects). Other groundwater COCs not included in this evaluation were not analyzed in samples collected from north end soils.

[2] Modified MTCA Method C (Equations 745-4 and 745-5 in WAC 173-340-745) was used to calculate soil concentrations (C_{soil}) to address the ingestion and dermal exposure pathways identified in the Conceptual Site Model (Figure 5).

[3] 95th UCL = 95% upper confidence limit on the mean soil concentration, as calculated by ProUCL. For 1,2-dichloropropane, the maximum detected soil concentration was used instead because a 95th UCL could not be calculated (zero variance).

[4] HQs were not calculated for toxic responses not identified for a chemical (Parametrix 2011a)

[5] The natural background concentration for total manganese is 1,100 mg/kg (Ecology 1994). This value was subtracted from the 95th UCL for comparison to the C_{soil} value.

[6] For calculating hazard indexes, the toxic effects for nitrate were also used for nitrite.

Table 7. Evaluation of Potential for North End Soils to Contribute to Groundwater Contamination Using the Fixed Parameter Three-phase Partitioning Model

IHS[1,2]	95th UCL Soil Value (mg/kg)[3]	Range of Detection Limits (mg/kg)	Detected in Groundwater?	Proposed Groundwater Cleanup Level (µg/L)[4]	K_{OC}(ml/g)	K_d(L/kg)[5]	H_{CC}[6]	Soil Concentration for Protection of Groundwater (mg/kg)[7]	May Contribute to Groundwater Contamination?[8]
1,2-Dichloropropane	0.0038	0.0006 to 0.12	Yes	1	47	0.047	0.064	0.005	No
Benzene	0.147	0.0006 to 0.11	Yes	1	62	0.062	0.133	0.005	Yes
cis-1,2-Dichloroethene	1.36	0.0006 to 0.12	Yes	16	35.5	0.0355	0.100	0.078	Yes
Manganese, Total[9,10]	252	All Detects	Yes	2,000	N/A	10	0	408	No
Toluene	0.724	0.0006 to 0.043	Yes	640	140	0.14	0.147	4.5	No
Trichloroethene (TCE)	0.351	0.0006 to 0.083	Yes	3.8	94	0.094	0.238	0.024	Yes
Vinyl Chloride	0.28	0.0006 to 0.12	Yes	0.2	18.6	0.0186	0.800	0.0012	Yes

Definitions:

IHS – indicator hazardous substance.

95th UCL –95% upper confidence limit on the mean concentration.

COC – contaminant of concern

K_{OC} – soil organic carbon-water partition coefficient.

K_d – distribution coefficient.

H_{CC} – Henry's Law constant (unitless).

[1] Only groundwater IHSs are included in this table to maintain consistency with the IHS approach.

[2] The following groundwater IHSs were not detected in north end soils: 1,1-dichloroethene, 1,2-dichloroethane (EDC), and methylene chloride. The remaining three groundwater IHSs,1,1,1-trichloroethane, 4-methylphenol, and chloroform, were not tested in soil samples collected from north end soils.

[3] 95th UCL = 95% upper confidence limit on the mean soil concentration, as calculated by ProUCL. For 1,2-dichloropropane, the maximum detected soil concentration was used instead because a 95th UCL could not be calculated (zero variance).

[4] Proposed CULs determined for groundwater, as shown in Table 8.

[5] K_d values from the CLARC Database were used for organic COCs. The K_d value for total manganese was derived as follows:

Manganese, total: The tendency of soluble manganese compounds to adsorb to soils depends on the cation exchange capacity and the organic composition of the soil. An observed range of manganese K_d values in agricultural soils and clays of pH 4.5 to 9.0 was 0.2 to 10,000 mL/g (= kg/L), increasing as a function of the organic content and the ion exchange capacity of the soil (page 353 in U.S. Department of Health and Human Services. Draft Toxicological Profile for Manganese. September 2008.). Given the lack of organic matter in uncapped north end soils, a value of 10 was used. Additionally, this value is a similar order of magnitude as Arsenic, total, for which a K_d value was provided in the CLARC Database.

[6] H_{CC} values for organics were converted for a groundwater temperature of 13°C. The CLARC Database provides H_{CC} values at 25°C.

[7] Calculated using Equation 747-1 in WAC 173-340-747(4).

[8] The 95th UCL soil value exceeds the calculated soil concentration for protection of groundwater.

[9] The natural background concentration for total manganese is 1,100 mg/kg (Ecology 1994). This value was subtracted from the 95th UCL for comparison to the soil concentration protective of groundwater.

[10] No measured concentration of total manganese in the north end soils exceeds the statewide maximum (2,750 mg/kg) as reported by Ecology (1994).

Table 8. Summary of Groundwater Cleanup Levels for the Ephrata Landfill RI/FS

							Northerly Plume Components[4]												Landfill Plume Components[4]					
				Source Area Groundwater (GW Only)[3]			Roza (GW Only)			Whitson (GW Only)			Interflow (GW / Air)			Alluvium (GW / Air)			Frenchman Springs (GW Only)			Outwash (GW / Air)		
IHS[1]	**CAS #**	**Units**	**Lowest Applicable Standard[2]**	**95th UCL**	**IHS**	**CUL**	**Cmax**	**IHS**	**CUL**	**Cmax**	**IHS**	**CUL**	**Cmax**	**IHS**	**CUL**	**Cmax**	**IHS**	**CUL**	**Cmax**	**IHS**	**CUL**	**95th UCL**	**IHS**	**CUL**
1,1,1-Trichloroethane	71-55-6	µg/L	200	229	YES	200	ND	NO	–	ND	NO	–	ND	NO	–	0.4	NO	–	ND	NO	–	ND	NO	–
1,1-Dichloroethene	75-35-4	µg/L	7	40	YES	7	0.86	NO	–	0.2	NO	–	ND	NO	–	ND	NO	–	ND	NO	–	0.066	NO	–
1,2-Dichloroethane (EDC)	107-06-2	µg/L	4.8	31	YES	4.8	3.8	NO	–	0.7	NO	–	0.2	NO	–	ND	NO	–	ND	NO	–	ND	NO	–
1,2-Dichloropropane	78-87-5	µg/L	5	103	YES	5	36	YES	1	5.3	YES	1	2.9	NO	–	0.4	NO	–	0.4	NO	–	ND	NO	–
4-Methylphenol (p-cresol)[5]	106-44-5	µg/L	40	210	YES	40	NT	NO	–	NT	NO	–	NT	NO	–	NT	NO	–	NT	NO	–	ND	NO	–
Benzene	71-43-2	µg/L	5	16	YES	5	39	YES	1	1	NO	–	ND	NO	–	ND	NO	–	ND	NO	–	ND	NO	–
Chloroform	67-66-3	µg/L	14	17	YES	14	ND	NO	–	ND	NO	–	ND	NO	–	ND	NO	–	ND	NO	–	ND	NO	–
cis-1,2-Dichloroethene	156-59-2	µg/L	16	76	YES	16	8.2	NO	–	3.2	NO	–	0.8	NO	–	0.053	NO	–	2.1	NO	–	ND	NO	–
Manganese, dissolved[6]	7439-96-5	µg/L	2,200	5,776	YES	2,200	3,088	YES	2,000	ND	NO	–	ND	NO	–	0	NO	–	0	NO	–	0	NO	–
Methylene chloride	75-09-2	µg/L	5	15	YES	5	14	YES	5	1	NO	–	ND	NO	–	ND	NO	–	ND	NO	–	0.5	NO	–
Toluene	108-88-3	µg/L	640	1,155	YES	640	0.4	NO	–	ND	NO	–	ND	NO	–	ND	NO	–	0.4	NO	–	ND	NO	–
Trichloroethene (TCE)	79-01-6	µg/L	4.0 (GW only) 3.8 (GW/Air)	8.2	YES	4.0	0.1	NO	–	0.4	NO	–	ND	NO	–	0.083	NO	–	0.4	NO	–	0.127	NO	–
Vinyl Chloride	75-01-4	µg/L	0.29	90	YES	0.29	2.5	YES	0.2	5.1	YES	0.2	ND	NO	–	ND	NO	–	0.028	NO	–	ND	NO	–

Definitions:

95th UCL – 95% upper confidence limit on the mean concentration (as calculated by ProUCL).
COC – contaminant of concern.
Cmax – maximum concentration.
CUL – cleanup level.
GW – groundwater.
IHS – indicator hazardous substance.
MCL – maximum contaminant level
ND – non-detect.
NT – Not tested (not part of routine RI groundwater analysis since generally not detected or considered a COC [PGG 2012]).
SFV – standard formula value.
– – not an IHS.

[1] The following COCs do not exceed their lowest applicable standards and thus are not IHSs requiring development of CULs (Table 4): 1,1,2-trichloroethane, 1,1-dichloroethane, 1,3,5-trimethylbenzene, 2-butanone, 4-methyl-2-pentanone (MIBK), acetone, dissolved arsenic, bis(2-ethylhexyl)phthalate, chloromethane, ethylbenzene, dissolved iron, naphthalene, nitrate as nitrogen, o-xylene, and xylene M+P. The following COCs did not have any applicable standards and were excluded from the calculations: 1,2,4-trimethylbenzene, 1,3-dichlorobenzene, 2-hexanone, 4-isopropyltoluene, bromobenzene, chloroethane (ethyl chloride), n-butylbenzene, and sec-butylbenzene.

[2] Sources include federal and state primary MCLs and standard MTCA Method B equations. Individual MCLs were adjusted downward as needed per WAC 173-340-705(5). CLARC SFVs were used if available. See Appendix C regarding MTCA Method B SFVs that were dropped from the CLARC Database in the April 2011 update. Unless otherwise noted, air and groundwater standards were equal for those IHSs identified where the indoor air exposure pathway is complete (Interflow, Alluvium, and Outwash plume components).

[3] Source area groundwater includes collective data from 29 monitoring wells in portions of the P1 and P2 zones, the Hole, Roza aquifer, Interflow Aquifer, and Outwash aquifer near sources of Site contamination. Source area groundwater is distinct from an exposure standpoint because it is neither accessible to residents nor utilized at the landfill. Because there is no exposure to landfill workers or residents, downward adjustment of CULs for total risk is not necessary.

[4] Of the northerly and landfill plume components, only the Outwash component of the landfill plume had sufficient data (n > 5) to calculate 95th UCLs, except for methylene chloride, which had insufficient sample size (n ≤ 5) to calculate a 95th UCL. For COCs in all other plume components, as well as methylene chloride in the Outwash plume component, Cmax was used to identify IHS. Proposed CULs for plume components were downward-adjusted per WAC 175-340-705(4).

[5] 4-Methylphenol was included in the CUL development process based on detections in groundwater samples collected in September 2010 from two source area wells (MW-35p2 and MW-38p2).

[6] The Site background concentration for dissolved manganese (32 µg/L) was subtracted from Cmax values and 95th UCLs. Values below background were set to 0.

Table 9. Screening of Groundwater Cleanup Technologies and Process Options

Medium	Cleanup Action Objectives	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
Source Area Groundwater (VOCs)	Reduce or eliminate routes of human exposure to groundwater containing COCs with concentrations exceeding cleanup levels (CULs). Reduce or eliminate migration of source area contaminants exceeding CULs to drinking water sources.	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 O&M requirements.	Low	**Retained.**
		Containment	Vertical Barriers	**Slurry Wall—**A physical barrier that contains contaminated groundwater or diverts 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 cleanup 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 complex basalt geology of the Site. 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. This approach may be effective at the Site for groundwater migration control if applied to specific aquifers. This is also an effective technology for dewatering of solid waste materials in the Hole and reducing the leaching potential of contaminants to groundwater.	This is a common, well-established, and accepted technology. It may be difficult to implement due to subsurface conditions and the complex basalt geology of the Site. However, it may be easier to implement downgradient in the outwash material. This approach has high O&M requirements.	Medium to High	**Retained.**
			Active Landfill Gas Extraction	**Landfill Gas System Enhancements—**Extracts landfill gas using a vacuum-blower system, and destroys the extracted gas using a flare system.	This system is technically feasible and has been effective at landfills, including the Hansville Landfill in Hansville, 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. However, Ephrata Landfill has experienced multiple refuse fires and the quality of gas available for extraction is poor. This technology would have an effect on the Landfill Plume; however, no risk exists associated with the Landfill Plume. This technology would have negligible effect on the Northerly Plume or source area.	This common landfill technology is easy to implement, and the existing system is designed for conversion to an active system. However, the existing passive system is not designed for the higher air flows necessary to effect the Northerly Plume and cannot operate the old landfill and new landfill in tandem. This approach has average O&M requirements.	Medium	Rejected due to effectiveness and implementability issues.
		Collection/Treatment	*Ex-situ* Biological Treatment (pump and treat)	**Bioreactors—**Generically, a system that degrades contaminants in groundwater and soil with microorganisms.	A bioreactor may be an effective technology for treating chlorinated VOCs, but it 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 hazardous waste sites. Although not commonly used for chlorinated compounds, several successful pilot projects have been completed. There are potential regulatory issues related to	High	Rejected due to effectiveness and implementability issues and cost.

Table 9. Screening of Groundwater Cleanup Technologies and Process Options (continued)

Medium	Cleanup Action Objectives	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
						volatilization to the atmosphere. This approach has average O&M requirements.		
			Ex-situ Physical/Chemical Treatment (pump and treat)	**Air Stripping—**Removes volatile organics 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. 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	**Retained.**
				Adsorption – GAC—Removes contaminants by passing contaminated water through granular activated carbon (GAC).	GAC is an effective technology for removal of most VOCs; however, its effectiveness is limited for water-soluble compounds, such as dichloroethane, acetone, and various ketones. It could potentially be used as a polishing step following treatment using a technology more applicable to water-soluble compounds. Carbon has a short-term duration, especially for high concentrations and would require a high frequency of O&M. 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 streams, replacement of carbon, and backwashing.	Medium to High	**Retained.**
				Advanced Oxidation - UV Treatment—Uses ultraviolet (UV) oxidation as a destruction process to oxidize organic contaminants in water.	The system does not destroy all VOCs; instead, the contaminants may be vaporized and would require treatment.	UV treatment is an innovative groundwater treatment technology that has been used in full-scale groundwater treatment application for more than 10 years. Energy requirements can be very high. This approach has high O&M requirements.	High	Rejected due to effectiveness issues and cost.
				Separation – Filtration, Reverse Osmosis, and Other Membrane Processes—Separates contaminants from water by pressure-gradient forces or filtration.	This is an effective technology for removing VOCs from groundwater. Potential issues arise with interference from floating products, such as oil. Additional waste streams are generated that require treatment and disposal.	This is an accepted technology, with most processes commercially available; however, it is not commonly used for hazardous waste sites. It is mainly used as a pre- or post-treatment process. This process has a high potential for fouling of membranes if suspended solid levels are high. This approach has high O&M requirements.	High	**Retained.**
				Physical Separation—Separates contaminants 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 and 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 pre-treatment process. This approach has high O&M requirements.	Medium to High	**Retained.**
				Liquid/Dual-Phase Extraction—Removes various combinations of groundwater, phase-separate product (normally light non-aqueous phase liquid [LNAPL]), and sometimes vapor from the subsurface.	This is an effective technology for removal of VOCs from groundwater. This is not a stand-alone technology and would require treatment of extracted liquid and vapor using another *ex-situ* treatment technology.	Liquid/dual-phase extraction is an established and accepted technology. Groundwater and LNAPL were extracted separately from the P1 zone near the drum area as part of an interim remedial action for the Site. Groundwater was also .extracted from the Hole as part of the interim action. LNAPL has not been observed in the Hole. This technology could be implemented with vapor extraction. This approach has high O&M requirements.	High	**Retained.**
			Ex-situ	**Evaporation Pond**—Uses	An evaporation pond can be an effective	Evaporation ponds are not commonly used for	Low	**Retained.**

Table 9. Screening of Groundwater Cleanup Technologies and Process Options (continued)

Medium	Cleanup Action Objectives	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
			Physical/Chemical Treatment Disposal (Note that 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.)	evaporation for treatment of VOCs in extracted groundwater.	technology for treatment of VOCs in groundwater. The extraction rate and volume for full-time groundwater extraction would be required to size the pond and determine ultimate feasibility.	treatment of contaminated groundwater. There are potential regulatory issues related to volatilization to the atmosphere. This approach has average O&M requirements.		
				Sprinkler Irrigation—Uses pressure to force water contaminated with VOCs through a sprinkler irrigation system.	This is an effective technology for removing VOCs from groundwater; however, sprinkler irrigation systems do not destroy contaminants. VOCs are transferred directly from water to the atmosphere. This technology is only applicable for very low concentrations of contaminants.	Sprinkler irrigation is a well-established and accepted technology that is readily implementable. There are potential regulatory issues related to volatilization to the atmosphere. There also is a potential for direct release to soil. This approach has low O&M requirements.	Low	Rejected due to effectiveness and implementability issues.
			In-situ Biological Treatment	**Monitored Natural Attenuation—**Allows natural subsurface processes, such as dilution, volatilization, biodegradation, and other physical and/or chemical processes, to reduce contaminant concentrations in the aquifer.	This is an effective method to reduce VOC contamination; however, it requires evaluation of contaminant degradation rates to determine if it is appropriate for a site. Current site conditions indicate some degradation of VOCs is occurring at the Site.	This is an accepted technology that has been implemented at numerous sites. It is easy to implement because little to no action is required. A long-term groundwater monitoring system would be required to verify the effectiveness of this technology. Institutional controls may be required, and the site 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 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 cleanup 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 chlorinated VOCs from groundwater. 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. Effectiveness at this site may be complicated due to multiple COCs with conflicting degradation environments.	This is an established and accepted technology. It may be difficult to implement due to subsurface conditions and the complex bedrock geology of the Site. Pilot testing and microcosm testing may be needed to evaluate the use of enhanced bioremediation at the Site before proceeding with full-scale cleanup action using this technology. This approach has high O&M requirements to ensure continued effectiveness of the contact technologies.	Medium	Rejected due to implementation issues.
			In-situ Physical/Chemical Treatment	**Permeable Reactive Barrier—**Treats contaminated groundwater as it flows through a permeable barrier composed of a reactive material.	This is an effective technology for preventing the horizontal migration of VOCs and treatment. 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 the 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 complex bedrock geology of the Site. Long-term operation (>30 years) would be required if source areas are 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.
				Electrical Resistance Heating—Uses electrical current	This is an effective technology for removal of VOCs from groundwater and most	This is a well-established and accepted technology; however, a limited number of	High	Rejected due to effectiveness issues

Table 9. Screening of Groundwater Cleanup Technologies and Process Options (continued)

Medium	Cleanup Action Objectives	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
				to heat soil and groundwater so contaminants are vaporized and collected for *ex-situ* treatment.	types of soil. It requires vapor-phase extraction and treatment for off-gas generated by heating and contaminant volatilization. Hydraulic containment may be required in soil with high hydraulic conductivity for the technology to be effective. It is not very cost-effective for low groundwater COC concentrations.	vendors of this technology exist. It would be difficult to implement at the Site due to subsurface conditions and the complex bedrock geology. Energy requirements can be very high. A performance monitoring program is required to assess the effectiveness of this technology. There are potential issues with heating of waste materials if used in the Hole, such as waste combustion and creation of hazardous byproducts. This approach has high O&M requirements.		and cost.
				Chemical Oxidation—Causes rapid degradation of organic compounds by injecting an oxidant, such as permanganate, is injected into the aquifer.	Chemical oxidation is an effective technology for destruction of VOCs from groundwater and various types of soil. 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. Chemical oxidants can be incompatible with municipal solid wastes, which contain organic material that can be highly reactive with oxidants, forming hazard by products or starting fires. Chemical oxidants could interfere with the anaerobic degradation of chlorinated solvents in the subsurface. It also can potentially mobilize metals. With high concentrations of metals (e.g., manganese and iron) in the subsurface, precipitants from the use of chemical oxidants could plug the soil and fracture basalt matrices. The wide range of contaminants may preclude use of a single chemical oxidant. 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 complex bedrock geology of the Site. Proper and uniform distribution of oxidant can be difficult in very heterogeneous materials. Additional investigation would be needed to understand small-scale subsurface characteristics and design an injection program. 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 and implementation issues and cost.
				Air Sparging—Creates a “stripper” that removes contaminants by volatilization by injecting air or other compatible gas through the contaminated aquifer.	Air sparging is an effective technology for removal of VOCs; however, it can be less effective for many chlorinated VOCs. The effectiveness of this technology can be impacted by very small changes in soil permeability/heterogeneity, which can lead to localized treatment around the sparge points or leave areas untreated. Due to the large areas of low transmissivity subsurface materials, air sparging would not be effective at remediating large portions of the Northerly plume. 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. This technology could	This is a well-established and accepted technology. It may be difficult to implement due to subsurface conditions and the complex bedrock geology of the Site. Pilot testing may be needed to evaluate the use of air sparging at the Site before proceeding with full-scale cleanup action using this technology. A performance monitoring program is required to assess the effectiveness of this technology. This approach has low O&M requirements.	Low to Medium	Rejected due to effectiveness and implementation issues.

Table 9. Screening of Groundwater Cleanup Technologies and Process Options (continued)

Medium	Cleanup Action Objectives	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
					potentially be used in conjunction with a landfill gas extraction system.			
				Soil Vapor Extraction -- Uses vacuum pressure to remove volatile and some semi-volatile contaminants (VOCs and SVOCs) from the soil.	SVE is an effective technology for removal of VOCs and SVOCs. Groundwater pumps would be used in conjunction with SVE in the P1 to keep groundwater from rising into the unsaturated zone as a result of vacuum pressure and to increase the depth of the unsaturated zone. Soil with high moisture requires higher vacuums, hindering the operation of the SVE system. Soils with high organic content or soils that are extremely dry have a high sorption capacity of VOCs. These conditions limit the effectiveness of SVE. Soils with low permeability also limit the effectiveness of SVE.	This is a well-established and accepted technology. It may be difficult to implement due to subsurface conditions and the complex bedrock geology of the Site. Pilot testing may be needed to evaluate the use of SVE at the Site before proceeding with full-scale cleanup 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.**
				Groundwater Circulation Well—Pumps groundwater to the surface to be aerated, removing most of the volatile compounds. The off-gas is then treated and water is re-injected.	These wells are an effective technology for removal and treatment of VOCs in groundwater. Vapors that are stripped off may require treatment before being discharged to the atmosphere. 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, and/or re-injection.	This is an established and accepted technology. It may be difficult to implement due to subsurface conditions and the complex bedrock geology of the Site. A performance monitoring program is required to assess the effectiveness of this technology. Washington State regulations require that injected water meet strict water quality standards. This approach has high O&M requirements.	Medium to High	Rejected due to effectiveness issues and cost.
Plume Component Groundwater (VOCs)	Reduce or eliminate routes of human exposure to groundwater containing COCs with concentrations exceeding CULs.	Land Use Control	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. It is likely only acceptable as temporary measure.	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 cooperation of multiple agencies and local governments. This approach would need to address existing and future new wells. Low O&M requirements.	Low	**Retained.**
		Collection/Treatment	*Ex-situ* Physical Treatment (pump and treat) (Note that 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	**Air Stripping—**Removes volatile organics 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. 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. Smaller systems for point-of-use treatment are available. Off-gas treatment by activated carbon adsorption or catalytic oxidation may be needed. This approach has average O&M requirements.	Medium	**Retained.**
				Adsorption – GAC—Passes contaminated water through GAC to remove contaminants.	This is an effective technology for removal of most VOCs; however, its effectiveness is limited for water-soluble compounds, such as dichloroethane, acetone, and various ketones. The GAC medium has a short-term life cycle and would need to be replaced periodically, especially for high COC concentrations and would require a high frequency of O&M. This approach could potentially be used as a polishing step following other treatment. This process requires transport and disposal or	This is a common, well-established, and accepted technology that is readily implementable. Logistical and economic disadvantages arise from the need to transport and decontaminate spent carbon. This approach has average O&M requirements, including monitoring of influent and effluent streams, regeneration and replacement of carbon, and backwashing.	Low to High	**Retained.**

Table 9. Screening of Groundwater Cleanup Technologies and Process Options (continued)

Medium	Cleanup Action Objectives	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
					regeneration of spent carbon. This would be an effective technology for treatment of PCE and other less water-soluble compounds in groundwater.			
				Advanced Oxidation - UV Treatment—Uses ultraviolet (UV) oxidation as a destruction process to oxidize organic contaminants in water.	This treatment was previously implemented at an offsite location (Whitson well) and was not effective. The system does not destroy some VOCs; instead, the contaminants may be vaporized and would require additional treatment.	UV treatment is an innovative groundwater treatment technology that has been used in full-scale groundwater treatment application for more than 10 years. Energy requirements can be very high. This approach has average O&M requirements.	High	Rejected due to effectiveness issues and cost.
				Separation – Filtration, Reverse Osmosis, and Other Membrane Processes—Separates contaminants from water by pressure-gradient forces or filtration.	This is an effective technology for removing VOCs from groundwater. Potential issues arise with interference from floating products, such as oil. Additional waste streams are generated that require treatment and disposal.	This is an accepted technology, with most processes commercially available; however, it is not commonly used for hazardous waste sites. It is mainly used as a pre- or post-treatment process. There is high potential for fouling of membranes if suspended solid levels are high. This approach has average O&M requirements.	High	Rejected due to implementability issues and cost.
			*In-sit*u Biological Treatment	**Monitored Natural Attenuation—**Allows natural subsurface processes, such as dilution, volatilization, biodegradation, and other physical and/or chemical processes, to reduce contaminant concentrations in the aquifer.	While this is an effective method to reduce VOC contamination, it requires modeling evaluation of contaminant degradation rates to determine if it is appropriate for a site. Current site conditions indicate some degradation of VOCs is occurring at the Site. Source area removal (drums) and capping over residual contamination is completed, reducing the need for active remediation.	Monitored natural attenuation is an accepted technology that has been implemented at numerous sites across the country. It is easy to implement because little to no action is required. A long-term groundwater monitoring system would be required to verify the effectiveness of this approach. Institutional controls may be required, and the site may not be available for re-use until contaminant levels are reduced. This approach has low O&M requirements.	Low	**Retained.**
		Alternative Water Supply	Other	**New Drinking Water Well—**Installs a new drinking water well into an uncontaminated aquifer. This would include decommissioning the existing well on the property.	This approach would prevent direct exposure to contaminated groundwater by providing a clean drinking water source. Decommissioning existing uncased wells would eliminate a potential conduit for contaminated groundwater to migrate to other aquifers.	A new drinking water well is a common, well-established, and accepted approach. It is readily implementable using well-established technologies. Low O&M requirements.	Medium	Rejected as an alternative water supply is no longer necessary due to the County purchase of the Whitson property.
				Connection to Local water System—Connects impacted residences to the existing City/County water supply system or a new local public water system with an uncontaminated source. This would include decommissioning existing wells.	This approach would prevent direct exposure to contaminated groundwater by providing a clean drinking water source. Decommissioning existing uncased wells would eliminate a potential conduit for contaminated groundwater to migrate to other aquifers.	Connection to a local water system is a common, well-established, and accepted approach. It is readily implementable using well-established technologies. Low O&M requirements.	Medium to High	Rejected as an alternative water supply is no longer necessary due to the County purchase of the Whitson property.

Table 9. Screening of Groundwater Cleanup Technologies and Process Options (continued)

Medium	Cleanup Action Objectives	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
Groundwater (inorganics)	Reduce or eliminate human exposure through direct ingestion of contaminated groundwater containing inorganics with concentrations exceeding SLs. Reduce or eliminate human exposure through direct contact (incidental ingestion and skin contact) with contaminated groundwater containing inorganics with concentrations exceeding SLs.	Land Use Control	Land Use Controls	Not Applicable.	This control would be effective because it restricts the use of groundwater. It does not directly address contaminant 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 cooperation of multiple agencies and local governments.	Low	**Retained.**
		Collection/Treatment – 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.	*Ex-situ* Physical Treatment (pump and treat)	**Adsorption - Activated Alumina—**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 onsite 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	**Retained.**
				Adsorption – Manganese Greensand/Pyrolusite Filtration—Converts soluble forms of iron and manganese to insoluble forms by oxidizing with permanganate and then removing the iron/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 onsite 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. Backwashing of the filter is necessary to remove accumulated sediments. This approach has high O&M requirements.	Medium	**Retained.**
				Separation – Membrane Filtration, Reverse Osmosis—A membrane separation technology that forces water under pressure through a membrane to remove dissolved constituents.	Reverse osmosis is an effective technology for removing inorganics from groundwater. Inorganics removal efficiencies depend on the form of the inorganic ion, but are generally high. Manganese removal efficiencies by reverse osmosis are typically high. Point-of-use reverse osmosis units are capable of removing metals and other inorganics, including nitrates, sodium, and organic compounds. Reverse osmosis performance is adversely affected by the presence of turbidity, silica, scale-producing compounds, and other constituents. This technology requires extensive pre-treatment for particle removal and often pre-treatment for dissolved constituents.	This is a common, well-established, and accepted technology for removal of inorganics from groundwater. Compact reverse osmosis treatment systems are available and can be used at wellhead locations or other onsite locations. This approach has average to high O&M requirements.	High	**Retained.**
				Ion Exchange—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 pre-treatment.	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 on 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	Medium	**Retained.**

Table 9. Screening of Groundwater Cleanup Technologies and Process Options (continued)

Medium	Cleanup Action Objectives	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
					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.	approach has average O&M requirements.		
				Coagulation/Filtration—Alters the physical or chemical properties of suspended material 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 and disposal.	Coagulation/filtration treatment produces inorganic-contaminated sludge requiring offsite disposal. 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.
			In-situ Biological Treatment	**Monitored Natural Attenuation—**Allows natural subsurface processes, such as dilution, volatilization, biodegradation, and other physical and/or chemical processes, to reduce contaminant concentrations in the aquifer.	This is an effective method to reduce VOC contamination; however, it requires modeling evaluation of contaminant degradation rates to determine if it is appropriate for a site. Current site conditions indicate some degradation of VOCs is occurring. Source area removal (drums) and capping over residual contamination is completed, reducing the need for active remediation.	This is an effective approach that has been implemented at numerous sites across the country. It is easy to implement because little to no action is required. A long-term groundwater monitoring system would be required to verify the effectiveness of this approach. Institutional controls may be required, and the site may not be available for re-use until contaminant levels are reduced. This approach has a low O&M intensity.	Low	**Retained.**
		Alternative Water Supply	Other	**New Drinking Water Well—**Installs a new drinking water well into an uncontaminated aquifer. This would include decommissioning the existing well on the property.	This approach would prevent direct exposure to contaminated groundwater by providing a clean drinking water source. Decommissioning existing uncased wells would eliminate a potential conduit for contaminated groundwater to migrate to other aquifers.	Installation of a new drinking water well is a common, well-established, and accepted approach. It is readily implementable using well-established technologies.	Medium	**Retained.**
				Connection to Local water System—Connects impacted residences to the existing City/County water supply system. This would include decommissioning existing wells.	This action would prevent direct exposure to contaminated groundwater by providing a clean drinking water source. Decommissioning existing uncased wells would eliminate a potential conduit for contaminated groundwater to migrate to other aquifers.	This action is a common, well-established, and accepted approach. It is readily implementable using well-established technologies.	Medium to High	**Retained.**

Definitions:
COC - contaminant of concern
CUL - cleanup level
GAC - granular activated carbon
LNAPL - light non-aqueous phase liquid
O&M – operation and maintenance
SVE - soil vapor extraction
SVOC - semi-volatile organic compounds
VOC - volatile organic compound

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

[2] The retained cleanup 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.

Table 10. Screening of North End Soils Cleanup Technologies and Process Options

Medium	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
Soil	Land Use Controls	Land Use/ Institutional Controls	Not Applicable.	This control is effective because it restricts the use/access to soil. 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 O&M requirements.	Low	**Retained.**
	In-situ Biological Treatment	Natural Attenuation	**Monitored Natural Attenuation**—Allows natural subsurface processes, such as dilution, volatilization, biodegradation, and other physical and/or chemical processes, to reduce contaminant concentrations.	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.	This is an accepted technology that has been implemented at numerous sites. It is easy to implement because little to no action is required. A long-term groundwater monitoring system would be required to verify the effectiveness of this technology. Institutional controls may be required, and the site may not be available for re-use until contaminant levels are reduced. This approach has low O&M requirements.	Low	**Retained.**
		Enhanced Biodegradation	**Enhanced Biodegradation**—Uses indigenous or inoculated micro-organisms (e.g., fungi, bacteria, and other microbes) to degrade (metabolize) organic contaminants found in soil and/or groundwater, converting them to innocuous end products. Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials.	This is an effective method to reduce VOC contamination; however, it requires evaluation of contaminant degradation rates to determine if it is appropriate for a site. Experimental results for inorganics are available; however, full-scale examples are limited. Due to the existence of commingled chlorinated and unchlorinated VOCs, nutrient characteristics are typically mutually exclusive.	This is an accepted technology that has been implemented at numerous sites. A long-term groundwater monitoring system would be required to verify the effectiveness of this technology. Institutional controls may be required, and the site may not be available for re-use until contaminant levels are reduced. Depths of contaminants at the site are limiting for the technology, and microorganism contact with nutrients is difficult to obtain. This approach has medium O&M requirements due to repeated dosings of nutrients.	Medium	Rejected due to feasibility and implementability issues.
		Bioventing	**Bioventing Wells**—Installs shallow wells in soil to provide oxygen to existing soil microorganisms. Bioventing uses low air flow rates to provide only enough oxygen to sustain microbial activity. Oxygen is most commonly supplied through direct air injection into residual contamination in soil.	This is an effective method to reduce VOC contamination; however, it requires evaluation of contaminant degradation rates to determine if it is appropriate for a site. Experimental results for inorganics are available; however, full-scale examples are limited. Due to the existence of commingled chlorinated and unchlorinated VOCs, chlorinated VOC remediation in aerobic environments is largely ineffectual.	This is an accepted technology that has been implemented at numerous sites. A long-term groundwater monitoring system would be required to verify the effectiveness of this technology. The site may not be available for re-use until contaminant levels are reduced. Microorganisms typically require supplemental nutrients to degrade VOCs to cleanup levels. This approach has medium O&M requirements due to repeated dosings of nutrients and the long-term nature of implementation.	Medium	Rejected due to feasibility and implementability issues.
		Phytoremediation	**Phytoremediation**—Uses plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment. The mechanisms of phytoremediation include enhanced rhizosphere biodegradation, phyto-extraction (also called phyto-accumulation), phyto-degradation, and phyto-stabilization.	This is an effective method to reduce inorganic contamination in shallow surface soil. Contaminants are either bioaccumulated in biomass or converted to less toxic byproducts via various biological activities. Remediation of VOCs is experimental and not well documented. Plants require large volumes of water for survival and are typically dormant during colder times of the year.	This is an accepted technology that has been implemented at numerous sites. Biomass requires harvesting and disposal in accordance with solid waste regulations. High O&M requirements in order to keep the vegetation viable during all times of the year.	Low	Rejected due to feasibility and implementability issues.
	In-situ Physical/ Chemical Treatment	Chemical Oxidation	**Physical/chemical Treatment**—Uses the physical properties of the contaminants or the contaminated medium to destroy (i.e., chemically convert), separate, or contain the contamination. Treatment residuals from separation techniques require treatment or disposal, which adds to total project costs and may require permits. Extraction fluids	Each of these technologies could be feasible and effective at specific areas of the facility; however, none of the technologies are applicable to all areas where soil contamination levels are above cleanup levels.	Each of these technologies has limited implementability for the specific contaminants. Due to the range of depths and relatively disperse nature of the contamination, *in-situ* physical/chemical treatment technologies are not readily implementable at the site. The cost to implement any of these technologies over a limited area and independent of other contaminated soil areas would be extremely high in relation to the removal of the limited target contaminants and concentrations.	High	Rejected due to feasibility, implementability issues, and cost.
		Electrokinetic Separation					
		Fracturing					
		Soil Flushing					
		Soil Vapor Extraction					
		Solidification/ Stabilization					
		Thermal Treatment					

Table 10. Screening of North End Soils Cleanup Technologies and Process Options (continued)

Medium	Cleanup Action Category	Cleanup Technology[1]	Process Options	Technical Feasibility/Effectiveness	Implementability	Cost	Retained/Rejected[2]
			from soil flushing increase the mobility of the contaminants, so provisions must be made for subsurface recovery.				
	Ex-situ Treatment	Biopiles	***Ex-situ* Treatment**—Uses biological, physical/ chemical, or thermal processes to lower contaminant concentrations or potential exposures. Bioremediation techniques are destruction or transformation techniques directed toward stimulating the microorganisms to grow and use the contaminants as a food and energy source by creating a favorable environment for the microorganisms. Generally, this means providing some combination of oxygen, nutrients, and moisture and controlling the temperature and pH. Physical/chemical treatment uses the physical properties of the contaminants or the contaminated medium to destroy (i.e., chemically convert), separate, or immobilize the contamination. Thermal processes use heat to increase the volatility (separation); burn, decompose, detonate (destruction); or melt (immobilization) the contaminants.	Each of these technologies could be feasible and effective at areas of the facility outside the landfill; however, none of the technologies are applicable to all areas where soil contamination levels are above cleanup levels. The low levels of contaminants within the soil and the disperse nature of the contamination would lead to substantial dilution and large volumes of excavated material, requiring large volumes of nutrients to degrade the relatively small amount of contamination.	Each of these technologies has limited implementability for the specific contaminants within the soil. Due to the range of depths, nature of the contaminants above cleanup levels, and relatively disperse nature of the contamination, *ex-situ* treatment technologies are not readily implementable at the site. The cost to implement any of these technologies over a limited area and independent of the other contaminated soil areas would be extremely high in relation to the removal of the limited target contaminants and concentrations. The low levels of contaminants within the soil and the disperse nature of the contamination would lead to substantial dilution and large volumes of excavated material, requiring large volumes of nutrients to degrade the relatively small amount of contamination.	High	Rejected due to feasibility and implementability issues and cost.
		Composting					
		Landfarming					
		Slurry Phase Biological Treatment					
		Chemical Extraction					
		Chemical Reduction/Oxidation					
		Dehalogenation					
		Separation					
		Soil Washing					
		Solidification/ Stabilization					
		Hot Gas Decontamination					
		Incineration					
		Pyrolysis					
		Thermal Desorption					
	Containment	Low-permeability Cap	**Low-permeability Cap**—Uses low-permeability material (e.g., bentonite amended soil, geomembrane, asphalt) on the surface above contamination to minimize the surface infiltration of precipitation and exposure to the contaminants.	This is an effective technology for minimizing vertical contaminant migration. 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. O&M requirements for this technology are relatively low and consist of repair of cap materials and maintenance of protective layers.	Medium	**Retained.**
		Excavation and Onsite Disposal	**Excavation and Onsite Disposal**—Soil contamination above cleanup levels would be excavated and disposed of at the Ephrata Landfill.	Based on the known limits of contaminated soils and assuming a soil layer thickness between 5 and 15 feet, the north end soil area is estimated to contain 40,000 to 50,000 cubic yards of contaminated soil.	This is a common, well-established, and acceptable technology. Once the material is excavated there are no ongoing O&M requirements.	High	**Retained**.

Definition:
O&M – operations and maintenance
VOC – volatile organic compound

[1] Cleanup technologies, descriptions, and applicability to the Site 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 cleanup 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.

Table 11. Cleanup Action Component Summary

Component	Purpose	IHS	Standard[2]	CUL	Compliance Year	Location	Initial Removal Rate of Organic COCs (kg/yr)	Component Cost[1]
Components for Which Northerly Plume Contaminant Reduction Over Time Was Modeled with REMChlor								
		Estimated Restoration Times for Select Northerly Plume IHSs						
		IHS	Standard[2]	CUL	Compliance Year			
Natural Attenuation	Allow post-drum-removal attenuation processes to occur while monitoring to ensure continued protection of public health and the environment.	1,2-DCP	5	1	2063	Landfill property line and beyond	200	$185,000
		benzene	5	1	2058			
		methylene chloride	5	5	2079			
		vinyl chloride	0.29	0.2	>2084			
Continuous Pumping from the Hole	Eliminate groundwater contact with refuse in the Hole, remove dissolved contaminants.	Note 3					0.18	$613,000
Continuous Pumping from the P1 Zone[4]	Reduce groundwater contact with contaminants in the P1 zone, remove dissolved contaminants, create vadose zone.	1,2-DCP	5	1	2039		131 to 145	$215,000
		benzene	5	1	2040			
		methylene chloride	5	5	2046			
		vinyl chloride	0.29	0.2	2047			
SVE[5]	Remove organic contaminants from a vadose zone to be created through long-term drawdown of the P1 zone.	1,2-DCP	5	1	2058		577	$789,000
		benzene	5	1	2049			
		methylene chloride	5	5	2043			
		vinyl chloride	0.29	0.2	2083			
Northerly Plume Capture	Disrupt the source of contaminants to the northerly plume, stopping and, to an extent, reversing contaminant migration north of the landfill.	1,2-DCP	5	1	2032		1.39	$222,000 to $342,000
		benzene	5	1	2032			
		methylene chloride	5	5	2023			
		vinyl chloride	0.29	0.2	2033			
Components Associated with Seasonal Groundwater Pumping								
Seasonal Pumping from the Hole	Reduce groundwater contact with refuse in the Hole, remove dissolved contaminants.					P1 zone, MW-34p1, MW-36p1 vicinity	0.14	$260,000
Seasonal Pumping from the P1 Zone	Reduce groundwater contact with contaminants in the LNAPL Area, remove dissolved contaminants.						60	$105,000
Manual LNAPL Removal	Support natural attenuation and seasonal pumping from the LNAPL Area by managing LNAPL that migrates into wells MW-34p1 and MW-36p1.						5.97	$142,000

Table 11. Cleanup Action Component Summary (cont.)

Pumped Groundwater Treatment and Disposal Components					
Evaporation	Groundwater disposal option for volumes generated by northerly plume capture or pumping of the Hole and LNAPL area (seasonal or continuous). Size of pond varies with pumping rates of components in each alternative.		Former Whitson parcel	N/A	$365,000 to $2,178,000
LNAPL Separation and Disposal	Support continuous pumping from the LNAPL area, which could yield mixed-phase groundwater and LNAPL.		Landfill or County parcel	N/A[6]	$96,000
Treatment	Reduce groundwater contaminant concentrations below groundwater standards (WAC 173-200) for either discharge to ground (infiltration) or to the City's Water Reclamation Facility.		County parcel	N/A	$7,580,000
Infiltration	Provide a disposal option for treated groundwater.		County parcel	N/A	$25,000
Compliance Monitoring					
Compliance Monitoring	Verify that the cleanup action achieves cleanup or other performance standards and that the cleanup action remains effective over time through installation of monitoring wells, sampling, and reporting. The scope of groundwater monitoring varies by alternative and may include sampling of discharge to evaporation pond to estimate pond emissions, sampling from treatment system, and SVE performance monitoring.		Existing and new monitoring wells, new facilities, depending on the selected alternative	N/A	$1,950,000 to $3,690,000
Whitson Well Modification[7]	Eliminate suspected conduit from the Roza aquifer and possibly the P1 zone to the Interflow aquifer.		Former Whitson parcel	N/A	$109,000
North End Soil Components					
NES Cap	Stop percolation to reduce groundwater/NES contact.	North end soils were calculated to be a potential source of groundwater recontamination based on the Fixed Parameter Three-phase Partitioning Model (WAC 173-340-747(4)). Potential groundwater concentration increases were not quantified.[8]	Old scale and maintenance shop area	9.71	$330,000
NES Clean Road Corridor	Stop percolation to reduce groundwater/NES contact, use clean fill for road corridor to prevent receptor/NES contact.			50	$403,000
NES Cap/Removal Hybrid	Remove NES from road corridor north to prevent receptor/NES contact, stop percolation to reduce groundwater/remaining NES contact.			81	$542,000
NES Removal	Remove NES to prevent groundwater/NES and receptor/NES contact.			160	$576,000

Notes:

[1] Costs are present worth based on a 30-year time interval.

[2] Standards for IHSs are found in Tables 4 and 8.

[3] Continuous pumping from the Hole and P1 zone were evaluated together based on calculations for the P1 zone. Implementation of either component individually might result in a longer restoration timeframe.

[4] The higher initial removal rate would be from LNAPL entrainment if wells are drawn down more than about 2 feet. *Ex situ* LNAPL separation and disposal would be needed in that case.

[5] SVE was evaluated using best estimate range for LNAPL extent and assumed 50% removal efficiency. SVE removal estimates are considered less certain than groundwater-based removal estimates.

[6] LNAPL separation is an *ex situ* treatment process. COC removal is included in the evaluation of continuous pumping from the P1 zone.

[7] The lower part of the Whitson well was sealed and a monitoring well installed per Chapter 173-160 WAC.

[8] COC removal rates listed for NES are one-time removal at implementation of each NES component.

Definitions:

1,2-DCP – 1,2-dichloropropane.
COC - contaminant of concern.
CUL – cleanup level.
IHS – indicator hazardous substance.
NES – north end soils.
LNAPL – light non-aqueous phase liquid.
N/A – not applicable.
SVE –soil vapor extraction.

Table 12. Groundwater Cleanup Action Component Compatibility Summary

		Treatment & Disposal					Pumping					LNAPL		
		Infiltration	Treatment	Evaporation, Small-scale	Evaporation, Medium-scale	Evaporation, Large-scale	Northerly Plume Capture	Continuous Pumping from the P1 Zone	Continuous Pumping from the Hole	Seasonal Pumping from the P1 Zone	Seasonal Pumping from the Hole	SVE	LNAPL Separation and Disposal	Manual LNAPL Removal
	Manual LNAPL Removal	1	1	3	1	1	2	1	2	3	2	1	1	
LNAPL	LNAPL Separation and Disposal	2	2	2	2	2	2	3	2	2	2	3		
	SVE	2	2	2	2	2	2	3	2	1	1			
	Seasonal Pumping from the Hole	2	2	3	1	1	2	2	1	2				
	Seasonal Pumping from the P1 Zone	2	2	3	1	1	2	1	2					
Pumping	Continuous Pumping from the Hole	2	2	1	2	3	2	2						
	Continuous Pumping from the P1 Zone	2	2	1	2	3	2							
	Northerly Plume Capture	2	2	1	2	3								
	Evaporation, Large-scale	1	1	1	1									
	Evaporation, Medium-scale	2	3	1										
Treatment & Disposal	Evaporation, Small-scale	1	1											
	Treatment	2												
	Infiltration													

Compatibility Rankings
1 = mutually exclusive
2 = compatible (neither dependent nor exclusive)
3 = mutually dependent

Definitions:
LNAPL – light non-aqueous phase liquid.
NES – north end soils.
SVE – soil vapor extraction.

Notes
1. Institutional controls and compliance monitoring are requirements common to all alternatives.
2. Natural attenuation will be a part of any cleanup action at the Site.
3. The Whitson well, which was recently modified for Interflow aquifer monitoring, is a component of all the alternatives.
4. Any NES component would be implementable with any groundwater component.

Table 13. Cleanup Action Alternative and Component Performance and Cost Summary

		Cost Summary							
Component	Component Cost[1]	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Components for Which Northerly Plume Contaminant Reduction Was Quantified									
Natural Attenuation	$185,000	$185,000	$185,000	$185,000	$185,000	$185,000	$185,000	$185,000	$185,000
Continuous Pumping from the Hole	$613,000			$613,000				$613,000	$613,000
Continuous Pumping from the P1 Zone	$215,000			$215,000	$215,000			$215,000	$215,000
SVE	$789,000				$789,000			$789,000	$789,000
Northerly Plume Capture[2]	$222,000					$342,000	$222,000	$222,000	$222,000
Components Associated with Seasonal Groundwater Pumping									
Seasonal Pumping from the Hole	$260,000		$260,000				$260,000		
Seasonal Pumping from the P1 Zone	$105,000		$105,000				$105,000		
Manual LNAPL Removal	$142,000	$142,000	$142,000			$142,000	$142,000		
Pumped Groundwater Treatment and Disposal Components									
Evaporation Pond (0.5 Acre)	$365,000		$365,000		$365,000				
Evaporation Pond (0.75 Acre)	$600,000			$600,000					
Evaporation Pond (2.6 Acres)	$1,360,000								$1,360,000
Evaporation Pond (3.9 Acres)	$1,889,000					$1,889,000			
Evaporation Pond (4.15 Acres)	$1,994,000						$1,994,000		
Evaporation Pond (4.65 Acres)	$2,178,000							$2,178,000	
LNAPL Separation and Disposal	$96,000			$96,000	$96,000			$96,000	$96,000
Treatment	$7,580,000								$7,580,000
Infiltration	$25,000								$25,000
Compliance Monitoring									
Compliance Monitoring	$1,950,000	$1,950,000							
	$2,430,000		$2,430,000						
	$2,870,000			$2,870,000					
	$3,550,000				$3,550,000				
	$3,330,000					$3,330,000			
	$3,600,000						$3,600,000		
	$3,600,000							$3,600,000	
	$3,690,000								$3,690,000
Whitson Well Modification	$109,000	$109,000	$109,000	$109,000	$109,000	$109,000	$109,000	$109,000	$109,000
North End Soil Components[4]									
NES Cap	$330,000		$330,000						
NES Clean Road Corridor	$403,000			$403,000					
NES Cap/Removal Hybrid	$542,000							$542,000	
NES Removal	$576,000								$576,000
	Total Estimated Cost[1]:	**$2,386,000**	**$3,926,000**	**$5,091,000**	**$5,309,000**	**$5,997,000**	**$6,617,000**	**$8,549,000**	**$15,460,000**

Table 13. Cleanup Action Alternative and Component Performance and Cost Summary (continued)

		Initial Removal Rate Summary by Alternative							
Component	Initial Removal Rate of Organic COCs (kg/yr)	Alternative 1	Alternative 2	Alternative 3	Alternative 4 [5]	Alternative 5	Alternative 6	Alternative 7 [5]	Alternative 8 [5]
Components for which Northerly Plume Contaminant Reduction Was Quantified									
Natural Attenuation	200	200	200	200	200	200	200	200	200
Continuous Pumping from the Hole	0.18			0.18				0.18	0.18
Continuous Pumping from the P1 Zone[5]	131			131	145			145	145
SVE	577				577			577	577
Northerly Plume Capture[2]	1.39						1.39	1.39	1.39
Components for which Northerly Plume Contaminant Reduction Was Quantified									
Seasonal Pumping from the Hole	0.14		0.14				0.14		
Seasonal Pumping from the P1 Zone	60		60				60		
Manual LNAPL Removal	5.97	5.97	5.97			5.97	5.97		
North End Soil Components[4]									
NES Cap	9.71		9.71						
NES Clean Road Corridor	50			50					
NES Cap/Removal Hybrid	81							81	
NES Removal	160								160
	Initial Removal Rate of Organic COCs (kg/yr):	**206**	**276**	**381**	**922**	**206**	**268**	**1,004**	**1,083**

	Performance and Cost Comparison							
Basis of Comparison	Alternative 1	Alternative 2	Alternative 3	Alternative 4 [6]	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Initial Cost per Unit of Organic COC Removed ($/kg/yr):	$11,584	$14,224	$13,373	$5,759	$29,115	$24,719	$8,511	$14,270
Estimated Year of Compliance with Cleanup Standard:	>2084	>2084	2047	2047	2033	2033	2033	2033
Estimated Restoration Timeframe from 2013:	>71	>71	34	34	20	20	20	20

Definitions:

CUL – cleanup level.

COC – contaminant of concern

LNAPL – light non-aqueous phase liquid.

NES – north end soils.

POC – point of compliance.

SVE – soil vapor extraction.

[1] Costs are present worth based on a 30-year time interval.

[2] Northerly plume capture costs for Alternative 5 are higher because pumping-related infrastructure costs are not shared among other pumping locations.

[3] Based on fate and transport modeling of northerly plume IHSs for a 30-year restoration timeframe.

[4] North end soils would not be removed or capped under Alternative 1, 4, 5, or 6. Groundwater would be monitored, and additional measures, such as capping or removal, would be evaluated if organic IHS concentrations in MW-41a groundwater samples approach source area CULs.

[5] The higher initial removal rates for Alternative 4, 6, and 7 reflect LNAPL entrainment in groundwater if wells are drawn down more than about 2 feet to support SVE.

[6] The estimated restoration timeframe is based on continuous pumping from the P1 zone, which is needed to implement SVE.

Table 14. Summary of Wells by Alternative

Alternative	Wells
1 & 2	**Existing Wells – Gauged and Sampled:** MW-2c, MW-3b, MW-4c, MW-5c, MW-6c, MW-7b, MW-9b, MW-19b, MW-20c, MW-21c, EW-1, MW-28d, MW-29b, MW-35p2, MW-39p2, MW-42b, MW-43p2, MW-44b, MW-48b, MW-51b, MW-53a, MW-56c **Existing Wells – Gauged Only[1]:** MW-34p1, MW-36p1 **New Wells – Gauged and Sampled:** MW-57p2, MW-58b, MW-59p2, MW-60b, MW-61c
3	**Existing Wells – Gauged and Sampled:** MW-2c, MW-3b, MW-4c, MW-5c, MW-6c, MW-7b, MW-9b, MW-19b, MW-20c, MW-21c, EW-1, MW-28d, MW-29b, MW-35p2, MW-39p2, MW-42b, MW-43p2, MW-44b, MW-48b, MW-51b, MW-53a, MW-56c **Existing Wells – Gauged Only[1]:** MW-34p1, MW-36p1 **New Wells – Gauged and Sampled:** MW-57p2, MW-58b, MW-59p2, MW-60b, MW-61c **New Wells – Gauged Only[1]:** EW-3, EW-4, EW-5, EW-6, EW-7, EW-8
4	**Existing Wells – Gauged and Sampled:** MW-2c, MW-3b, MW-4c, MW-5c, MW-6c, MW-7b, MW-9b, MW-19b, MW-20c, MW-21c, EW-1, MW-28d, MW-29b, MW-35p2, MW-39p2, MW-42b, MW-43p2, MW-44b, MW-48b, MW-51b, MW-53a, MW-56c **Existing Wells – Gauged Only[1]:** MW-34p1, MW-36p1 **New Wells – Gauged and Sampled:** MW-57p2, MW-58b, MW-59p2, MW-60b, MW-61c **New Wells – Gauged Only[1]:** EW-6, EW-7, EW-8
5 & 6	**Existing Wells – Gauged and Sampled:** MW-2c, MW-3b, MW-4c, MW-5c, MW-6c, MW-7b, MW-9b, MW-19b, MW-20c, MW-21c, EW-1, MW-28d, MW-29b, MW-35p2, MW-39p2, MW-42b, MW-43p2, MW-44b, MW-48b, MW-51b, MW-53a, MW-56c **Existing Wells – Gauged Only[1]:** MW-34p1, MW-36p1 **New Wells – Gauged and Sampled:** MW-57p2, MW-58b, MW-59p2, MW-60b, MW-61c, MW-62p2, MW-63b, MW-64p2, MW-65b, MW-66p2, MW-67b **New Wells – Gauged Only[1]:** EW-9, EW-10
7 & 8	**Existing Wells – Gauged and Sampled:** MW-2c, MW-3b, MW-4c, MW-5c, MW-6c, MW-7b, MW-9b, MW-19b, MW-20c, MW-21c, EW-1, MW-28d, MW-29b, MW-35p2, MW-39p2, MW-42b, MW-43p2, MW-44b, MW-48b, MW-51b, MW-53a, MW-56c **Existing Wells – Gauged Only[1]:** MW-34p1, MW-36p1 **New Wells – Gauged and Sampled:** MW-57p2, MW-58b, MW-59p2, MW-60b, MW-61c, MW-62p2, MW-63b, MW-64p2, MW-65b, MW-66p2, MW-67b **New Wells – Gauged Only[1]:** EW-3, EW-4, EW-5, EW-6, EW-7, EW-8, EW-9, EW-10

[1] Although wells used for extraction would not be sampled individually, combined discharges to either an evaporation or treatment system would be sampled as part of compliance monitoring for the system.

Table 15. Comparison of Cleanup Action Alternatives to Objectives

Objective	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Threshold Requirements (WAC 173-340-360(2)(a)) - Section 7.1.1								
Protect human health and the environment.	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]
Comply with cleanup standards[2].	>2084	>2084	2047	2047	2033	2033	2033	2033
Comply with ARARs[2].	>2084	>2084	2047	2047	2033	2033	2033	2033
Provide for compliance monitoring.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other Requirements (WAC 173-340-360(2)(b)) - Section 7.1.1								
Use permanent solutions to the maximum extent practicable[3].	Comparatively low contaminant removal	Moderate contaminant removal	Moderate contaminant removal	Comparatively high contaminant removal	Comparatively low contaminant removal	Moderate contaminant removal	Comparatively high contaminant removal	Comparatively high contaminant removal
Provide for a reasonable restoration timeframe.	>71	>71	34	34	20	20	20	20
Consider public concerns.	To be addressed through implementation of a public participation plan prepared by Ecology.							
Groundwater Cleanup Objectives - Section 7.1.2								
Prevent further migration of COCs in concentrations exceeding CULs to drinking water sources through source removal and containment[4].	Comparatively low contaminant removal and control	Moderate contaminant removal and control	Moderate contaminant removal and control	Comparatively high contaminant removal and moderate control	Comparatively low contaminant removal and high control	Moderate contaminant removal and high control	Comparatively high contaminant removal and control	Comparatively high contaminant removal and control
Reduce or eliminate human exposure through ingestion of groundwater containing COCs at concentrations that exceed CULs in the northerly plume.	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]
Soil Cleanup Objectives - Section 7.1.3								
Ensure that contaminants in north end soils do not increase groundwater COC concentrations above CULs.	Yes[5]	Yes	Yes	Yes[5]	Yes[5]	Yes[5]	Yes	Yes

Definitions:

ARAR – applicable or relevant and appropriate requirement.

COC – contaminant of concern.

CUL – cleanup level.

POC – point of compliance.

SVE – soil vapor extraction.

[1] Northerly plume groundwater is not used anywhere that COC concentrations exceed CULs. Potential use during restoration can be prohibited through institutional controls.

[2] Estimated year of atainment of CULs for slect northerly plume IHS.

[3] A permanent solution is not feasible because the Site includes the Ephrata Landfill. Alternatives are compared based on estimated COC removal.

[4] The drums, free liquid presumed to have leaked from the drums, and highly contaminated soil, collectively considered to be a significant source of groundwater contamination, were removed in 2008. This comparison refers to additional source removal.

[5] North end soils would not be removed or capped under Alternative 1, 4, 5, or 6. Groundwater would be monitored, and additional measures, such as capping or removal, would be evaluated if organic IHS concentrations in MW-41a groundwater samples approach source area CULs.

Table 16. Disproportionate Cost Analysis Summary

					Benefits Evaluation		
Alternative	**Key Cleanup Action Components[1]**	**Initial Removal Rate of Organic COCs (kg/yr)**	**Present Worth**	**Incremental Cost**	**Favorable Elements**	**Unfavorable Elements**	**Incremental Benefits**
1	Natural attenuation	206	$2,386,000	---	Protective with institutional controls Provides for compliance monitoring Manual LNAPL removal Whitson well conversion	Restoration timeframe > 71 years Non-permanent Comparatively low source removal	Not applicable
2	Natural attenuation Seasonal pumping from the Hole and P1 zone NES cap	276	$3,926,000	$1,540,000	Protective with institutional controls Provides for compliance monitoring Seasonal removal of source area groundwater Manual LNAPL removal Whitson well conversion NES cap	Restoration timeframe > 71 years Non-permanent	Seasonal removal of source area groundwater NES cap
3	Natural attenuation Continous pumping from the Hole and P1 zone NES clean road corridor	381	$5,091,000	$1,165,000	Protective with institutional controls during restoration Provides for compliance monitoring 34-year restoration timeframe Continuous removal of source area groundwater LNAPL separation and disposal Whitson well conversion NES partial cap, partial removal	Non-permanent	Continuous removal of source area groundwater More LNAPLremoval Partial NES removal Shorter restoration time frame
4	Natural attenuation Continuous pumping from the P1 zone SVE	922	$5,309,000	$218,000	Protective with institutional controls Provides for compliance monitoring 34-year restoration timeframe Removes vapor-phase COCs from LNAPL area Continuous removal of source area groundwater LNAPL separation and disposal Whitson well conversion	Non-permanent	More source removal
5	Natural attenuation Northerly plume capture	206	$5,997,000	$688,000	Protective with institutional controls during restoration Provides for compliance monitoring 20-year restoration timeframe Hydraulic capture of the northerly plume Manual LNAPL removal Whitson well conversion	Non-permanent Comparatively low source removal	Protective with institutional controls during restoration Hydraulic capture of the northerly plume Shorter restoration time frame
6	Natural attenuation Seasonal pumping from the Hole and P1 zone Northerly plume capture	268	$6,617,000	$620,000	Protective with institutional controls during restoration Provides for compliance monitoring 20-year restoration timeframe Seasonal removal of source area groundwater Hydraulic capture of the northerly plume Manual LNAPL removal Whitson well conversion	Non-permanent	None[2]
7	Natural attenuation Continuous pumping from the Hole and P1 zone SVE Northerly plume capture NES cap/removal hybrid	1004	$8,549,000	$1,932,000	Protective with institutional controls during restoration Provides for compliance monitoring Comparatively high permanance 20-year restoration timeframe Removes vapor-phase COCs from LNAPL area Continuous removal of source area groundwater Hydraulic capture of the northerly plume LNAPL separation and disposal Whitson well conversion NES partial cap, partial removal	Non-permanent	Increased NES Removal[2]
8	Natural attenuation Continuous pumping from the Hole and LNAPL area SVE Northerly plume capture NES removal	1083	$15,460,000	$6,911,000	Protective with institutional controls during restoration Provides for compliance monitoring Comparatively high permanence 20-year restoration timeframe Removes vapor-phase COCs from LNAPL area Continuous removal of source area groundwater Hydraulic capture of the northerly plume LNAPL separation and disposal Whitson well conversion NES removal	Non-permanent	Complete NES removal[2]

[1] North end soils would not be removed or capped under Alternative 1, 4, 5, or 6. Groundwater would be monitored, and additional measures, such as capping or removal, would be evaluated if organic IHS concentrations in MW-41a groundwater samples approach source area CULs.

[2] No (other) unique incremental benefit compared to each lower numbered alternative, respectively.

Definitions:

ARAR – applicable or relevant and appropriate requirement.
COC – contaminant of concern.
CUL – cleanup level
LNAPL – light non-aqueous phase liquid.
NES – north end soils.
SVE – soil vapor extraction.

APPENDIX A

Hydrogeologic Calculations and Considerations in Support of Ephrata Landfill FS Draft Technical Memorandum

PACIFIC groundwater GROUP

REMCHLOR FATE AND TRANSPORT MODELING
FEASIBILITY STUDY SUPPORT
EPHRATA LANDFILL

August 29, 2012

REMCHLOR FATE AND TRANSPORT MODELING
FEASIBILITY STUDY SUPPORT
EPHRATA LANDFILL

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August 29, 2012
JE0714
REMChlorModel_FSAppendix_Final_v2.docx

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SIGNATURE

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1.0 INTRODUCTION

Fate and transport modeling of the Roza aquifer component of the northerly groundwater contaminant plume at the Ephrata Landfill was completed to support the Feasibility Study (FS). Specifically, the model was used to assess four scenarios, which correspond with certain cleanup action components described in the FS:

1. Natural Attenuation (NA)
2. Long Term Groundwater Extraction of P1 source area
3. Soil Vapor Extraction (SVE) in the P1 source area
4. Northerly Plume Capture in the Roza Aquifer at the Northern Landfill Property Boundary

The analytical model REMChlor (Falta, 2007) was selected to perform fate and transport modeling. Fate and transport modeling was performed for the four volatile organic compounds (VOCs) in the Roza aquifer component of the northerly plume that were identified as indicator hazardous substances (IHS) in the FS (Parametrix, 2012):

1. 1,2-dichloropropane (1,2-DCP)
2. Vinyl chloride (VC)
3. Benzene
4. Methylene Chloride

Model sensitivity was also assessed given the uncertainty in key input parameter values. Manganese is the fifth IHS in the Roza aquifer component of the northerly plume but it was not modeled.

The following sections describe the REMChlor model and our approach for using it to simulate the Roza aquifer component of the northerly plume. Subsequent sections describe model input parameters, model calibration, predictive simulations, and model uncertainty.

Our professional services were performed, our findings obtained, and our report prepared in accordance with generally accepted hydrogeologic practices. This warranty is in lieu of all other warranties, expressed or implied.

2.0 CONCEPTUAL MODEL AND MODEL ASSUMPTIONS

REMChlor is a 1-D fate and transport analytical model which assumes uniform groundwater flow and uses single, fixed values for hydrogeologic and chemical variables such as groundwater velocity, initial source concentration (Co), and initial source mass (Mo). REMChlor makes no assumption with regard to flow direction along its single spatial dimension (direction could be horizontal or vertical), and cannot simulate aquifer heterogeneities or hydraulic effects (such as changes in groundwater flow due to pumping);

however, it is capable of simulating the effects of source removal, enhanced plume decay, and NA.

We developed a REMChlor model to represent the center line of the Roza aquifer component of the northerly plume (Figure 1). The flow path along the plume center line extends northward from the P1 source area (by the former buried drums) and then northeastward and terminates at distance of about 575 m. This pathway is based on groundwater elevations and VOC concentrations observed in Roza aquifer wells. The contaminant transport pathway in the Roza aquifer is likely more complex with some contaminants being transported towards the Roza high transmissivity zone before migrating northward (Figure 1). This is one example of the simplified nature of the model.

Beyond 575 m along the plume center line, groundwater in the Roza is believed to discharge laterally into alluvium near a bedrock draw with some vertical migration to deeper aquifers also occurring. Enhanced vertical flow from the Roza aquifer to deeper aquifers may also have occurred through the Whitson domestic well[1] (Figure 1). Discharge and vertical migration of the plume to other aquifers is not simulated in the REMChlor model; however, these processes contribute to attenuation of the leading edge of the northerly plume by means of mixing, dilution, and evapotranspiration. The nature and extent of ground-water contamination is discussed in detail in the Remedial Investigation (RI) report (PGG, 2010).

REMChlor simulates depletion of the P1 contaminant source mass (kg) over time due to groundwater dissolution, source decay, and/or source removal (Figure 2). Groundwater dissolution of the source mass results in a source concentration (ug/L) over time which forms the upgradient boundary condition to the simulated dissolved phase groundwater plume (Figure 2). Contamination in the plume is transported downgradient along the 1-D flow path due to groundwater advection and dispersion. Dissolved phase concentrations are also depleted within the plume due to decay.

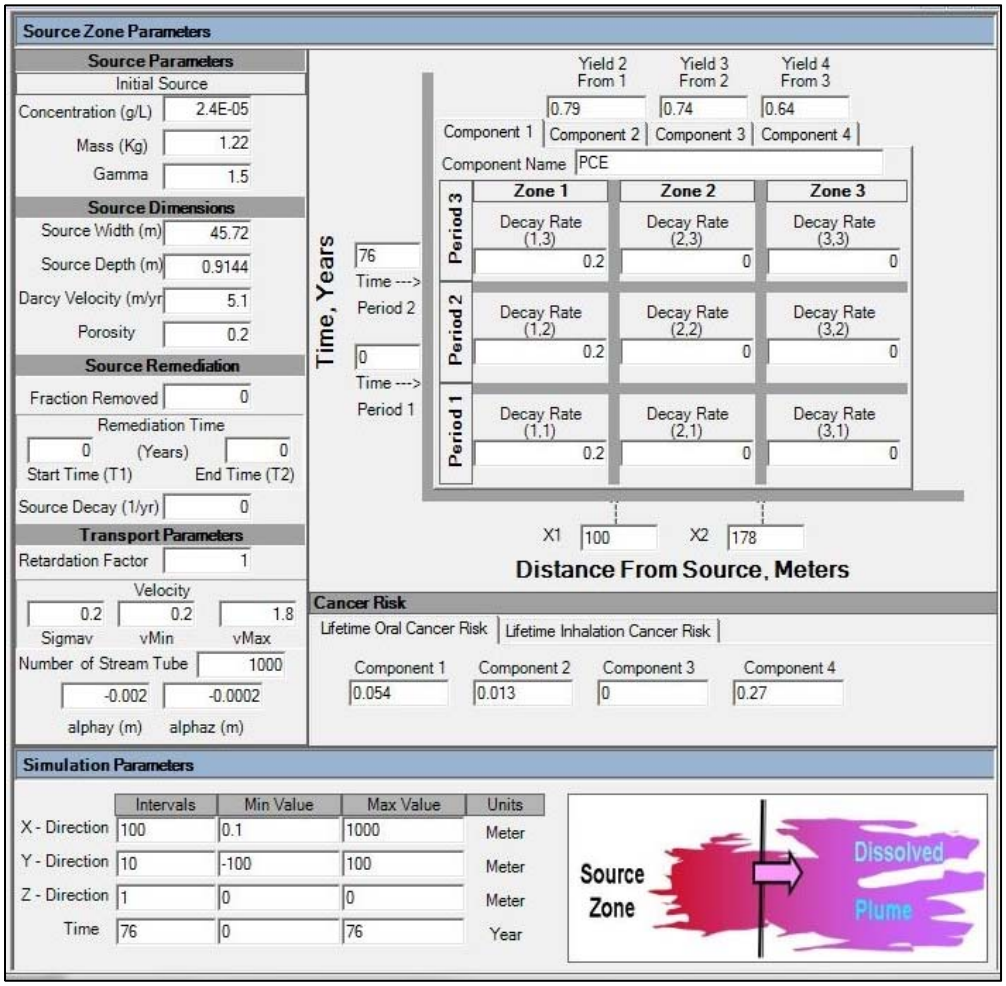
These model features allow predictive simulations for potential future source removal and/or enhanced plume decay cleanup actions, as well as NA. The model has many attractive features; however, it is a highly simplified approximation of the site and does not represent all the natural and engineered complexities.

2.1 REMCHLOR INPUT PARAMETERS

The following sections summarize REMChlor model input parameters for defining contaminant source, source remediation, groundwater plume transport, and plume decay. Below is an example of the REMChlor model interface:

---

[1] The Whitson well was an open borehole from 19 to 294 feet below ground surface between 1997 when well was first drilled to 2012. In 2012 the bottom portion of the well was sealed and a new monitoring well was constructed in accordance with Chapter 173-160 WAC. The new well was constructed in the Interflow aquifer (The new well ID is MW-56c).



Source Zone Parameters

Source Parameters

Initial Source

Concentration (g/L)	2.4E-05
Mass (Kg)	1.22
Gamma	1.5

Source Dimensions

Source Width (m)	45.72
Source Depth (m)	0.9144
Darcy Velocity (m/yr	5.1
Porosity	0.2

Source Remediation

Fraction Removed 0

Remediation Time (Years)

Start Time (T1) 0

End Time (T2) 0

Source Decay (1/yr) 0

Transport Parameters

Retardation Factor 1

Velocity

Sigmav	vMin	vMax
0.2	0.2	1.8

Number of Stream Tube 1000

alphay (m)	alphaz (m)
-0.002	-0.0002

Yield 2 From 1	Yield 3 From 2	Yield 4 From 3
0.79	0.74	0.64

Component 1 | Component 2 | Component 3 | Component 4

Component Name PCE

Time, Years

76 Time ---> Period 2

0 Time ---> Period 1

	Zone 1	Zone 2	Zone 3
Period 3	Decay Rate (1,3) 0.2	Decay Rate (2,3) 0	Decay Rate (3,3) 0
Period 2	Decay Rate (1,2) 0.2	Decay Rate (2,2) 0	Decay Rate (3,2) 0
Period 1	Decay Rate (1,1) 0.2	Decay Rate (2,1) 0	Decay Rate (3,1) 0

X1 100 X2 178

Distance From Source, Meters

Cancer Risk

Lifetime Oral Cancer Risk | Lifetime Inhalation Cancer Risk

Component 1	Component 2	Component 3	Component 4
0.054	0.013	0	0.27

Simulation Parameters

	Intervals	Min Value	Max Value	Units
X - Direction	100	0.1	1000	Meter
Y - Direction	10	-100	100	Meter
Z - Direction	1	0	0	Meter
Time	76	0	76	Year

2.1.1 Source Model Input Parameters

Source model parameters include source zone dimensions (width and depth), source mass (kg), initial source concentration (g/L), and gamma (a user specified term in REMChlor). In REMChlor, the source mass is depleted over time as contaminants move downgradient with groundwater from the source zone. As such, the depletion of the source mass is also a function of the groundwater velocity assigned to the model. Faster velocity results in a more rapid depletion of the source mass.

The source concentration (the concentration in groundwater in contact with the source) also decreases over time as the source mass is depleted. The relationship between source mass depletion and associated source concentration is defined in REMChlor using a power function and gamma is the exponent which determines the relationship. A gamma-value of 1.0 results in a 1:1 relationship between the decrease in source mass and corresponding decrease in source concentration. Gamma values greater than 1 result in rapid decrease in source concentration at early time followed by a slow decrease in later time (this is known as the “tailing effect” and represents matrix diffusion conditions where the source is dominantly in low permeability zones). In contrast, gamma values less than 1 result in slow decrease in source concentration at early time followed by rapid decrease at later time. A gamma value of 0 is a unique case that results in a constant source concentration until the source mass is fully depleted (Falta, 2007).

2.1.2 Source Remediation Parameters

Source remediation is simulated in REMChlor as a human-caused reduction in source mass over a specified period of time. Input parameters include mass fraction removed from the source and the start and end year of the source removal. REMChlor also allows for a constant first order source decay rate which reduces the source mass over time by other processes besides dissolution and flushing (Falta, 2007).

2.1.3 Plume Transport Parameters

Plume transport parameters include Darcy velocity (m/yr), porosity, retardation, and dispersivity. In REMChlor the longitudinal dispersion (alpha-x) is scale dependent and represented using a number of streamtubes that have a normal velocity distribution with a mean velocity (Vmean) and standard deviation (σ):

alpha-x = Sigmav^2/2*Xmean

Where Sigmav = the coefficient of variation for the velocity distribution = σ^2/Vmean. (Sigmav is user specified)

Xmean = the average advective front location.

The upper and lower bounds of the streamtube velocity distribution are user specified and defined by:

vMin-normalized = minimum normalized streamtube velocity (a value of zero suggested)

vMax-normalized = maximum normalized streamtube velocity (a value of 1+4*Sigmav suggested)

Ideally Vmin-normalized and Vmax-normalized are symmetrical around 1.0 (Falta, 2007).

Transverse (alpha-y) and vertical (alpha-z) dispersivities are user specified and can be constant or scale dependent in REMChlor. Scale dependent dispersivity values are calculated in REMChlor as proportional to the distance from the source (Falta, 2007).

2.1.4 Plume Decay Parameters

REMChlor simulates the destruction of contaminant concentrations in the plume as a result of reductive dechlorination, biodegradation, and other destructive processes through the use of plume decay parameters. Plume decay parameters include user specified first order decay rates (yr-1) and parent/daughter yield coefficients. REMChlor can simulate both the chemical decay of the parent product and the associated production and decay of daughter products through the use of yield coefficients. Up to three daughter products in the decay pathway from a parent product can be simulated in REMChlor (e.g. TCE, cis-

1,2-DCE and VC from PCE). Decay rates for parent and daughter products can vary in time and space, with up to three spatial and temporal plume decay zones available.

3.0 APPROACH FOR USING REMCHLOR

Our approach for using REMChlor was to first calibrate the model to current plume conditions and then run the calibrated model into the future to assess plume attenuation over time under different scenarios which correspond with certain cleanup action components described in the FS.

The following chemicals were simulated:

- Chloride
- 1,2-Dichloropropane (1,2-DCP)
- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- cis-12-Dichloroethene (cis-1,2-DCE)
- Vinyl Chloride (VC)
- Benzene
- Methylene Chloride

These chemicals include VOC IHS identified in the FS for the Roza aquifer northerly plume component, additional chloro-ethenes that are part of the degradation pathway for vinyl chloride, and chloride, which was used to calibrate the dispersion term. Each chemical is simulated independently using REMChlor. Note that for the chloro-ethenes, daughter products produced during the decay of a parent product (e.g. TCE, cis-1,2-DCE, and VC from PCE) were added to subsequent model results of those chemicals as parent products. This method of super-positioning model results was deemed necessary because site conditions indicate the source mass is composed of relatively high concentrations of daughter products (e.g. cis-1,2-DCE and VC). Super-positioning of model results was also used to simulate the historical development of the current plume followed by attenuation of the future plume as described below. This approach of super-positioning of REMChlor results has been used at other sites (Henderson et al, 2009) and was discussed with the developers of REMChlor as a feasible approach.

3.1 APPROACH FOR SIMULATING CURRENT AND FUTURE PLUME

The super-position method for simulating the current and future VOC plumes involved running two simulations. The first simulation began in 1975 (year of drum burial) and modeled the historical development of the current plume assuming a constant continuous source concentration up until completion of interim actions in 2008 (drum removal). The historical constant source concentration was assumed to be the same as the current source concentration (see Section 4.1 below). At completion of interim actions the historical source concentration was assumed to be zero and this first simulation continued to model the plume into the future with a zero source concentration. This type of changing source concentration (constant concentration until 2008 followed by a zero concentration) was achieved in REMChlor by using a gamma value of 0 and calculating the required initial source mass such that it was fully depleted by 2008. The purpose of the first model was to create a current plume configuration that the second model was then superimposed upon.

The second simulation began in 2008 and modeled the plume 76 years out (2084) assuming a source concentration that slowly decreased over time as the finite source mass is depleted. The finite source mass was specified based on post-interim action residual source data (see Section 4.1 below). The initial source concentration was the same as the historical source concentration used in the first model and was estimated using a mass flux approach (see Section 4.1 below). A decreasing source concentration in the second model was achieved by using a gamma value greater than 0.

Concentrations in the future plume were then calculated using the super-position method by adding the results of the first and second models.

4.0 MODEL INPUT PARAMETERS

Model input parameter values are shown in Table 1 and discussed individually below.

4.1 SOURCE PARAMETERS

Source geometry, mass, and concentrations for chloride and VOCs are described below.

4.1.1 Chloride

The chloride source was assumed to be associated with the original landfill. The source width and depth for the chloride source was assumed to be 1000-ft long (perpendicular to groundwater flow) and 10-ft deep. This geometry was based on the approximate cross section of the Roza aquifer along the northern edge of the landfill (1000-ft) and the average thickness of the Roza aquifer (10-ft).

The source mass for the chloride model (Table 1) was assumed to be infinite and assigned an arbitrary large value (10^9 kg) so that the source was never depleted during the simulation. The source concentration was assigned an average concentration based on observed concentrations in the source area by the former drums and the Roza aquifer in the vicinity of the shop (1.0 g/L). For the chloride simulation we assumed the source concentration was constant and continuous and therefore used a gamma value of 0 (Table 1).

4.1.2 Volatile Organic Compounds (VOCs)

The source for each VOC was assumed to be dominantly associated with the former drums and residual contamination in the P1 zone. The source width and depth for each VOC was assumed to be 150-ft and 3-ft respectively. This geometry was based on the best estimate of the approximate length of the P1 source area perpendicular to groundwater flow (150-ft) and the average thickness of the P1 zone (3-ft). The P1 source area was assumed to be the approximate area where light non-aqueous phase liquids (LNAPL) are estimated to occur in the P1 zone.

The initial source mass value (Mo) for each simulated VOC was different in the first and second models (Table 1). The value of Mo in the first model was calculated using REMChlor equations (Falta, 2007) such that it is fully depleted by 2008. The value of Mo in the second model was calculated based on estimates of source mass in residual soil and LNAPL by the former drums (PGG, 2012a).

The initial source concentration (Co) for each simulated VOC was the same in both the first and second models (Table 1) and was based on a calculation of plume mass flux (PGG, 2012a)[2]. The plume mass flux was assumed to be the same as the mass flux through the source area Q*Co (g/yr). REMChlor uses the Darcy velocity (q) to calculate the groundwater flux through the source area (Q), where Q = q*A with A being the cross-sectional dimension of the source area. Since Q is a fixed parameter in REMChlor, the value of Co was calculated as the concentrations required to make Q*Co equal to the plume mass flux (PGG, 2012a).

Minimum and maximum values in Mo and Co were also estimated based on uncertainty in the source area dimension (PGG, 2012a). Model sensitivity to the values of Mo and Co was tested in subsequent model runs (see Section 7 below).

4.1.3 Gamma

A gamma value of 0 was used to simulate a constant continuous source for the chloride simulation and the first model in the VOC simulations (Table 1). A gamma value of 1.5 was used for the second model in the VOC simulations (Table 1). Gamma values for most sites are thought to range from 0.5 to 2.0 (Newell et al, 2011). As mentioned above, gamma values greater than 1 are generally assigned to sites with high heterogeneity and where matrix diffusion from low permeability zones is expected to result in long-term “tailing” of contaminant concentrations. We therefore expect a representative gamma value between 1 and 2 for the Ephrata site and chose 1.5 as a “middle” value.

The sensitivity of gamma was tested in subsequent model runs (see Section 7 below).

4.1.4 Source Remediation

For the model calibration and predictive simulation of NA we assume no source remediation (Table 1). Source remediation parameters were adjusted later during the predictive simulation of other scenarios (see Section 6 below).

---

[2] Because the observed concentrations in the P1 source area may include LNAPL, and therefore overestimate dissolved phase concentrations, a mass flux approach was developed for estimating the initial source concentration (Co) for each simulated VOC in REMChlor. However, since vinyl chloride is created through the degradation of PCE, TCE and cis-1,2-DCE downgradient from the source, the mass flux approach resulted in an overestimated Co value for vinyl chloride at the source (PGG, 2012a). We therefore used the observed concentration in the P1 source area for vinyl chloride, which was less than that calculated using the mass flux approach (PGG, 2012a).

4.2 TRANSPORT PARAMETERS

Groundwater transport parameters are described below.

4.2.1 Darcy Velocity

The Darcy velocity or specific discharge rate (q) was assumed constant in all model simulations and was set equal to the best estimate of specific discharge in the Roza Aquifer (5.1 m/yr). This value was derived using the geometric mean hydraulic conductivity (K) for the Roza aquifer (3.5 ft/d) and the average groundwater gradient (i) in the Roza aquifer along the northerly plume centerline (0.013)[3]:

$q = K*i = 3.5*0.013 = 0.0455$ ft/dy = 5.1 m/yr

The actual discharge rate in the aquifer; however, is expected to be highly variable at different locations. This is one example of the simplified nature of the model.

Assuming a porosity (n) of 0.2, the groundwater seepage velocity (v) was calculated to be:

$v = q/n = 5.1 /0.2 = 25.5$ m/yr (84 ft/yr)

In REMChlor, the Darcy velocity (q) is also used to calculate the groundwater flux (Q) through the source zone area (A):

$Q = q*A = 0.0455$ ft/dy * (150-ft x 3-ft) = 20.5 ft^3/dy = 212 m^3/yr

The groundwater velocity parameter therefore effects the simulation of both the plume and the source mass attenuation over time. This is another example of the simplified nature of the model. In essence, REMChlor simulates the source mass as if it is within the Roza aquifer, whereas in Ephrata the source mass is actually in the overlying P1 zone.

The mass flux through the source area is Q*Co (g/yr). Since a separate groundwater flux (Q) cannot be assigned to the source area in REMChlor; the initial source mass (Co) was calculated based on estimates of mass flux through the source area (PGG, 2012a).

Model sensitivity to the Darcy velocity was tested in subsequent model runs (see Section 7 below).

4.2.2 Porosity

The porosity of the Roza aquifer was assumed to be 0.2. This is consistent with our interpretation that the weathered zone of the Roza aquifer is a porous medium.

4.2.3 Retardation Factor

The retardation factor (Rf) for a particular contaminant is the ratio between the rate of groundwater movement and rate of contaminant movement:

---

[3] The groundwater gradient was calculated using water level data collected in March, June and September 2011.

Rf = v/vc

Where v = groundwater seepage velocity

vc = contaminant velocity

When v = vc, Rf = 1.

For organic chemicals, the dominant process contributing to retardation is adsorption of the contaminant to solid surfaces and Rf is calculated as:

Rf = 1 + [ρb/n]*Kd

Where ρb = aquifer bulk density

n = aquifer porosity

Kd = partitioning coefficient associated with the aquifer and contaminant

Because organic chemicals partition primarily onto the organic carbon fraction of an aquifer (foc), Kd values are commonly estimated using the value of the organic carbon fraction of aquifer solids (foc) and the octanol-water partition coefficient (Koc):

Kd = Koc*foc

Koc values are chemical specific and are readily available in Ecology's Cleanup Levels and Risk Calculations (CLARC) online database and other sources; however, the foc is aquifer specific. MTCA recommends using a value of 0.001 in the absence of field data. However, sorption in basalt aquifers is typically considered to be relatively insignificant due to the absence of organic material (Sorenson et al, 1998). We have not been able to find any definitive references on sorption specifically for the Wanapum basalt in the literature.

Given the low organic content expected in the Roza basalt aquifer, we expect that the MTCA default values for deriving Kd values could result in an over prediction of retardation and therefore an under prediction of the contaminant velocity. Given this uncertainty, we took the approach of regarding the groundwater velocity term in REMchlor as a contaminant velocity term and set the retardation factor equal to 1.0 for all VOCs.

Our best estimate for the groundwater seepage velocity was 25.5 m/yr (see Section 4.2 above) and we estimated a minimum (12.5 m/yr) and maximum (91 m/yr) contaminant velocity based on field observations (see Section 7.0 below).

While the Rf parameter affects the contaminant velocity in REMChlor, it does not affect the groundwater flux (Q) through the source zone area. This distinction could be important because the groundwater flux (Q) controls the mass flux (Q*Co) through the source area which effects the source mass depletion rate (Drate):

Drate = Q*Co/Mo [dy-1]

Where Q = groundwater flux (constant)

Co = source concentration

Mo = source mass

Treating the groundwater velocity term in REMChlor as a contaminant velocity term and setting the retardation value equal to 1.0 could result in an under prediction of source depletion if retardation is in fact an important process.

However, as explained in Section 4.1.2 above, we have estimated the mass flux through the source area (Q*Co) outside of REMChlor and fixed this value in REMChlor by adjusting Co. Therefore, the potential for underestimating the source depletion rate by using a retardation factor of 1 is eliminated.

The chloride plume was also assumed to not be retarded by sorption processes and therefore an Rf value of 1.0 was used for the Chloride Model (Table 1).

4.2.4 Dispersivity Parameters

As discussed above, the dispersivity parameters (Sigmav, vMin-normalized, vMax-normalized, alpha-y, and alpha-z) were adjusted during calibration of the chloride model to current chloride concentrations. Final calibrated values are shown in Table 1 and discussed below in Section 5.0.

4.3 PLUME DECAY RATES

Plume decay rates were adjusted during calibration of the VOC models to current concentrations. Decay rates were adjusted within the range of values reported in the literature (U.S. Geological Survey, 2006; Aronson and Howard, 1997; U.S. EPA, 1999; and Suarez and Rifai, 1999). Final model calibrated values are shown in Table 1 and discussed further in Section 5.0 below. Plume decay rates were assumed to be zero for the chloride model.

4.4 SIMULATED TIME

Development of the current chloride plume was assumed to occur over a 53 year period (1955 to 2008). The start date of 1955 is about 10 years after operation of the landfill first began and when groundwater levels at the site increased significantly in response to the Columbia Basin Irrigation project. The start of the irrigation project is likely when groundwater in the Hole first developed.

Development of the VOC plume was assumed to occur over a 34 year period, from the initial burial of the drums in 1975 to the removal of drums and associated soils in 2008. The future plume was simulated for an additional 76 years to 2084.

5.0 MODEL CALIBRATION RESULTS

Targets used in the calibration are discussed below followed by a discussion of the calibration results. Calibration results are shown as simulated concentration profiles (Figures 3 through 10) along the plume center line (Figure 1). The plume center line extends from the source area (0 m) to the approximate extent of the Roza aquifer component of the northerly plume (575 m).

5.1 TARGETS

Except for groundwater concentrations at the source, concentration targets representing current conditions along the plume center line were developed by contouring RI groundwater data from Roza aquifer wells and the Whitson well. The groundwater concentration at the source (Co) was based on calculations of plume mass flux (Q*Co) as described above in Section 4.1.2

Concentration targets are shown in Table 2. The furthest target from the source area is the Whitson well at 1400-ft, which is completed through multiple aquifers, including the Roza. Data collected from the Whitson well is therefore a mixture between aquifers and the concentration in the Roza aquifer at this location is likely higher than what is observed in the Whitson well. This furthest target was therefore qualified as “greater than” (Table 2).

5.2 CHLORIDE CALIBRATION RESULTS

The results of the calibrated chloride simulation are shown in Figure 3. The best fit to target data was achieved with a Sigmav = 0.2. This is equivalent to a longitudinal dispersivity of 6 meters at a distance of 1000-ft, which is similar to those reported in Gelhar et al (1992) for a distance of 1000-ft. Scale dependent transverse and vertical dispersivities were 0.002 and 0.0002 respectively, which is equivalent to 0.6 and 0.06 meters at a distance of 1000-ft.

5.3 1,2-DCP CALIBRATION RESULTS

The 1,2-DCP model was calibrated relatively well to the target concentration values (Figure 4). The best fit to the targets was achieved with a relatively low decay rate of 0.055 (yr-1) assigned to all three plume decay zones (Table 1). We did not find available published data on decay rates for 1,2-DCP; however the rate of degradation of 1,2-DCP in the environment is thought to be relatively slow (U.S. EPA, 1979).

5.4 PCE CALIBRATION RESULTS

The PCE model was calibrated relatively well to the target concentration values (Figure 5). The best fit to the targets was achieved with a decay rate of 0.2 (yr-1) assigned to plume decay zone 1 and a zero decay rate assigned to zones 2 and 3 (Table 1). This value is within the range reported in the literature.

5.5 TCE CALIBRATION RESULTS

The TCE model was calibrated relatively well to the target concentration values (Figure 6). The best fit to the targets was achieved with a decay rate of 0.7 (yr-1) assigned to plume decay zone 1, a decay rate of 0.1 (yr-1) assigned to zone 2, and a zero decay rate assigned to zone 3 (Table 1). These values are within the range reported in the literature.

5.6 CIS-1,2-DCE CALIBRATION

The cis-1,2-DCE model was calibrated relatively well to the target concentration values (Figure 7). The best fit to the targets was achieved with a decay rate of 0.7 (yr-1) assigned to plume decay zone 1, a decay rate of 0.2 (yr-1) assigned zone 2, and a zero decay rate assigned to zone 3 (Table 1). These values are within the range reported in the literature.

5.7 VINYL CHLORIDE CALIBRATION RESULTS

The vinyl chloride model was calibrated relatively well to the target concentration values except for the target at 85 m (Figure 8). The target for vinyl chloride at 85 m (10 ug/L) was based on data projected from Roza well MW-42b (Figure 1); however, in order to match the observed concentration of vinyl chloride at the Whitson well (> 5 ug/L at 427 m), a modeled concentration of 150 ug/L was required at 85 m.

The concentration of vinyl chloride is highly variable near the north end of the landfill. Concentrations were over 500 ug/L in some wells near the source area, about 60 ug/L in the Hole (approximately 100 meters west from the source); and about 30 ug/L in the Roza aquifer at MW-3b (approximately 200 meters northwest from the source). Thus the accuracy of projected data points for vinyl chloride near the source can be questionable.

For the calibration we honored the observed concentration target at the Whitson well (target at 427 m) at the expense of the projected target at 85 m. Final calibration was achieved with a decay rate of 0.5 (yr-1) assigned to plume decay zones 1 and 2 and zero decay rate assigned to zone 3 (Table 1). These values are within the range reported in the literature.

5.8 BENZENE CALIBRATION RESULTS

The benzene model was calibrated relatively well to the target concentration values except for the target at 293 m (Figure 9). The target for benzene at 293 m (30 ug/L) was based on data projected from Roza well MW-44b (Figure 1). Even with plume decay rates set to zero, the model could not simulate a concentration of 30 ug/L at 293 m given a source concentration of 113 ug/L. The simulated concentration at 293 meters is about 1/3 the target value (10 ug/L). The higher target value suggests the historic mass and source concentration may be different than our current assumptions. Thus, plume attenuation and restoration time periods may be longer than predicted by the model. The concentration of benzene measured in MW-44b during the RI has shown a decreasing trend from 39 ug/L in September 2009 to 25 ug/L in September 2010 (PGG, 2012b), suggesting the plume may be re-equilibrating from an elevated past source concentration.

The final calibration uses a decay rate of zero assigned to all three plume decay zones (Table 1).

5.9 METHYLENE CHLORIDE CALIBRATION RESULTS

The methylene chloride model was calibrated relatively well to the target concentration values (Figure 10). The best fit to the targets was achieved with a decay rate of 0.01 (yr-1) assigned to all three plume decay rate zones (Table 1). These values are within the range reported in the literature.

6.0 MODEL PREDICTIVE SIMULATIONS

The calibrated models were used to perform predictive simulations for the following scenarios, which correspond with certain cleanup action components described in the FS:

1. NA
2. Long Term Groundwater Extraction of P1 source area
3. SVE in the P1 source area
4. Northerly Plume Capture in the Roza Aquifer at the Northern Landfill Property Boundary

The main simulation goal was to estimate IHS concentrations in groundwater over time at various points along the northerly plume centerline. Of interest were:

1. The point at which the northerly plume centerline crosses the north landfill property boundary, which is proposed in the FS as a point of compliance (POC), and

2. The time intervals (restoration time frames) needed under each scenario for IHS concentrations to be reduced to clean up levels (CUL) at the POC and/or at locations downgradient of the POC (Figure 1).

Simulation results were used to evaluate IHS attenuation (changes in plume concentrations over time) and restoration time frames (Table 3). For these simulations, NA and P1 Pumping were assumed to start in 2008, whereas SVE and northerly plume capture were assumed to start in 2013.

Table 3 also shows the locations within the plume (either at the POC or some distance downgradient of the POC) estimated to take the longest time for IHS concentrations to be reduced to CULs. Under NA and SVE, the longest time to meet CULs occurs at the POC. Under northerly plume capture, the longest time to meet CULs occurs at the EOP or between the POC and EOP (methylene chloride). Under P1 Pumping the locations depends on the individual IHS (Table 3).

The simulated effects of NA were combined with the results of each of the other scenarios. However, combinations of P1 pumping, SVE, and northerly plume capture (e.g. active measures) were not simulated. P1 pumping would be needed to create a vadose zone for SVE, and northerly plume capture could accompany any of the other scenarios. Although combinations of active measures were not evaluated, conducting multiple actions would likely reduce plume concentrations more than conducting each action exclusively. Therefore, the restoration time frame would probably be shorter than predicted for the individual actions.

A detailed discussion for each scenario follows.

6.1 NATURAL ATTENUATION

The simulation for NA involved running the calibrated models out into the future with no change to model input parameters. Attenuation of the plume was the result of source depletion due to groundwater dissolution, and plume attenuation due to advection, dispersion, and plume decay (Figure 11). NA was simulated as starting in 2008 and continuing to the end of the simulation (2084).

NA simulation results for each IHS are presented below. Simulated plume concentration profiles are plotted for years 2013, 2018, 2028, 2038 and 2043 for each IHS (Figures 12-15). Also plotted is the CUL for each IHS in the Roza aquifer component for the northerly plume and the POC at the north landfill property boundary (Figure 1).

6.1.1 1,2-DCP Results (NA)

The NA simulation for 1,2-DCP shows concentrations attenuating over time (Figure 12), with concentrations estimated to be in compliance by the year 2063; a 55 year restoration time period (Table 3).

6.1.2 Vinyl Chloride Results (NA)

The NA simulation for vinyl chloride shows concentrations attenuating over time (Figure 13), with concentrations estimated to be in compliance sometime after the year 2084 (the last time step in the model); a restoration time period greater than 76 years (Table 3).

The results of the vinyl chloride simulation show plume concentrations closest to the source (near 0 meters in Figure 13) attenuate significantly over time. However, concentrations increase immediately downgradient of the source before decreasing (Figure 13). The simulated increase in concentrations downgradient from the source is due to vinyl chloride being generated from the decay of PCE, TCE, and cis-1,2-DCE.

6.1.3 Benzene Results (NA)

The NA simulation for benzene shows concentrations attenuating over time (Figure 14), with concentrations estimated to be in compliance by the year 2058; a 50 year restoration time period (Table 3).

6.1.4 Methylene Chloride Results (NA)

The NA simulation for methylene chloride shows concentrations attenuating over time (Figure 15), with concentrations estimated to be in compliance by the year 2079; a 71 year restoration time period (Table 3).

6.2 P1 LONG TERM GROUNDWATER PUMPING

The simulation for P1 long term groundwater pumping considers additional mass removed in extracted groundwater beyond that already removed with natural dissolution of the source area. We did not consider additional mass removed with LNAPL[4]. The limited drawdown available in the P1 source area makes it impossible to hydraulically reverse the vertical gradient by pumping the P1. Hydraulic containment of the P1 source area is therefore not possible simply by pumping the P1. However, implementation of long term pumping would remove source mass over time and contribute to faster rates of source depletion compared to that simulated under NA.

The annual amount of mass removed over time M(t) was estimated using the design extraction volume per year for P1 pumping (PGG, 2012a) and the estimated source concentration over time C(t):

$M(t) = C(t)*V$ [1]

Where

V = extracted groundwater volume per year

$C(t) = [M(t)/Mo]^{\Gamma} * Co$ [2][5]

Mo = initial source mass

Co = initial source concentration

Γ = gamma (1.5)

The design extraction volume per year for the P1 was estimated to be 250,000 gallons (PGG, 2012a). Since the extracted groundwater is likely to be diluted with cleaner groundwater being drawn in from less contaminated portions of the aquifer, and achieving 250,000 gallons per year may be difficult, we assumed that only 50% (125,000 gallons per year) is extracted at the relatively high source concentration.

The values of M(t) and C(t) over time were estimated using the equations 1 and 2 above through an iterative process. For the first time step, M(t) was calculated using the initial source concentration Co as the value for C(t). The resulting value for M(t) was then input into equation 2 to calculate a new value for C(t) which was then used in equation 1

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[4] Extractable LNAPL volume calculated is expected to be relatively low (possibly only a few gallons per year), and the IHS mass removed with LNAPL is expected to be relatively low compared to that removed with extracted groundwater.

[5] REMChlor power function relationship between source concentration and source mass (Falta, 2007)

for calculation of M(t) in the next time step. This process was continued for each time step in the model. Values of M(t) over time were then plotted and the REMChlor time depended equation for M(t) was fitted to the plotted data by adjusting the source decay term (λ):

$$M(t) = \{(-QCo/\lambda Mo^{\Gamma})+(Mo^{1-\Gamma}+QCo/\lambda Mo^{\Gamma})e^{(\Gamma-1)\lambda t}\}^{\Gamma/1-\Gamma} \qquad [3]$$ [6]

As mentioned, REMChlor does not simulate pumping and hydraulic effects; thus the reduction in source mass over time was simulated in REMChlor using the fitted source decay term (Figure 16).

The source decay term in REMChlor is required to be constant throughout the duration of the simulation, so this scenario was simulated as starting in 2008 and continuing through 2084 (Table 4). Results for each IHS are presented below.

6.2.1 1,2-DCP Results (P1 Long Term Pumping)

The P1 Pumping simulation for 1,2-DCP shows concentrations attenuating with time (Figure 17), with concentrations estimated to be in compliance by the year 2039; a 31 year restoration time period (Table 3).

6.2.2 Vinyl Chloride Results (P1 Long Term Pumping)

The P1 Pumping simulation for vinyl chloride shows concentrations attenuating over time (Figure 18), with concentrations estimated to be in compliance by the year 2047; a 39 year restoration time period (Table 3).

Similar to the NA simulation, the results of the P1 Pumping simulation shows vinyl chloride concentration profiles increase downgradient of the source before decreasing (Figure 18). This is due to additional vinyl chloride generated from the decay of PCE, TCE, and cis-1,2-DCE.

6.2.3 Benzene Results (P1 Long Term Pumping)

The P1 Pumping simulation for benzene shows concentrations attenuating over time (Figure 19), with concentrations estimated to be in compliance by the year 2040; a 32 year restoration time period (Table 3).

6.2.4 Methylene Chloride Results (P1 Long Term Pumping)

The P1 Pumping simulation for methylene chloride shows concentrations attenuating over time (Figure 20), with concentrations estimated to be in compliance by the year 2046; a 38 year restoration time period (Table 3).

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[6] Equation (4) in Falta (2007)

6.3 SOIL VAPOR EXTRACTION

The SVE simulation considers additional source mass removal from the P1 area beyond that already removed with natural dissolution. The estimated source mass removal associated with SVE in the FS is 50% of the source mass (Parametrix 2012).

Source removal in REMChlor was assumed to occur over a four year period and was simulated using the linear Source Fraction Removed parameter (Figure 21 and Table 5) and setting the start of removal at model year 5 (2013) and ending at model year 9 (2017). Thus 5 years of natural attenuation occurs before the start of SVE in the model simulation. In contrast, the simulation of SVE performance in order to calculate an initial organic COC mass removal rate for Table 11 of the FS main text assumed exponential decay of 50% of the current source mass. Therefore, the initial (one year) mass removal rate in FS Table 11 is greater than simulated in REMChlor, but the ultimate source reduction is assumed to be 50% in both sets of calculations.

SVE will also require long term groundwater pumping from the P1 source area in order to create a vadose zone for vapor extraction. The SVE simulations did not include source mass removed with P1 groundwater pumping. As mentioned above, active measures were simulated independently (i.e. no simulations were conducted for combinations of active measures). However, all simulations do include the simulated effects of NA.

SVE simulation results for each IHS are presented below.

6.3.1 1,2-DCP Results (SVE)

The SVE simulations for 1,2-DCP (Figure 22) shows concentrations attenuating over time. 1,2-DCP concentrations were estimated to be in compliance by the year 2058; a 45 year restoration time period (Table 3).

6.3.2 Vinyl Chloride Results (SVE)

The SVE simulation for vinyl chloride (Figure 23) shows concentrations attenuating over time. Vinyl chloride concentrations were estimated to be in compliance by the year 2083; a 70 year restoration time period (Table 3).

6.3.3 Benzene Results (SVE)

The SVE simulation for benzene (Figure 24) shows concentrations attenuating over time. Benzene concentrations were estimated to be in compliance by the year 2049; a 36 year restoration time period (Table 3).

6.3.4 Methylene Chloride Results (SVE)

The SVE simulation for methylene chloride (Figure 25) shows concentrations attenuating over time. Methylene chloride concentrations were estimated to be in compliance by the year 2043; a 30 year restoration time period (Table 3).

6.4 NORTHERLY PLUME CAPTURE AT LANDFILL PROPERTY BOUNDARY

The northerly plume capture simulations assume the northerly plume is hydraulically captured at the north landfill property boundary. Hydraulic capture would be achieved by pumping from a high transmissivity zone of the Roza aquifer which underlies a portion of that area (Figure 1). This scenario would interrupt the main pathway of IHS feeding the downgradient northerly plume.

REMChlor cannot simulate the hydraulic effects of pumping. We therefore simulated plume containment by forcing plume concentrations to zero upgradient of the landfill property boundary. For this simulation we assumed plume containment is achieved within one year of pumping (starting in 2013). The landfill property boundary is located about 178 m north (downgradient) from the source along the Roza northerly plume center line (Figure 1). Plume concentrations were artificially forced to zero in REMChlor by assuming an artificially high plume decay rate at all locations between 0 and 178 m (Table 6 and Figure 26). Thus plume attenuation simulated downgradient of 178 m (i.e. the landfill property boundary) is an approximation of what would be expected under conditions of hydraulic capture. Because of this approach, the results of this simulation are only valid downgradient (north) of the landfill property boundary along the plume center-line (i.e. for distances greater than 178 m).

Continuing hydraulic containment beyond the restoration time frame could be needed to maintain the effectiveness of northerly plume capture. Although concentrations downgradient of the property boundary may decrease below a CUL after a given period of time with this action, continued pumping may be required if the source has not been sufficiently depleted (i.e. if pumping were to stop before sufficient source depletion, plume expansion could resume).

Northerly Plume Capture simulation results for each IHS are presented below.

6.4.1 1,2-DCP Results (Northerly Plume Capture)

The northerly plume capture simulation for 1,2-DCP shows concentrations attenuating relatively rapidly with time (Figure 27), with concentrations estimated to be in compliance by the year 2032; a 19 year restoration time period (Table 3).

6.4.2 Vinyl Chloride Results (Northerly Plume Capture)

The northerly plume capture simulation for vinyl chloride shows concentrations attenuating relatively rapidly with time (Figure 28), with concentrations estimated to be in compliance by the year 2033; a 20 year restoration time period (Table 3).

6.4.3 Benzene Results (Northerly Plume Capture)

The northerly plume capture simulation for benzene shows concentrations attenuating relatively rapidly with time (Figure 29), with concentrations estimated to be in compliance by the year 2032; a 19 year restoration time period (Table 3).

6.4.4 Methylene Chloride Results (Northerly Plume Capture)

The northerly plume capture simulation for methylene chloride shows concentration attenuating relatively rapidly with time (Figure 30), with concentrations estimated to be in compliance by the year 2023; a 10 year restoration time period (Table 3).

7.0 MODEL SENSITIVITY

The results of the simulations presented above used our best estimates for model input parameters (Table 1). However, given simplifying model assumptions (Section 2) and uncertainty in model parameter values, there is uncertainty in the simulation results and estimated restoration time periods (Table 3).

To address some of the model uncertainty, we conducted a model sensitivity assessment for the 1,2-dichlropropane simulation under NA. For this assessment we tested the sensitivity of the model results to a range of values in four key model input parameters:

1. Contaminant Velocity
2. Initial Source Mass (Mo)
3. Initial Source Concentration (Co)
4. Gamma

For this assessment we varied the value of a single parameter while leaving all other parameter values equal to the best-estimated value (Table 7). The sensitivity assessment for each parameter used a minimum and maximum value within the range of uncertainty we estimated for each parameter. The range of uncertainty in each parameter is discussed below followed by a discussion of the sensitivity assessment results.

7.1 CONTAMINANT VELOCITY RANGE OF UNCERTAINTY

The range of contaminant velocities was estimated using field observations.

The minimum contaminant velocity was based on the minimum velocity required for contaminants to be transported from the P1 source area to the Whitson well within 34 years (the time between initial drum burial and first documentation of contamination at the Whitson well). The Whitson well is located approximately 1400 feet along the plume center line from source area (Figure 1) and the minimum contaminant velocity (vmin)[7] was initially calculated as follows:

Initial vmin = (1400 feet/34 years) = 41.2 ft/yr = 12.5 m/yr

REMChlor input uses a user specified Darcy velocity (q) that is divided by a user specified porosity to derive the groundwater seepage velocity (v). Thus model input for the minimum velocity is:

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[7] vmin and vmax velocity is different from the vMin-normalized and vMax-normalized in Table 7 (see Section 2.1.3 for discussion of vMin-normalized and vMax-normalized).

Initial qmin = vmin*n = 12.5 m/yr*0.2 = 2.5 m/yr

Due to the effects of dispersion, simulated concentrations of 1,2-DCP actually continued to increase after 34 years. Monitoring of the Whitson well since 2009 shows the concentrations of 1,2-DCP to be relatively stable, we therefore increased the minimum velocity until relatively stable concentrations were simulated at this location at this time:

Final qmin = 4 m/yr (Table 7)

Final vmin = Final qmin/n = 4/0.2 = 20 m/yr

The maximum contaminant velocity was based on field data from MW-44b. The concentration of 1,2-DCP in MW-44b has shown a slow increasing trend with some variability since monitoring first began in 2009, suggesting the attenuation effects of drum removal in 2008 have not reached MW-44b as of 2011. MW-44b is located approximately 900 feet along the pathway from the former drums and the maximum contaminant velocity (vmax) was calculated as:

vmax = (900 feet/3 years) = 300 ft/yr = 91 m/yr

qmax = 91 m/yr*0.2 = 18 m/yr (Table 7)

Our best-estimate value of the Darcy velocity (q) calculated from aquifer parameters (5.1 m/yr), as described in Section 4.2.1 above, falls within this range of values calculated from observed contamination (4 m/yr to 18 m/yr).

Use of historic data to infer current contaminant velocity assumes that historic conditions are similar to current conditions. Historic pumping of groundwater north of the landfill could cause this assumption to be invalid.

7.2 INITIAL SOURCE MASS RANGE OF UNCERTAINTY

To assess the sensitivity of the model to the initial source mass (Mo), we ran the model using the maximum (3.5 kg) and minimum (0.5 kg) Mo values estimated for 1,2-DCP (Table 7). The best-estimated value for Mo is 0.96 kg. The range in Mo values was based on estimated ranges of residual source mass in LNAPL and soil by the former drums (PGG, 2012a).

7.3 INITIAL SOURCE CONCENTRATION RANGE OF UNCERTAINTY

As explained in Section 4.1.2 above, the initial source concentration (Co) is based on a calculation of Roza plume mass flux and the assumption that the Roza plume mass flux is the same as the mass flux (Q*Co) through the source area (PGG, 2012a)[8]. REMChlor uses the Darcy velocity (q) to calculate the groundwater flux through the source area (Q), where Q = q*A with A being the cross-sectional dimension of the source area. The best-

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[8] The mass flux approach results in an overestimated value for vinyl chloride; therefore, the observed concentration in the P1 source area was used for vinyl chloride. All other simulated VOCs used the mass flux approach (see PGG, 2012a for discussion on the development of the initial source concentration).

estimate value of Co (597 ug/L) was therefore based on calculations of plume mass flux and a best estimate of the dimension of the source area (A).

Given the uncertainty in the dimension of the source area, we estimated a maximum (869 ug/L) and minimum (516 ug/L) value for Co (Table 7) based on estimated maximum and minimum dimension of the source area (PGG, 2012a). Note that with our approach for simulating the current and future plume independently (Section 2.0), the value of the initial source mass (Mo) in the first model had to be adjusted so that it was fully depleted by 2008 given the value of Co (Table 7).

7.4 GAMMA RANGE OF UNCERTAINTY

To assess the sensitivity of the model to gamma, we ran the model using the minimum and maximum range of gamma values expected for the Ephrata site (gamma = 1 and gamma = 2). As discussed in Section 2.1.1, the relationship between source mass and source concentration is defined in REMChlor using a power function and gamma is the exponent which determines the relationship. Gamma values for most sites are thought to range from 0.5 to 2.0 and values greater than 1 are generally assigned to sites with high heterogeneity and where matrix diffusion from low permeability zones are expected to result in long-term “tailing” of contaminant concentrations. We therefore expect a representative range of gamma value between 1 and 2 for the Ephrata site, with the best-estimated value being 1.5 (Table 7).

7.5 MODEL SENSITIVITY RESULTS

The sensitivity assessment for the range of uncertainty in the above model parameters was performed on the model simulation of 1,2-DCP for NA. The results of the sensitivity assessment were evaluated by comparing the simulated concentration at the landfill property boundary in the year 2038; 30 years after the start of NA (Figure 31). The range of simulated concentrations for each model parameter (vertical line in Figure 31) shows the sensitivity of the model to that parameter uncertainty. The larger the range, the more sensitive the model was to the parameter uncertainty. These results show that the most sensitive model parameter was the source mass. The uncertainty in source mass (Table 7) resulted in simulated concentration of 1,2-DCP ranging from 23.7 ug/L to 1.2 ug/L at the landfill property boundary 30 years after the start of NA(Figure 31).

The range of simulated concentrations was also relatively large for the uncertainty in groundwater velocity, with concentrations ranging from 1.1 to 5.9 ug/L; while the sensitivity to source concentration and gamma was noticeably lower (Figure 31).

Collectively, the results of the sensitivity assessment show that the uncertainty in a single model input parameter can lead to an approximate ten-fold range in the predicted concentrations (1.2 to 23.7 ug/L). From our experience, a ten-fold range due to uncertainty is not uncommon for groundwater models.

There was also at least a 44 year uncertainty in the simulated restoration time period for 1,2-DCP under NA given the range in source mass. Given the uncertainty in source mass, the minimum simulated restoration time period for 1,2-DCP un-der NA was 32 years and the maximum simulated restoration time period was greater than 76 years – end of model simulation.

This sensitivity assessment did not combine the uncertainty in key model parameters; rather each parameter was analyzed independently. Combining the uncertainty in key parameters would result in a larger range of simulated plume concentrations and restoration time periods.

Figure 31 also plots the best estimate simulated concentration (4.4 ug/L) at the landfill property boundary after 30 years and the CUL for 1,2-DCP (1 ug/L). This shows that even within the range of single-value uncertainties, all NA simulations for 1,2-DCP result in concentrations being above the CUL at the landfill property boundary 30 years after the start of NA(Figure 31).

7.5.1 Discussion of Model Sensitivity

Although we did not conduct an uncertainty analysis of 1,2-DCP for the active measure scenarios, a 10-fold range in simulated plume concentrations at the landfill property boundary would also be expected for the P1 Groundwater Pumping and SVE scenario (based on uncertainty in the source mass term). However, both of these active measures would result in lower plume concentrations over time compared to the NA scenario.

The model simulation for northerly plume capture is not expected to be sensitive to the source mass parameter since this simulation assumed the plume was cut off from the source at the landfill property boundary. The model uncertainty for this scenario is mainly associated with the seepage velocity (v) parameter and related effects on plume geometry and attenuation downgradient of the landfill property boundary. The range in estimated seepage velocities was used to estimate a range of uncertainty in simulated restoration time periods (although differences in plume geometry and dispersion would also contribute to differences in restoration time periods). The average seepage velocity was estimated to range between 20 m/yr and 91 m/yr with the best estimate being 25.5 m/yr. The range in restoration time period was thus estimated as:

v/vmin = 25.5/20 = 1.3 times longer than the best estimated restoration time.

v/vmax = 25.5/91 = 0.3 times longer (ie: shorter) than the best estimated restoration time.

The simulated restoration time period for northerlry plume capture using the best-estimated value of seepage velocity was about 20 years for all IHS except Methylene Chloride which was 10 years (Table 3). Thus, even using the minimum seepage velocity, the simulated restoration time period (1.3 times longer) would likely still be less than 30 years.

The uncertainty in simulated plume concentrations and restoration time periods for other IHS under NA, P1 pumping, and SVE would be somewhat different than 1,2-DCP given the differences in source mass depletion rates for each IHS.

The source mass depletion rate in REMchlor is defined as:

Drate = Q*Co/Mo [dy-1]

Where Q = groundwater flux (constant)

Co = source concentration

Mo = source mass

Source mass depletion rates based on best estimate values for the above parameters are presented in Table 8.

Vinyl chloride has been identified as the most challenging IHS to achieve compliance (i.e. simulated longest restoration time period under all scenarios). Despite having the highest source mass depletion rate (Table 8), vinyl chloride continued to persist in groundwater due to the creation of new vinyl chloride during the breakdown of PCE, TCE, and cis-1,2-DCE (all of which have relatively lower depletion rates). In particular, cis-1,2-DCE, with the highest values of Co and Mo, was the largest contributor to the simulated persistence of vinyl chloride. Furthermore, vinyl chloride has a very low CUL (0.2 ug/L).

The uncertainty in the predicted vinyl chloride concentrations and associated restoration time periods under NA, P1 Pumping and SVE is likely at least as great as that estimated for 1,2-DCP because new vinyl chloride is simulated as being created from the breakdown of other chlorinated ethenes. The simulated restoration time period for vinyl chloride under the four simulated scenarios (using our best-estimates of model input parameters) was (Table 3):

1. NA > 76 years
2. P1 Pumping = 39 years
3. SVE = 70 years
4. Roza Capture = 20 years

Given the uncertainty in model parameters discussed above, NA, P1 pumping and SVE may not achieve compliance for vinyl chloride within 30 years. However, northerly plume capture is estimated to achieve vinyl chloride compliance in a 30-year timeframe within the range of assessed model uncertainty..

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Table 1. REMChlor Model Calibration Parameter Values

		REMChlor MODELS															
MODEL INPUT PARAMETERS	Calibration Parameter	Chloride	1,2-Dichloropropane		Tetrachloroethene (PCE)		Trichloroethene (TCE)		cis-1,2-Dichloroethene		Vinyl Chloride		Benzene		Methylene Chloride	
			1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model
Source Parameters[1]																	
Source Width (ft)	No	1000	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Source Depth (ft)	No	10	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Initial Source Mass; Mo (kg)	No	1.E+09	4.33	0.96	0.17	0.66	0.47	0.31	10.22	3.50	5.44	0.30	0.82	0.30	1.12	1.51
Initial Source Concentration; Co (g/L)	No	1	0.000597	0.000597	0.0000240	0.0000240	0.000065	0.000065	0.001409	0.001409	0.00075	0.00075	0.000113	0.000113	0.000154	0.000154
Gamma	No	0	0	1.5	0	1.5	0	1.5	0	1.5	0	1.5	0	1.5	0	1.5
Source Remediation Parameters																	
Source Fraction Removed	No	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Remediation Start Year	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Remediation End Year	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Souce Decay (1/yr)	No	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport Parameters																	
Darcy Velocity; q (m/yr)	No	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Porosity	No	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Retardation Factor	No	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sigmav	Yes	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
vMin (Normalized)	Yes	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
vMax (Normalized)	Yes	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
alpha-y (m)[2]	Yes	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
alpha-z (m)[2]	Yes	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002
Plume Decay (Component 1)[3]																	
Time Period 1 (year)[4]	No	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Time Period 2 (year)	No	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76
X1 (meters)[5]	Yes	178	178	178	100	100	100	100	100	100	100	100	100	100	100	100
X2 (meters)	Yes	304	304	304	178	178	178	178	178	178	178	178	178	178	178	178
Zone 1/Period 1 Decay Rate (1/yr)	Yes	0.0	0.055	0.055	0.2	0.2	0.7	0.7	0.7	0.7	0.5	0.5	0	0	0.01	0.01
Zone 2/Period 1 Decay Rate (1/yr)	Yes	0.0	0.055	0.055	0	0	0.1	0.1	0.2	0.2	0.5	0.5	0	0	0.01	0.01
Zone 3/Period 1 Decay Rate (1/yr)	Yes	0.0	0.055	0.055	0	0	0	0	0	0	0	0	0	0	0.01	0.01
Zone 1/Period 2 Decay Rate (1/yr)	Yes	0.0	0.055	0.055	0.2	0.2	0.7	0.7	0.7	0.7	0.5	0.5	0	0	0.01	0.01
Zone 2/Period 2 Decay Rate (1/yr)	Yes	0.0	0.055	0.055	0	0	0.1	0.1	0.2	0.2	0.5	0.5	0	0	0.01	0.01
Zone 3/Period 2 Decay Rate (1/yr)	Yes	0.0	0.055	0.055	0	0	0	0	0	0	0	0	0	0	0.01	0.01
Zone 1/Period 3 Decay Rate (1/yr)	Yes	0.0	0.055	0.055	0.2	0.2	0.7	0.7	0.7	0.7	0.5	0.5	0	0	0.01	0.01
Zone 2/Period 3 Decay Rate (1/yr)	Yes	0.0	0.055	0.055	0	0	0.1	0.1	0.2	0.2	0.5	0.5	0	0	0.01	0.01
Zone 3/Period 3 Decay Rate (1/yr)	Yes	0.0	0.055	0.055	0	0	0	0	0	0	0	0	0	0	0.01	0.01
Simulation Time[6]																	
Start Year	No	1955	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008
End Year	No	2008	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084

Notes

1 See Appendix B in Feasibility Study for development of source mass and source concentration values

2 Negative values for alpha-y and alpha-z are used as a flag in REMChlor to indicate the values are scale dependent.
Values are actually calculated as absolute in the simualtion.

3 REMChlor can simulate up to four components in a 1st order chemical decay reaction. One parent product (component 1) and up to three daughter products (components 2, 3 and 4) can be simulated through the use of plume decay rates and yield coefficients.
Only the pararent component was simulated for 1,2-DCP, Benzene and Methylene Chloride. Daughter product components for chlorinated ethenes (PCE, TCE, cis-1-2-DCE, VC) were simulated to estimate contribution to VC from reductive dechlorination.
Note that the same decay rates used to simulate a particular chlorinated ethene as a parent product were used to simulate it as a daugher product.
For example the decay rates assigned to vinyl chloride as a parent product were the same decay rates assigned to vinyl chloride as a breakdown component for PCE, TCE, and cis-1,2-DCE.

4 Different plume decay rates can be assigned at various times during the simulaiton. Up to three time periods with different decay rates in each zone (see note 5 below) can be simulated.
The three time periods are specified by parameter Time Period 1 and Time Period 2 which breaks the time period into 0 to Time Period 1 (1st time period); Time Period 1 to Time Period 2 (2nd time period); and Time Period 2 to end of simulaiton (3rd time period).
For model calibration the plume decay rates for a given location (zone) were assumed constant over time.

5 Different plume decay rates can be assinged at various distance from the source. Up to three locations (zones) with different decay rates can be defined downgradient of the source.
The three zones are specified by parameter X1 and X2 which breaks the plume length into 0 to X1 meters (zone 1); X1 to X2 meters (zone 2); and X2 to end of plume (zone 3)
For model calibration the plume decary rates were either the same in all three zones, or higher decay rates were used closer to source area. All decay rates are within values reported in the literature.

6 The simulation time is model specific (see text for details)

Table 2. Concentration Targets for Current Condition Simulation

Chloride		PCE		TCE		cis-1,2-DCE		Vinyl Chloride		Methylene Chloride		1,2-DCP		Benzene	
Plume Distance (ft)	Concentration (mg/L)	Plume Distance (ft)	Concentration (ug/L)	Plume Distance (ft)	Concentration (ug/L)	Plume Distance (ft)	Concentration (ug/L)	Plume Distance (ft)	Concentration (ug/L)	Plume Distance (ft)	Concentration (ug/L)	Plume Distance (ft)	Concentration (ug/L)	Plume Distance (ft)	Concentration (ug/L)
1	1000	1	24	1	65	1	1409	1	750	1	154	1	597	1	113
960	400	400	3	520	1	320	30	280	10	960	12	1000	25	960	30
1400	>90	1400	>0.5	1400	>0.3	800	7	1400	>5	1400	>0.7	1400	>5	1400	>1
						1400	>3.0								

Note:

Chloride concentrations at 1-ft are based on average concentrations in the P2 source area zone and Roza aquifer by the original shop area.

VOC concentrations at 1-ft are based on values for the source concentration (Co) in Model.

Concentrations at 1400-ft are based on data from the Whitson domestic well which until recently (July 2012) was completed through multiple aquifers (most likely including the Roza).

Due to completion of Whitson well, concentrations in the Roza aquifer at the Whitson location are likely higher that data collected from the Whitson well. Targets therefore qualified as "greater than".

All other target concentrations are based on observed and contoured data from Roza aquifer wells.

Table 3. Simulated IHS Restoration Times and Plume Concentrations at the Northern Landfill Property Boundary

SIMULATED RESTORATION YEAR

IHS	CUL (ug/L)	Simulated Scenario			
		NA 2008 Start Year	P1 Pump 2008 Start Year	SVE 50% 2013 Start Year	Roza Capture 2013 Start Year
1,2-Dichloropropane	1	2063	2039	2058	2032
Vinyl Chloride	0.2	>2084	2047	2083	2033
Benzene	1	2058	2040	2049	2032
Methlyene Chloride	5	2079	2046	2043	2023

SIMULATED YEARS UNTIL RESTORATION

IHS	CUL (ug/L)	Simulated Scenario			
		NA 2008 Start Year	P1 Pump 2008 Start Year	SVE 50% 2013 Start Year	Roza Capture 2013 Start Year
1,2-Dichloropropane	1	55	31	45	19
Vinyl Chloride	0.2	>76	39	70	20
Benzene	1	50	32	36	19
Methlyene Chloride	5	71	38	30	10

SIMULATED PLUME AREA WITH LONGEST RESTORATION TIME

IHS	CUL (ug/L)	Simulated Scenario			
		NA 2008 Start Year	P1 Pump 2008 Start Year	SVE 50% 2013 Start Year	Roza Capture 2013 Start Year
1,2-Dichloropropane	1	POC	EOP	POC	EOP
Vinyl Chloride	0.2	POC	POC	POC	EOP
Benzene	1	POC	EOP	POC	EOP
Methlyene Chloride	5	POC	POC	POC	b/t POC and EOP

SIMULATED CONCENTRATION AT NORTH PROPERTY BOUNDARY AFTER 30 YEARS COMPARED TO CURRENT CONCENTRATION

IHS	CUL (ug/L)	Simulated Scenario				CURRENT CONCENTRATION (2008)
		NA 2008 Start Year	P1 Pump 2008 Start Year	SVE 50% 2013 Start Year	Roza Capture 2013 Start Year	
1,2-Dichloropropane	1	4.4	0.8	2.3	0.0	67
Vinyl Chloride	0.2	1.6	0.4	0.8	0.0	16
Benzene	1	2.8	0.7	1.3	0.0	19
Methlyene Chloride	5	12.4	7.2	5.5	0.0	24

Restoration time frames based on model simulations of plume attenuation to below the CUL at and/or downgradient of the POC.

Simulation of vinyl chloride requires simluation of other VOCs in chlorinated ethene degradation pathway (PCE-TCE-DCE-VC)

Note that relatively high concentration and mass of cis-1,2-dichloroethene (DCE) in the source area contributes to persistence of vinyl chloride

All simulated scenarios include the effects of NA

CUL = cleanup level derived in Feasibility Study

POC = Point of Compliance developed in the Feasibility Study. The northern POC is the landfill property boundary.

NA = Natural Attenuation

SVE = Soil Vapor Extraction

EOP = End of Plume

IHS = Indicator Hazardous Substance

Table 4 Model Parameter Values for Predictive Simulation - P1 Source Area Long Term Groundwater Extraction

(Simulated Start Year of P1 Extraction FS Component = 2008)

Model Paremeters Changed to Simulate this FS Component are Shaded Below	1,2-Dichloropropane		Tetrachloroethene (PCE)		Trichloroethene (TCE)		cis-1,2-Dichloroethene		Vinyl Chloride		Benzene		Methylene Chloride	
	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model
Source Remediation Parameters[1]														
Source Fraction Removed	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Remediation Start Year	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Remediation End Year	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Souce Decay (1/yr)	0	0.07	0	0.007	0	0.03	0	0.055	0	0.19	0	0.05	0	0.018
Simulation Time	NA	NA												
Start Year	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008
End Year	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084

Notes

[1] A first order source decay rate was used to simulate source mass removal with long term groundwater extraction.
Because the source decay must begin at the start of the simulation (i.e. it can be time varying) this FS component starts in 2008.
Since the first model simulates the source mass going to zero by 2008 , it is only necessary to assign the source decay to the second model.
See text for details on this approach.

Table 5 Model Parameter Values for Predictive Simulation - Soil Vapor Extraction (SVE)

(Simulated Start Year of SVE FS Component = 2013)

Model Paremeters Changed to Simulate this FS Component are Shaded Below	1,2-Dichloropropane		Tetrachloroethene (PCE)		Trichloroethene (TCE)		cis-1,2-Dichloroethene		Vinyl Chloride		Benzene		Methylene Chloride	
	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model
Source Remediation Parameters[1]														
Source Fraction Removed	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5	0	0.5
Remediation Start Year	NA	5	NA	5	NA	5	NA	5	NA	5	NA	5	NA	5
Remediation End Year	NA	9	NA	9	NA	9	NA	9	NA	9	NA	9	NA	9
Souce Decay (1/yr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Simulation Time														
Start Year	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008
End Year	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084

Notes

[1] The source fraction removed parameter was used to simulate SVE

SVE is estimated to remove 50% of the source mass within the first few years of operation

For the predictive simulation the source mass removal was assumed to occur over a four year period (2013 to 2017)

Table 6 Model Parameter Values for Predictive Simulation - Roza Plume Capture

(Start Year of Roza Capture FS Component = 2013)

	1,2-Dichloropropane		Tetrachloroethene (PCE)		Trichloroethene (TCE)		cis-1,2-Dichloroethene		Vinyl Chloride		Benzene		Methylene Chloride	
Model Paremeters Changed to Simulate this FS Component are Shaded Below	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model
Plume Decay (Component 1)														
Time Period 1 (year)[1]	40	5	40	5	40	5	40	5	40	5	40	5	40	5
Time Period 2 (year)	76	76	76	76	76	76	76	76	76	76	76	76	76	76
X1 (meters)[2]	178	178	100	100	100	100	100	100	100	100	100	100	100	100
X2 (meters)	304	304	178	178	178	178	178	178	178	178	178	178	178	178
Zone 1/Period 1 Decay Rate (1/yr)	0.055	0.055	0.2	0.2	0.7	0.7	0.7	0.7	0.5	0.5	0	0	0.01	0.01
Zone 2/Period 1 Decay Rate (1/yr)	0.055	0.055	0	0	0.1	0.1	0.2	0.2	0.5	0.5	0	0	0.01	0.01
Zone 3/Period 1 Decay Rate (1/yr)	0.055	0.055	0	0	0	0	0	0	0	0	0	0	0.01	0.01
Zone 1/Period 2 Decay Rate (1/yr)	20.2	20.2	17	17	18	18	22	22	21	21	18.55	18.55	18.86	18.86
Zone 2/Period 2 Decay Rate (1/yr)	0.055	0.055	17	17	18	18	22	22	21	21	18.55	18.55	18.86	18.86
Zone 3/Period 2 Decay Rate (1/yr)	0.055	0.055	0	0	0	0	0	0	0	0	0	0	0.01	0.01
Zone 1/Period 3 Decay Rate (1/yr)	20.2	20.2	17	17	18	18	22	22	21	21	18.55	18.55	18.86	18.86
Zone 2/Period 3 Decay Rate (1/yr)	0.055	0.055	17	17	18	18	22	22	21	21	18.55	18.55	18.86	18.86
Zone 3/Period 3 Decay Rate (1/yr)	0.055	0.055	0	0	0	0	0	0	0	0	0	0	0.01	0.01
Simulation Time	NA	NA												
Start Year	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008
End Year	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084

Notes

1 To simulate Roza Plume Capture at the landfill property boundary a large plume decay rate was assigned to Zones 1 and/or 2 for Period 2 and 3.

This results in plume concentrations going to zero at the landfill property boundary within 1 to 2 years of the start of this FS component (starting in 2013 and continuing to end of simulation).

2 To simulate Roza Plume Capture at the landfill property boundary an artificially large plume decay rate was assigned from 0 to 178 meters (zone 1 for 1,2-DCP and zone 1 and zone 2 for the other chemicals)

This results in all plume concentrations from near the source to 178 meters going to zero (area upgradient of landfill property boundary).

With this approach, results are only used to assess plume attenuation downgradient of the landfill property boundary (locations greater than 178 meters).

Table 7. Model Parameter Values Tested in Model Sensitivity Assessment

(Sensitivity Assessment Performed on Simulation of 1,2-dichloropropane under MNA)

	Best Estimate Values		Gamma = 1		Gamma = 2		Max Source Mass		Min Source Mass		Max Source Concentration[1]		Min Source Concentration[1]		Max Velocity (qmax)[2]		Min Velocity (qmin)[2]	
Model Paremeters Changed to Simulate this FS Component are Shaded Below	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model	1st Model	2nd Model
Source Parameters																		
Source Width (ft)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Source Depth (ft)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Initial Source Mass; Mo (kg)	4.33	0.96	4.33	0.96	4.33	0.96	4.33	3.50	4.33	0.50	6.30	0.96	3.74	0.96	4.33	0.96	4.33	0.96
Initial Source Concentration; Co (g/L)	0.000597	0.000597	0.000597	0.000597	0.000597	0.000597	0.000597	0.000597	0.000597	0.000597	0.000869	0.000869	0.000516	0.000516	0.000169	0.000169	0.000761	0.000761
Gamma	0	1.5	0	1	0	2	0	1.5	0	1.5	0	1.5	0	1.5	0	1.5	0	1.5
Transport Parameters																		
Darcy Velocity; q (m/yr)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	18	18	4	4
Porosity	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Retardation Factor	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sigmav	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
vMin (Normalized)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
vMax (Normalized)	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
alpha-y (m)	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
alpha-z (m)	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002
Simulation Time	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Start Year	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008	1975	2008
End Year	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084	2051	2084

Notes

1 Sensitivity runs involving changes in source concentration include changing the source mass in the first model in order to achieve a source mass that depletes to zero by 2008

2 Sensitivity runs involving changes in groundwater velocity include changing the source concentration to values that maintain the same mass flux (Q*Co) through the source area as the calibrated model

Table 8. Source Mass Depletion Rates for Simulated VOCs

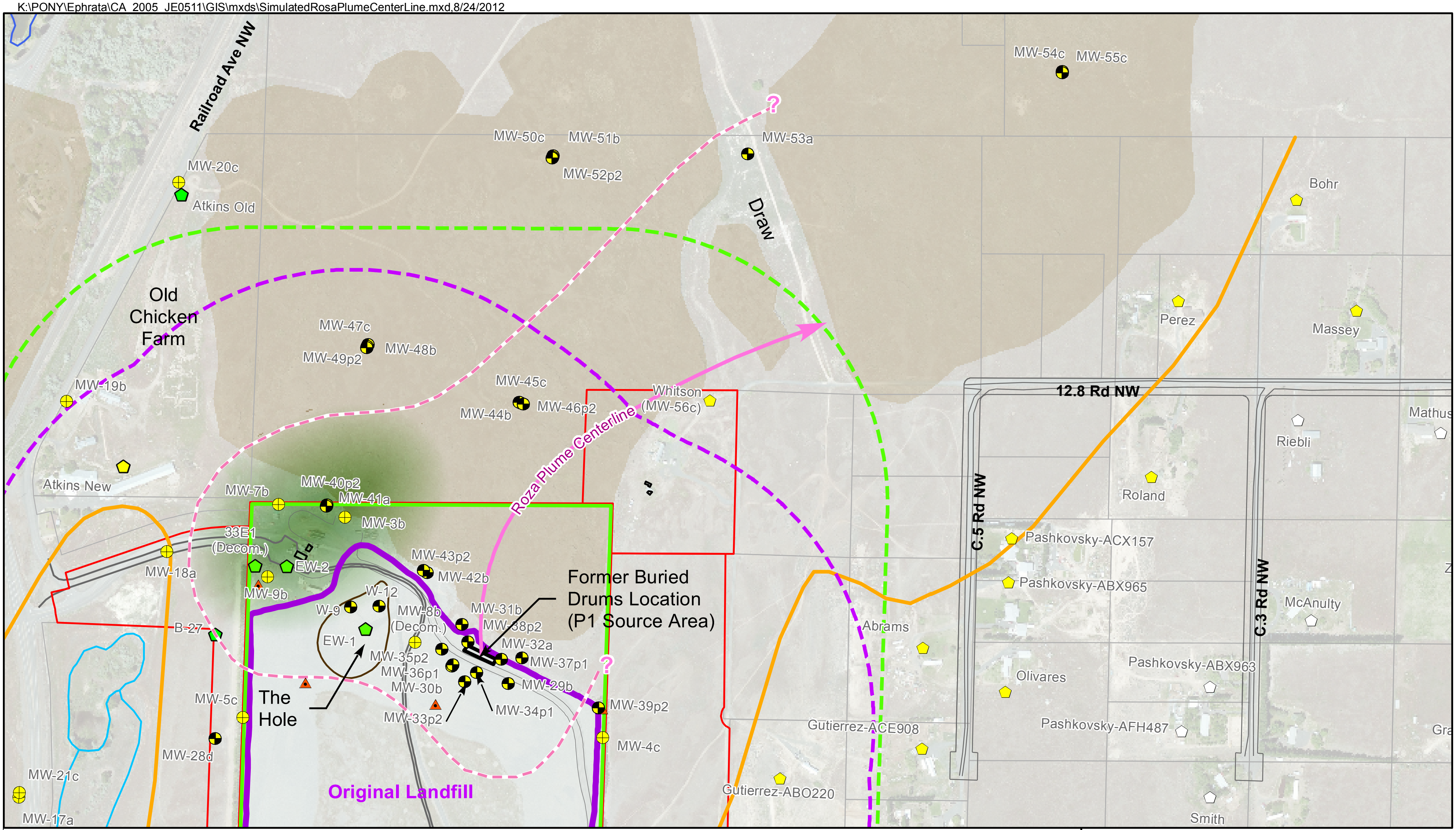
Simulated VOC	D_{rate}[1]	Co (ug/L)	Mo (kg)	Q (ft^3/dy)
Tetrachloroethene (PCE)	0.008	24	0.66	20
Methylene chloride	0.021	154	1.51	20
Trichloroethene (TCE)	0.043	65	0.31	20
cis-1,2-Dichloroethene	0.083	1409	3.50	20
Benzene	0.077	113	0.30	20
1,2-Dichloropropane	0.128	597	0.96	20
Vinyl chloride[2]	0.515	750	0.30	20

Notes

1 D_{rate} = Source mass depletion rate in REMCHlor = Q*Co/Mo [yr^{-1}]
Where Q is the simulated groundwater flux through the source area (constant)
Co is the initial source concentration
Mo is the initial source mass

2 Despite having the highest source mass depletion rate, vinyl chloride continues to persist in groundwater due to the creation of new vinyl chloride during breakdown of PCE, TCE, and cis-1,2-DCE.

K:\PONY\Ephrata\CA_2005_JE0511\GIS\mxds\SimulatedRosaPlumeCenterLine.mxd,8/24/2012



- ⊕ Quarterly Monitoring Well (MW)
- ◐ Remedial Investigation Monitoring Well (MW) Locations A-G (Phase 2 RI Wells)
- ▲ Gas Probe (GP)
- ⬟ Other Wells
- ⬠ Sampled Off-site Wells
- ⬠ Other Off-site Wells
- — Outwash Water Table / Top of Basalt Contact
- ▨ Basalt Outcrops
- ☐ County Owned Parcels

Approximate Extent of Groundwter Contamination (VOCs' Above RI Screening Levels)

- - - - Roza Plume

- ☐ Extent of Refuse
- ☐ Permitted Landfill Property Boundary

1000-ft Buffers

- ⬚ from Refuse
- ⬚ from Permitted Landfill Property Boundary

→ Simulated Roza Northerly Plume Center Line

🟩 Approximate Area of High-Transmissivity in Roza

0 Feet 500

N

2011 Bing Aerial Photo

Figure 1

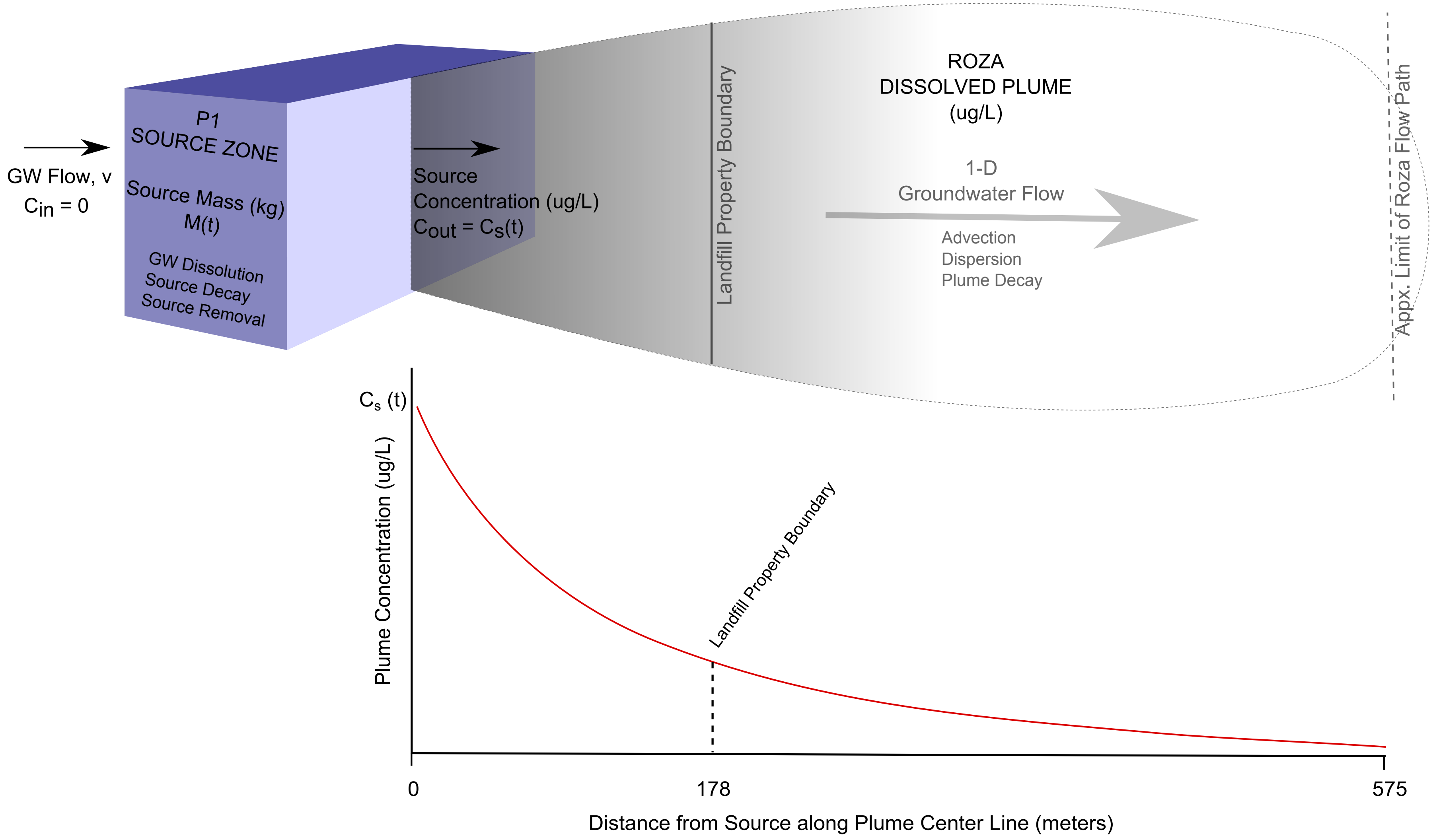
Simulated Roza Aquifer Northerly Plume Center Line

Ephrata Landfill
RI/FS

PGG

Source Mass/Source Concentration Relationship:

$$C_S(t)/C_o = [M(t)/M_o]^{Gamma}$$



v = groundwater velocity (m/yr)
C = Concentration (ug/L)
M = Mass (kg)
t = time (years)
GW = groundwater

Figure 2 Conceptual REMChlor Model

Ephrata Landfill RI/FS

Figure 3
Simulated Current Chloride Concentrations - Roza Northerly Plume

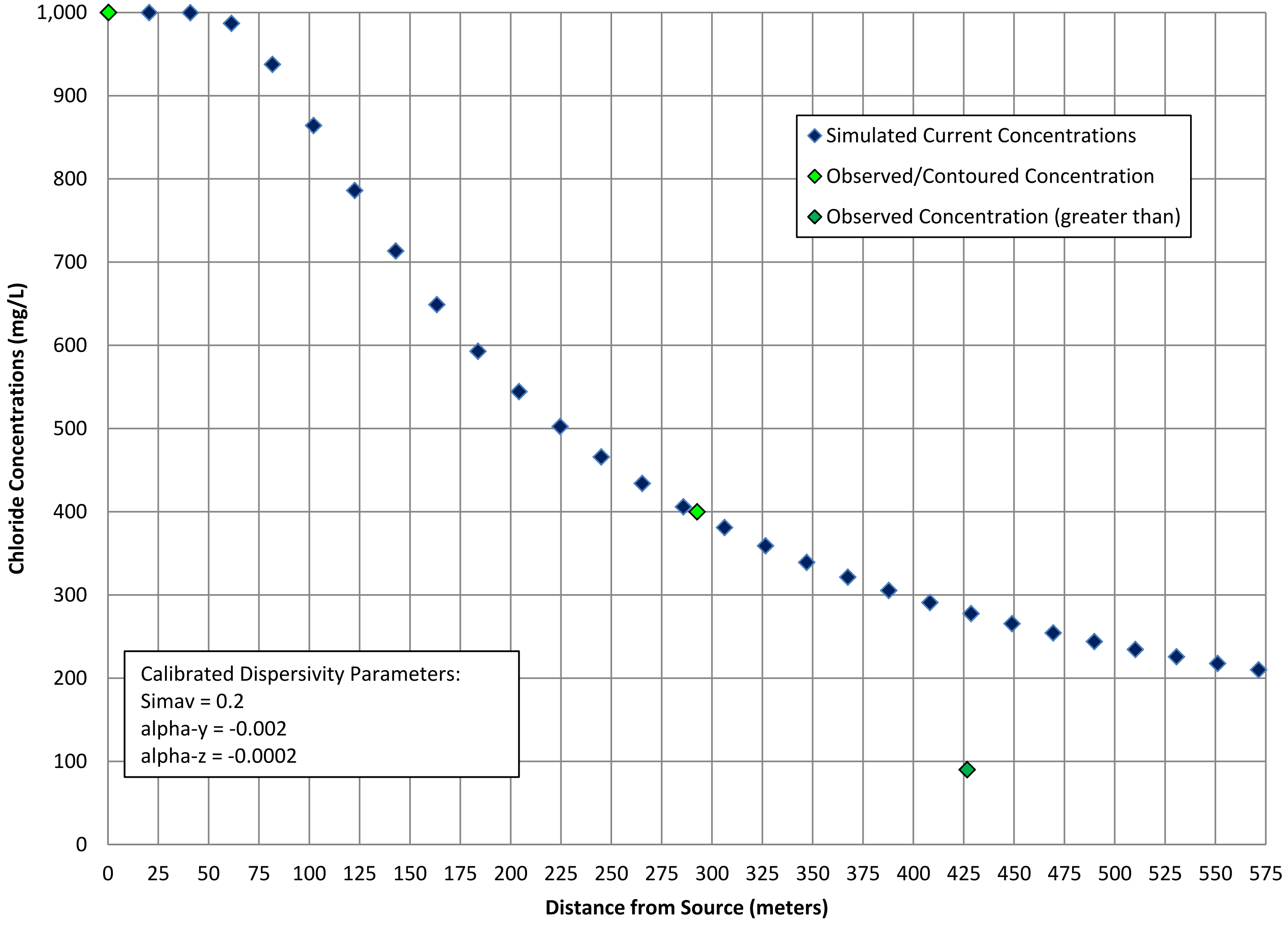


Figure 4

Simulated Currrent 1,2-DCP Concentration Profile - Roza Northerly Plume

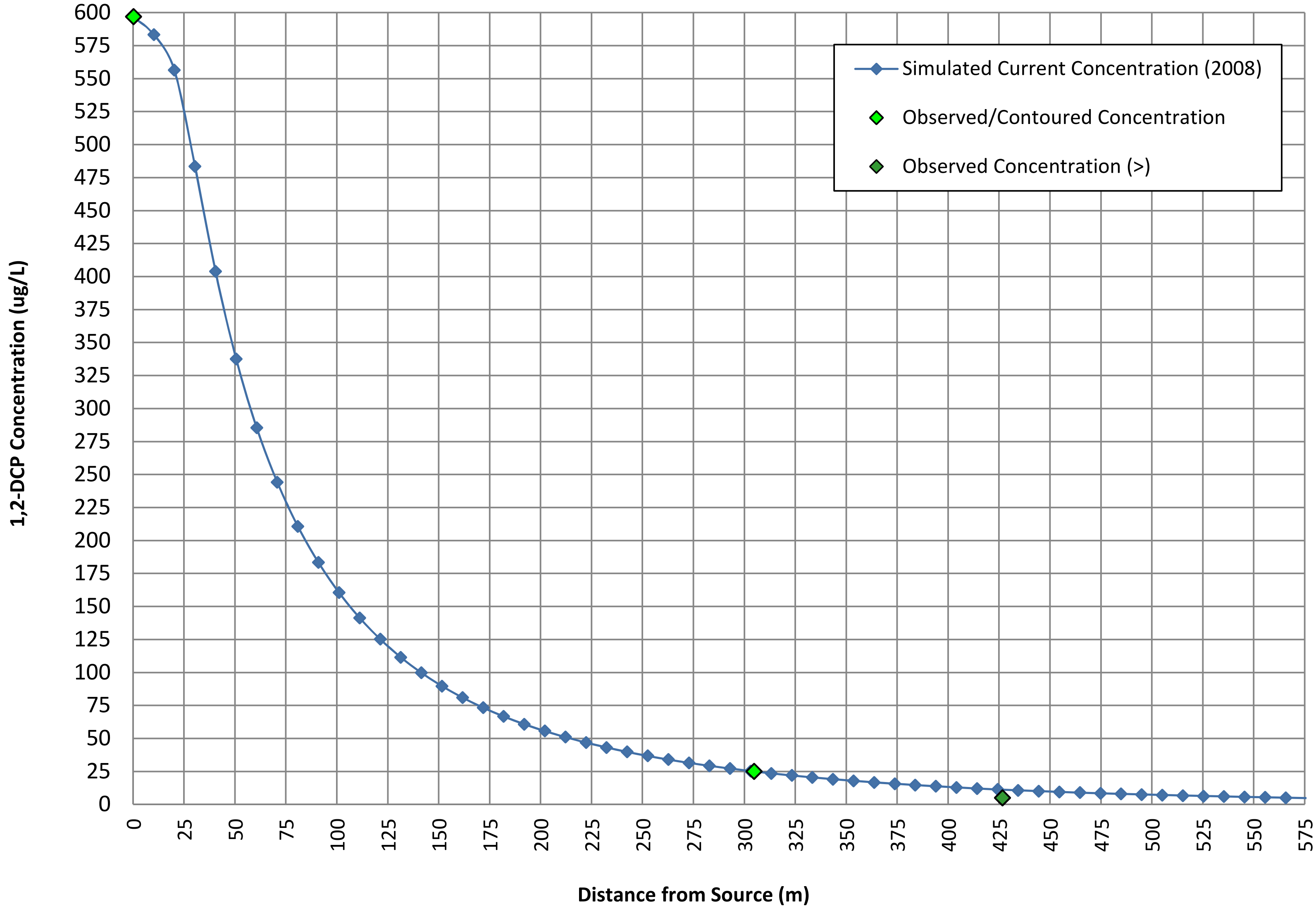


Figure 5
Simulated Currrent PCE Concentration Profile - Roza Northerly Plume

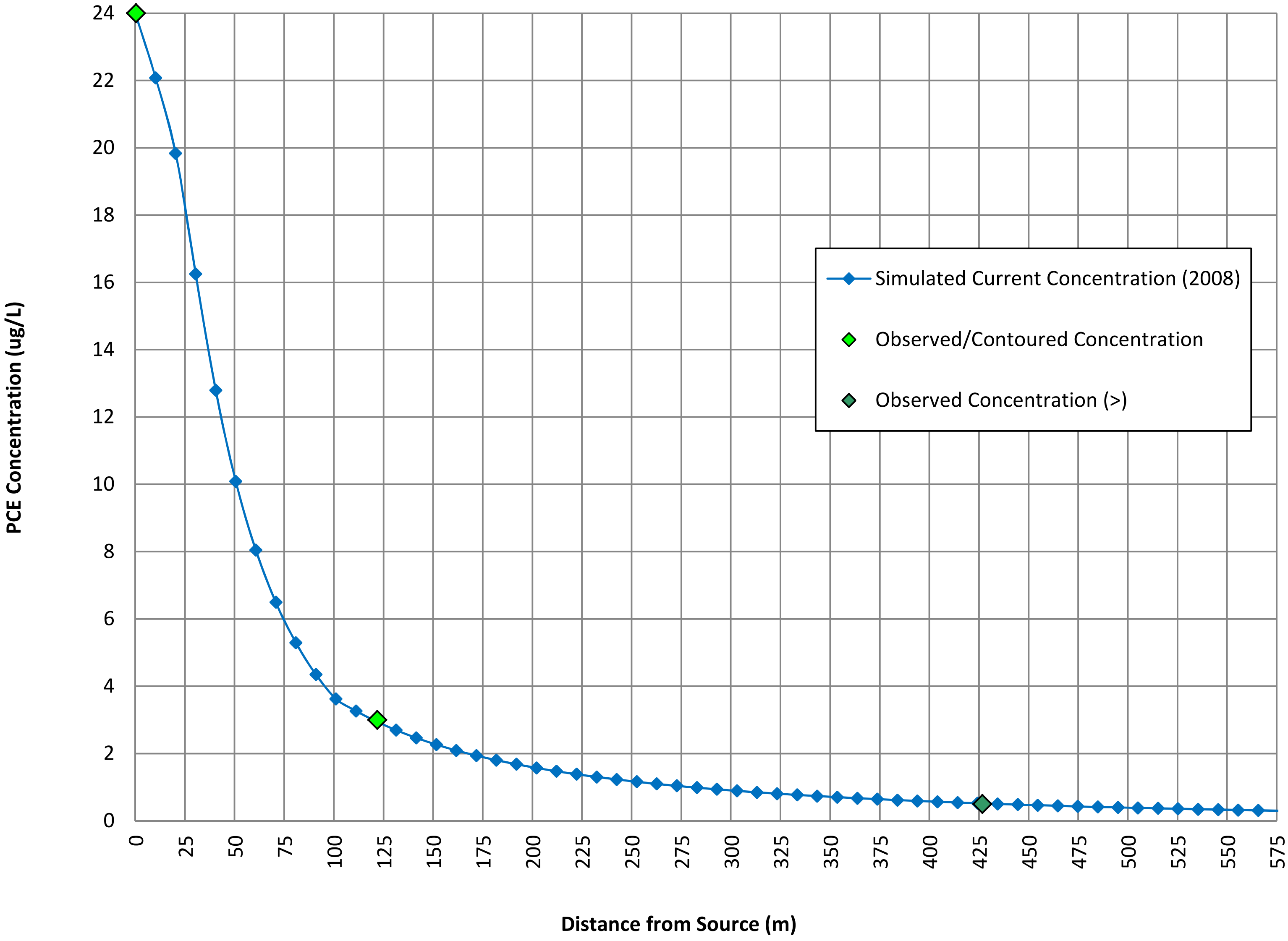


Figure 6
Simulated Currrent TCE Concentration Profile - Roza Northerly Plume

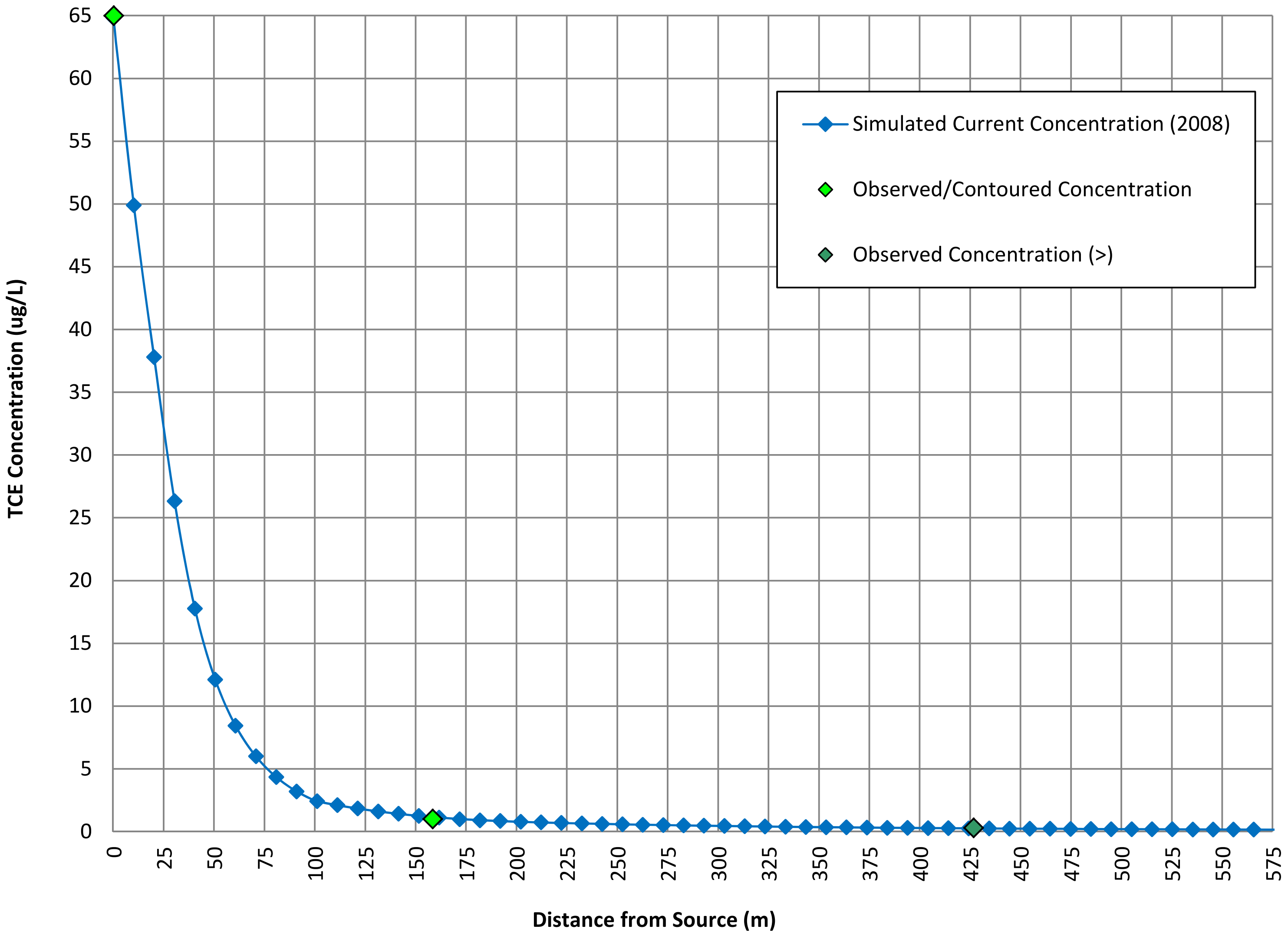


Figure 7

Simulated Currrent cis-1,2-DCE Concentration Profile - Roza Northerly Plume

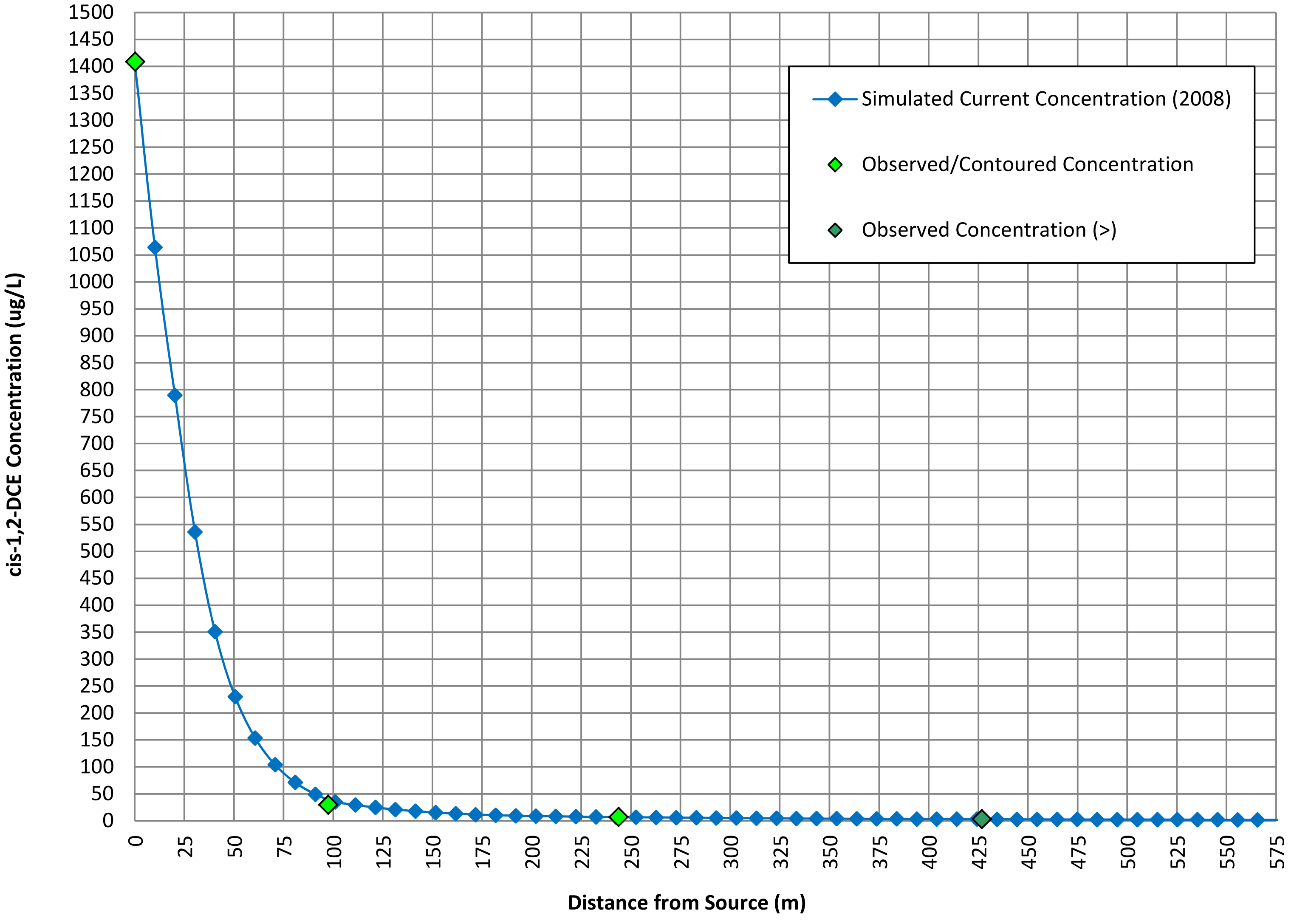


Figure 8
Simulated Currrent Vinyl Chloride Concentration Profile - Roza Northerly Plume

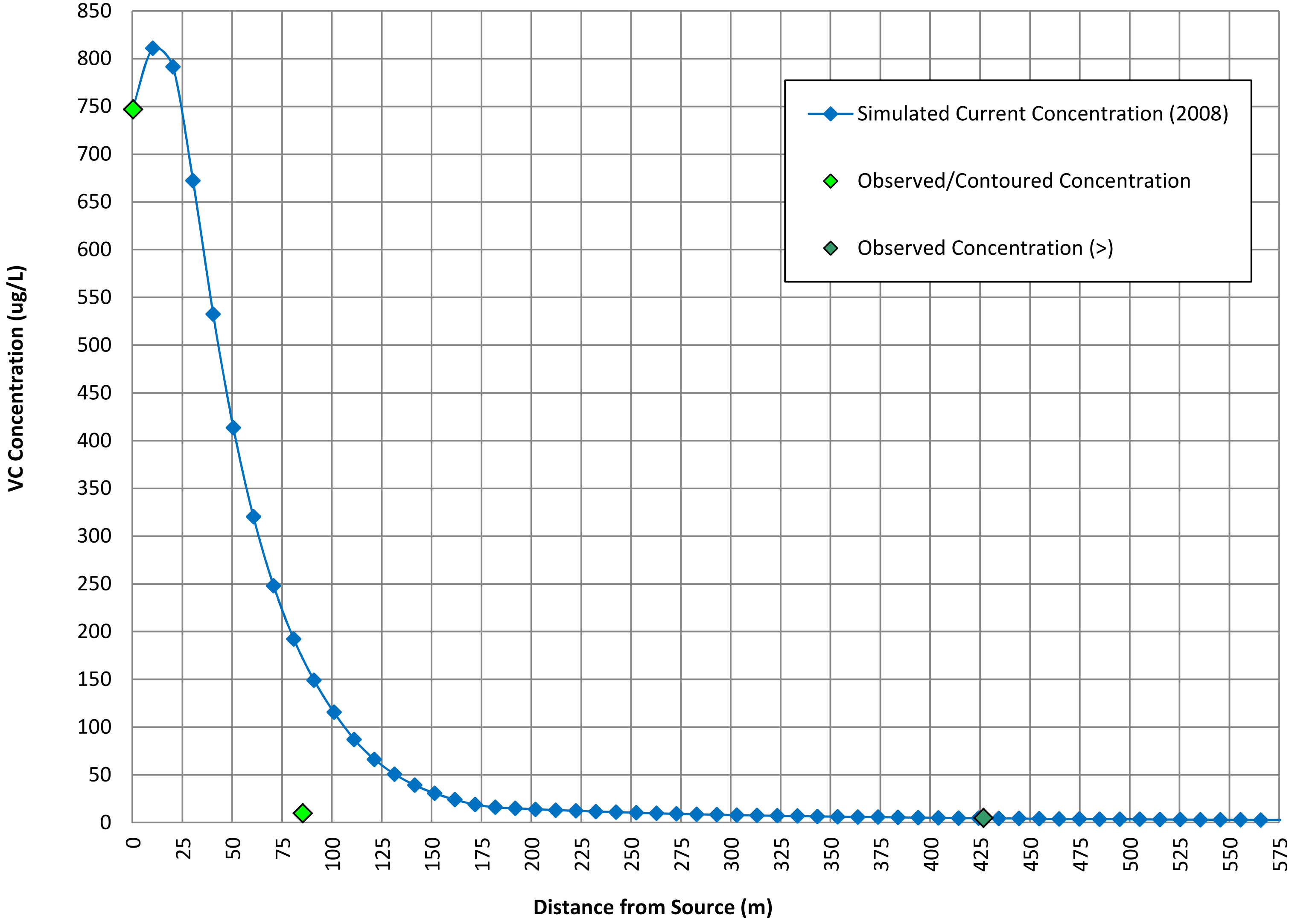


Figure 9
Simulated Currrent Benzene Concentration Profile - Roza Northerly Plume

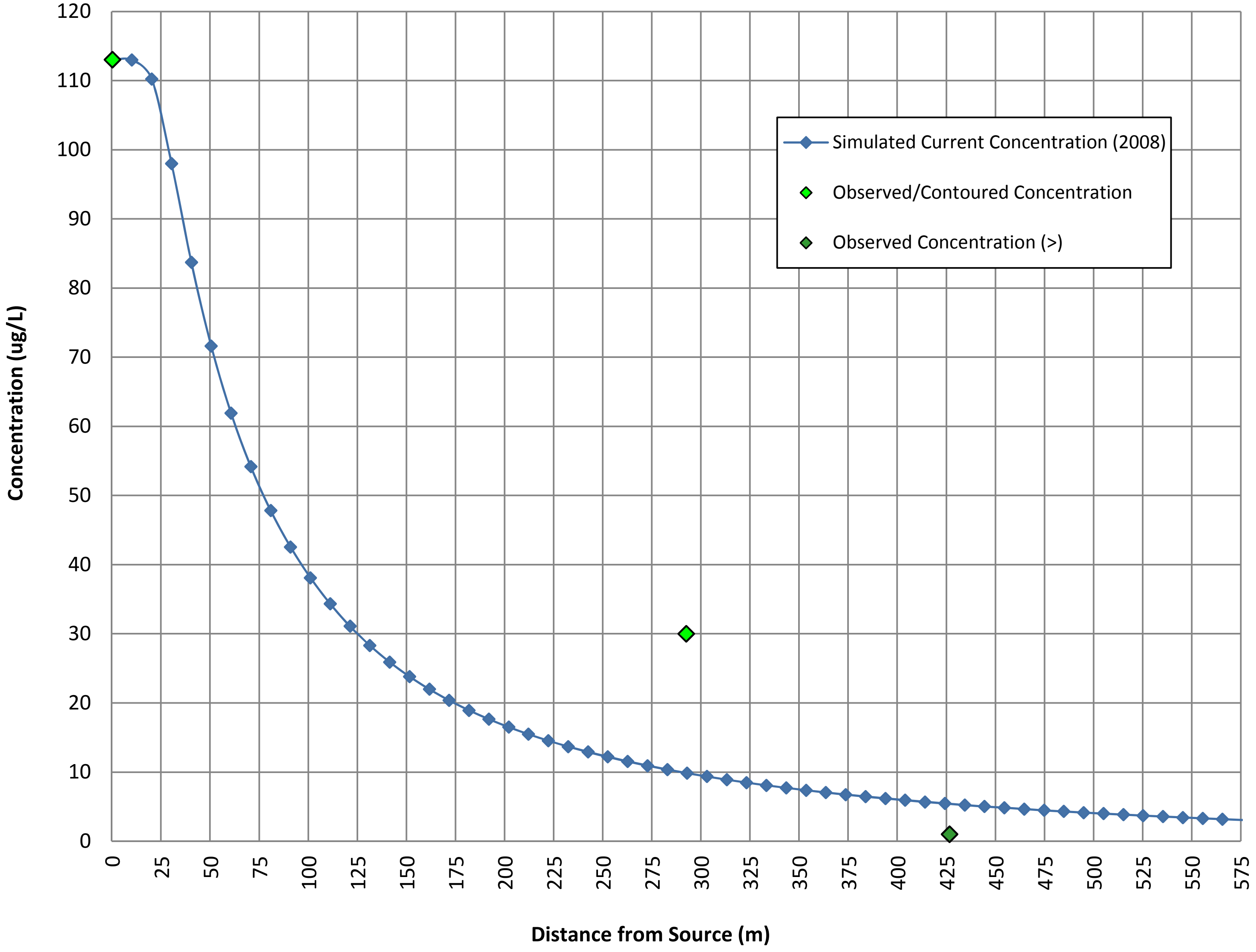
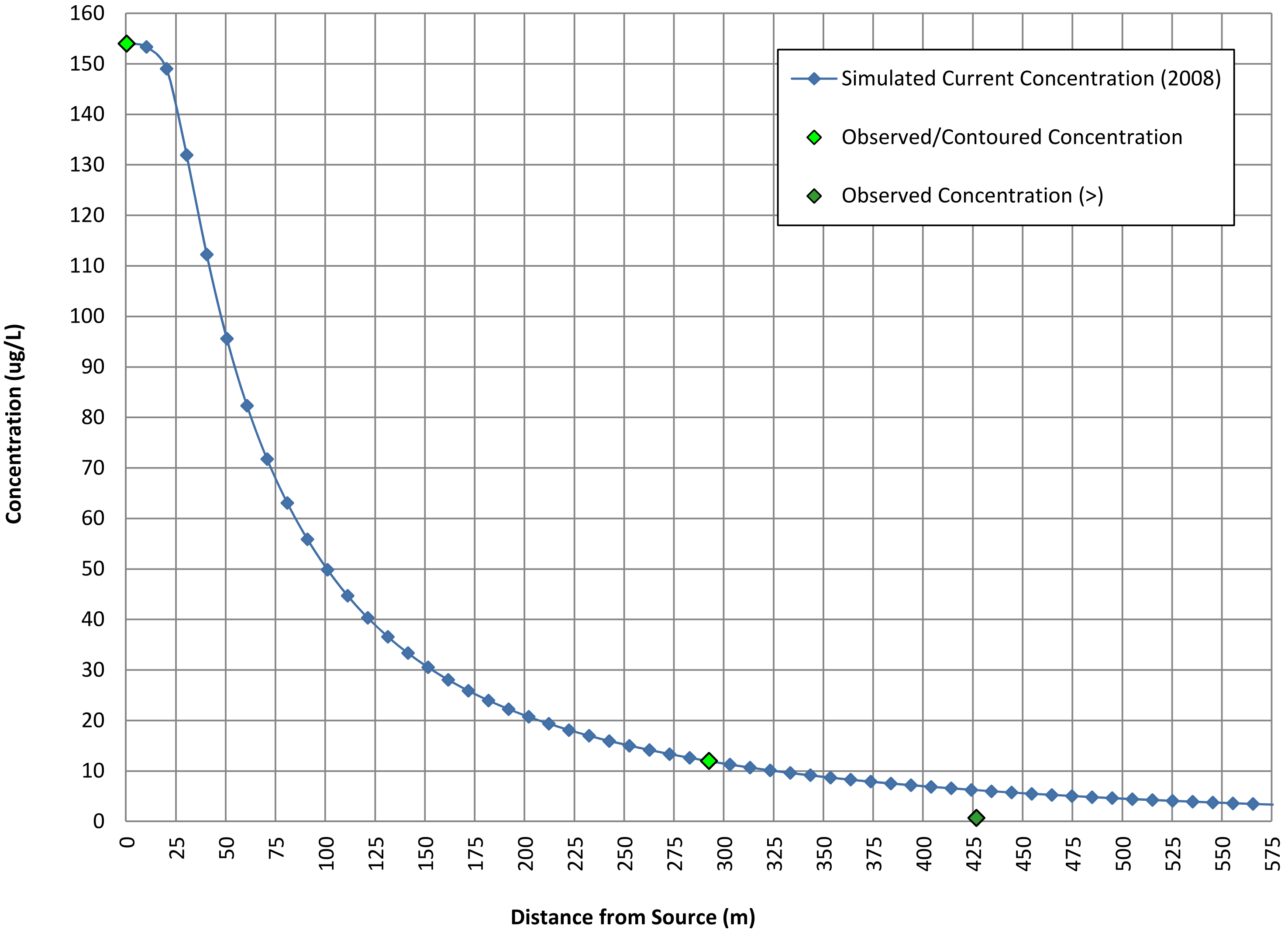


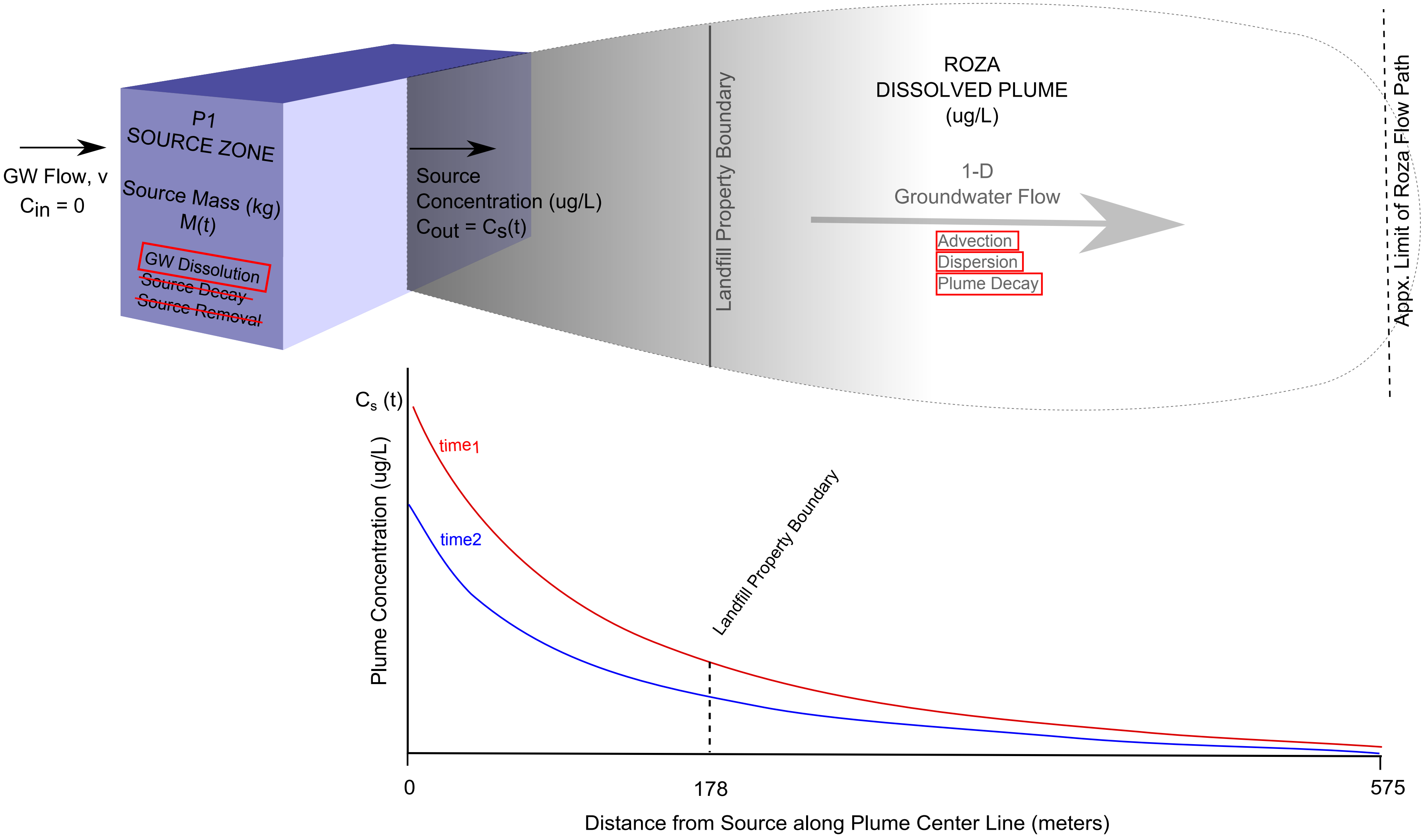
Figure 10

Simulated Currrent Methylene Chloride Concentration Profile - Roza Northerly Plume



Source Mass/Source Concentration Relationship:

$$C_S(t)/C_o = [M(t)/M_o]^{Gamma}$$



Source and Plume processes used to simulate this component are highlighted in red. Processes not simulated are crossed out in red.

Figure 11 Conceptual REMChlor Model - Natural Attenuation

Ephrata Landfill RI/FS

Figure 12
Simulated Future 1,2-DCP Concentration Profiles - Roza Northerly Plume
(FS Component: Natural Attenuation)

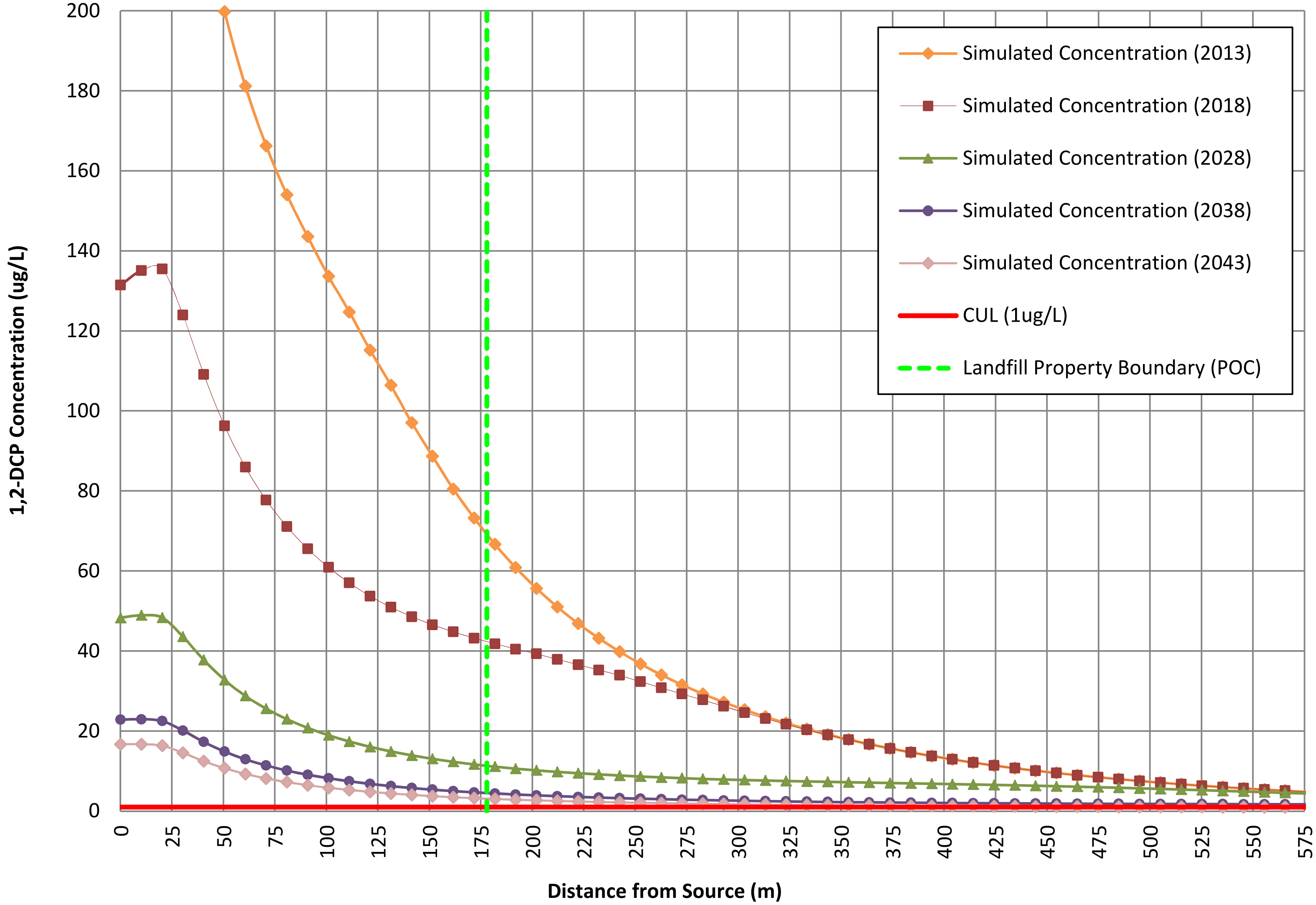


Figure 13

Simulated Future Vinyl Chloride Concentration Profiles - Roza Northerly Plume

(FS Component: Natural Attenuation)

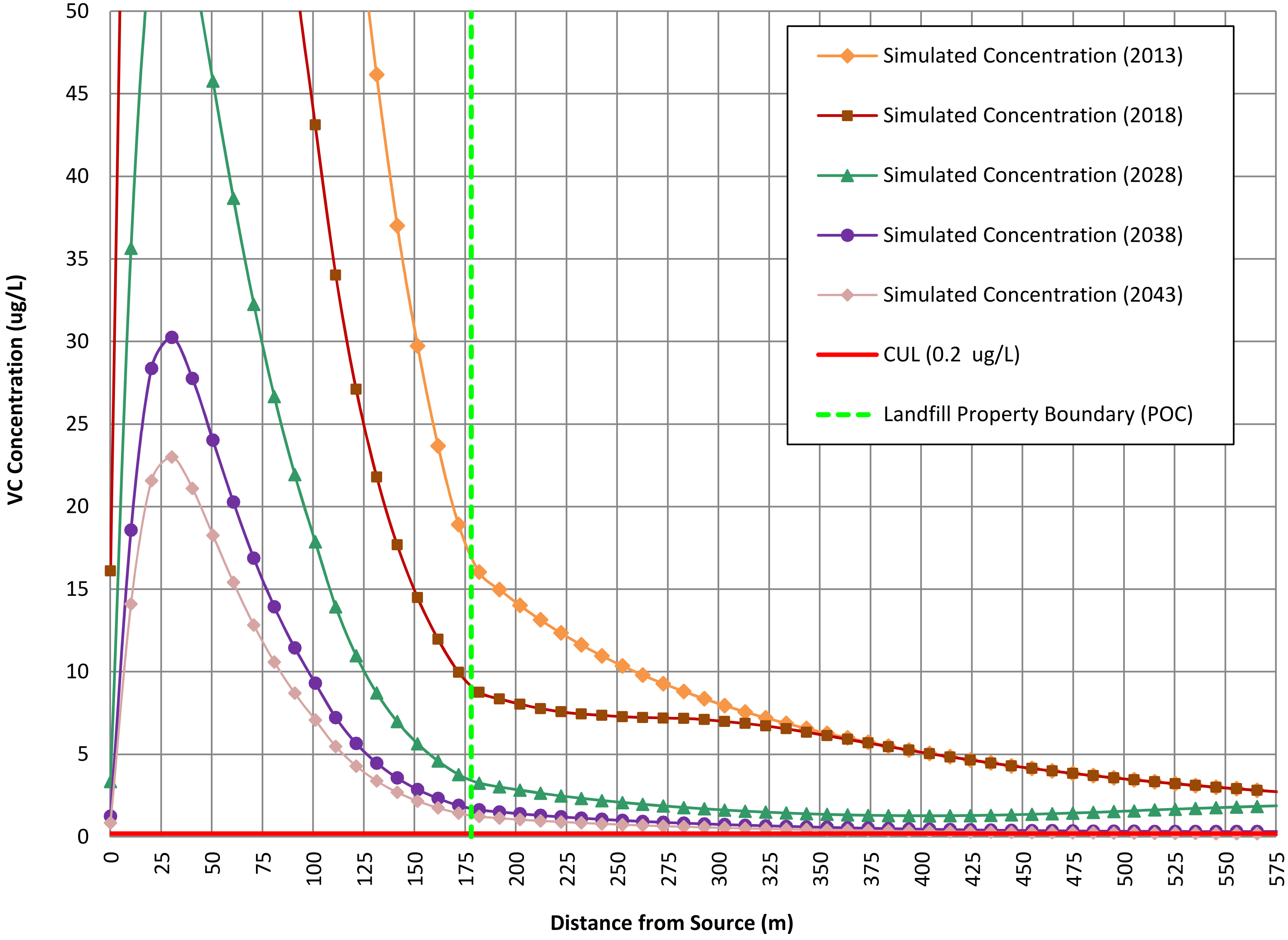


Figure 14

Simulated Future Benzene Concentration Profiles -Roza Northerly Plume

(FS Component: Natural Attenuation)

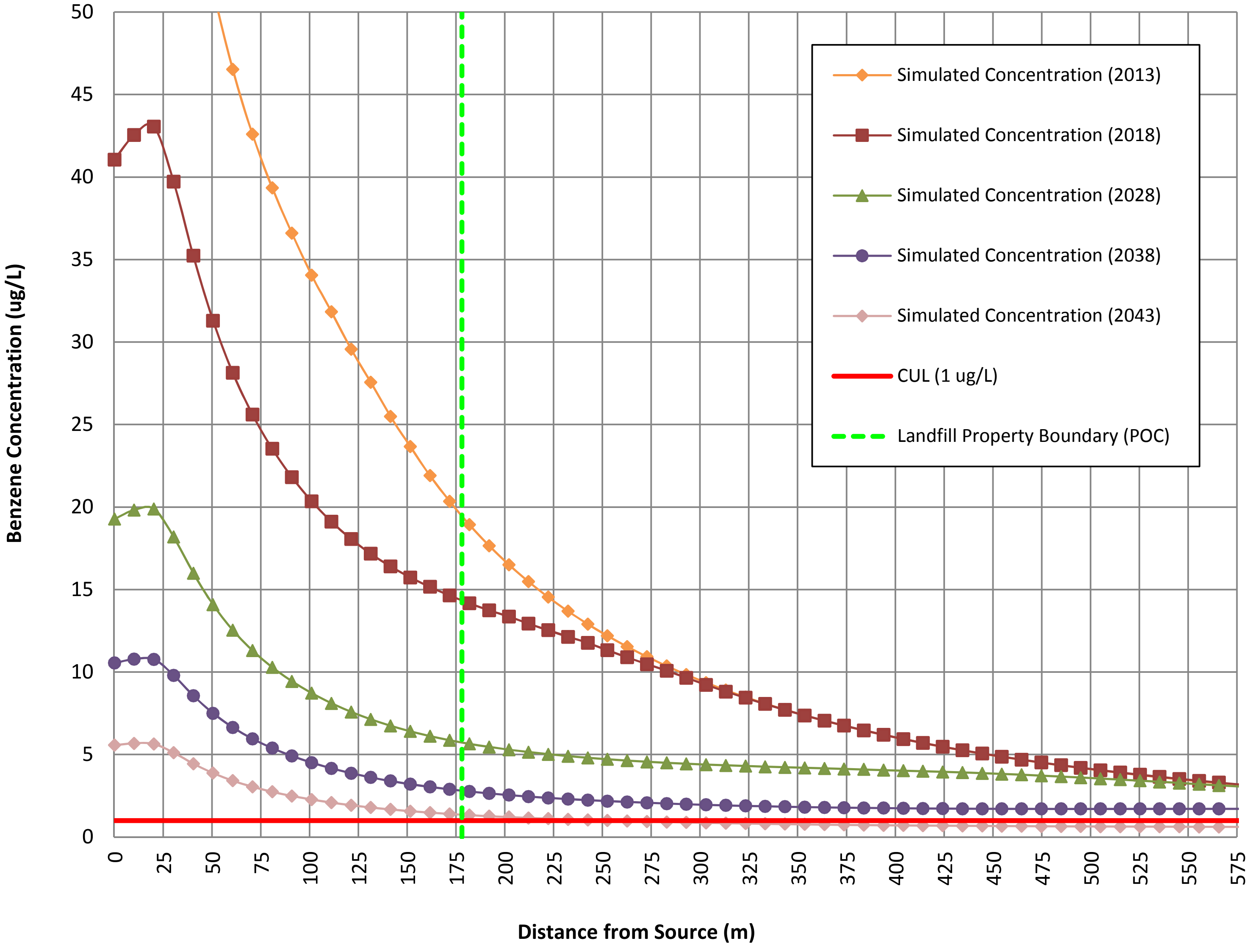
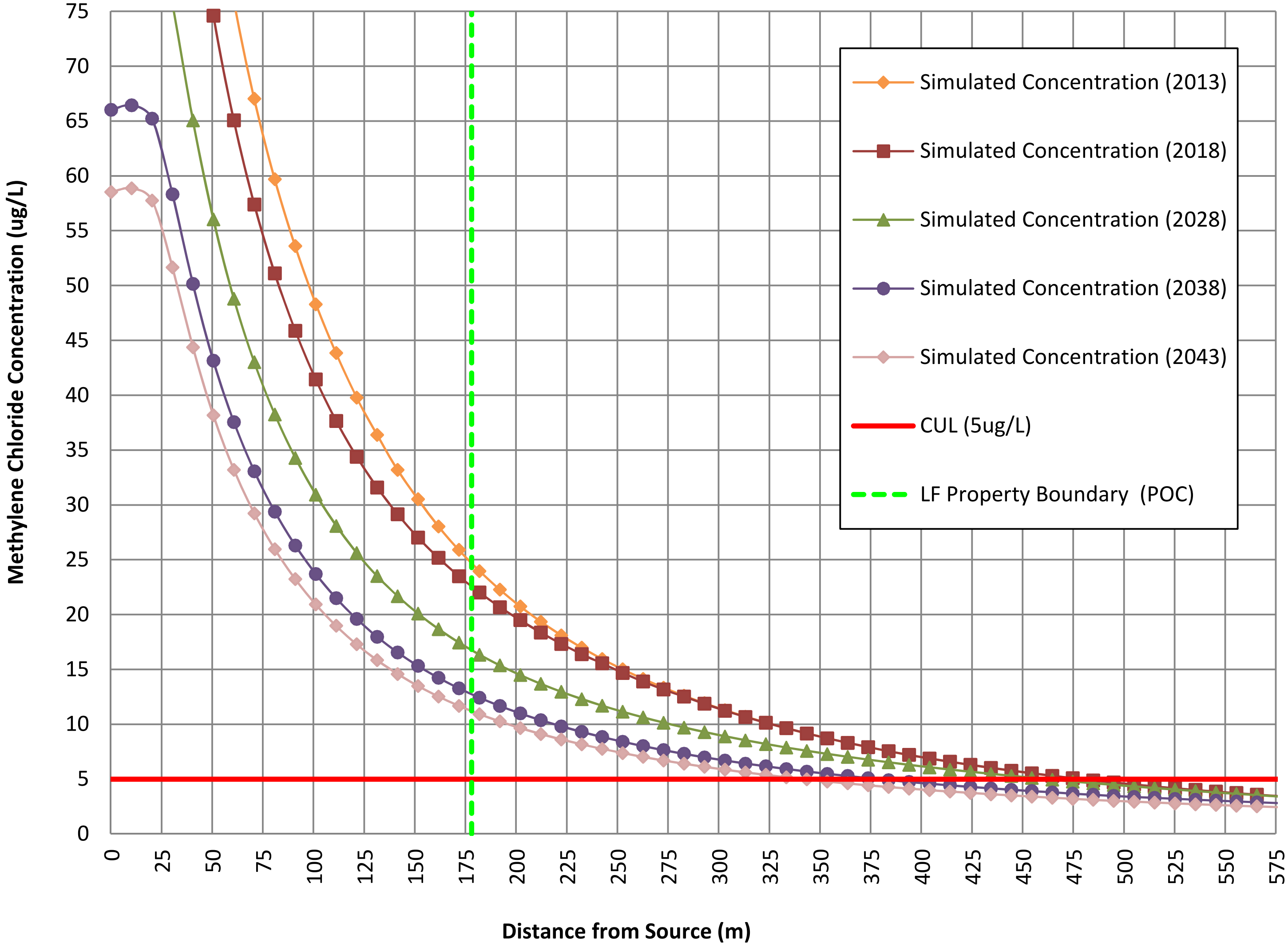


Figure 15

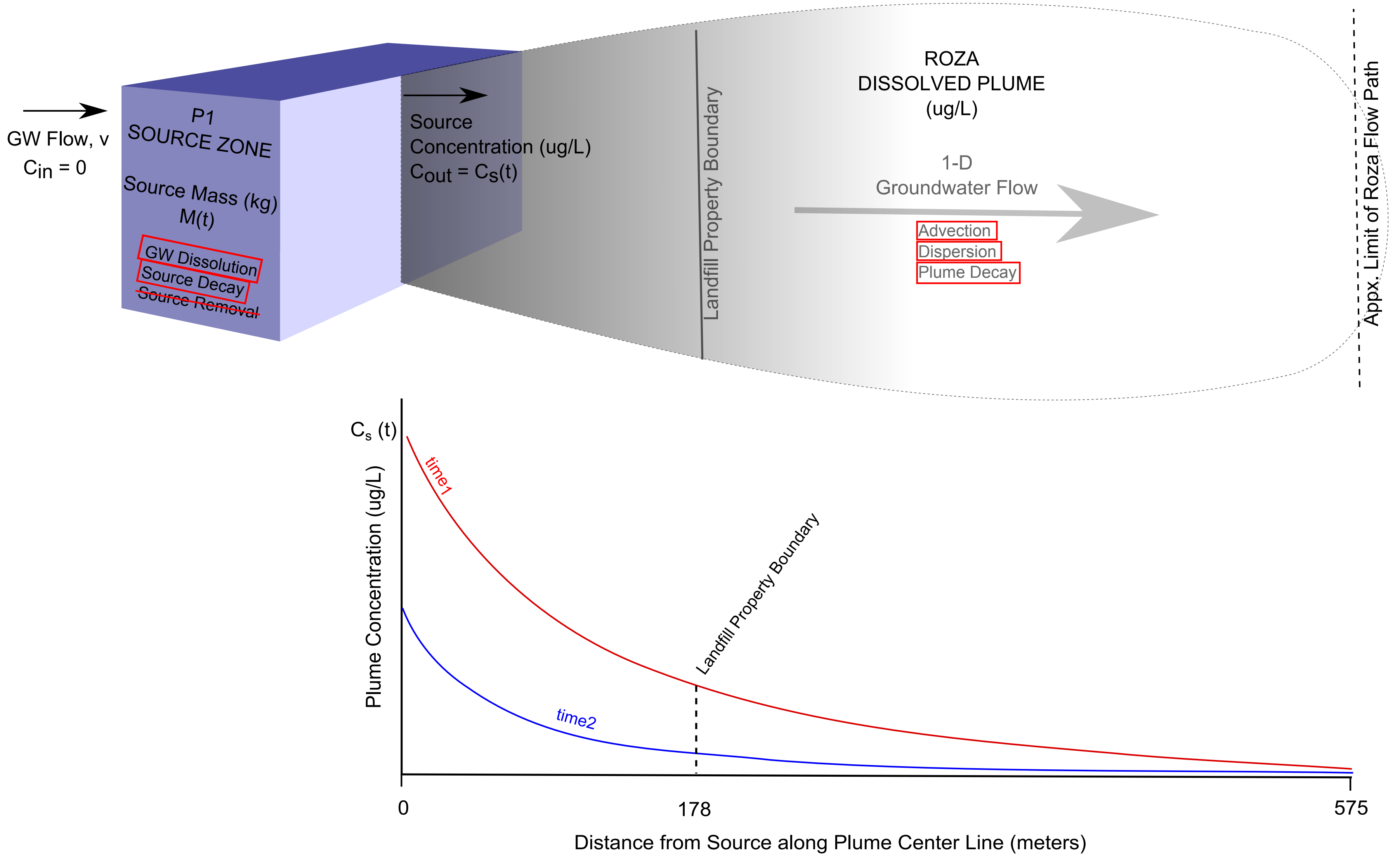
Simulated Future Methylene Chloride Concentration Profiles - Roza Northerly Plume

(FS Component: Natural Attenuation)



Source Mass/Source Concentration Relationship:

$$C_S(t)/C_o = [M(t)/M_o]^{Gamma}$$



Source and Plume processes used to simulate this component are outlined in red.
Processes not simulated are crossed out in red.

Figure 16 Conceptual REMChlor Model - P1 Source Area Long Term Pumping

Ephrata Landfill RI/FS

Figure 17
Simulated Future 1,2-DCP Concentration Profiles - Roza Northerly Plume
(FS Component: P1 Long Term Groundwater Pumping)

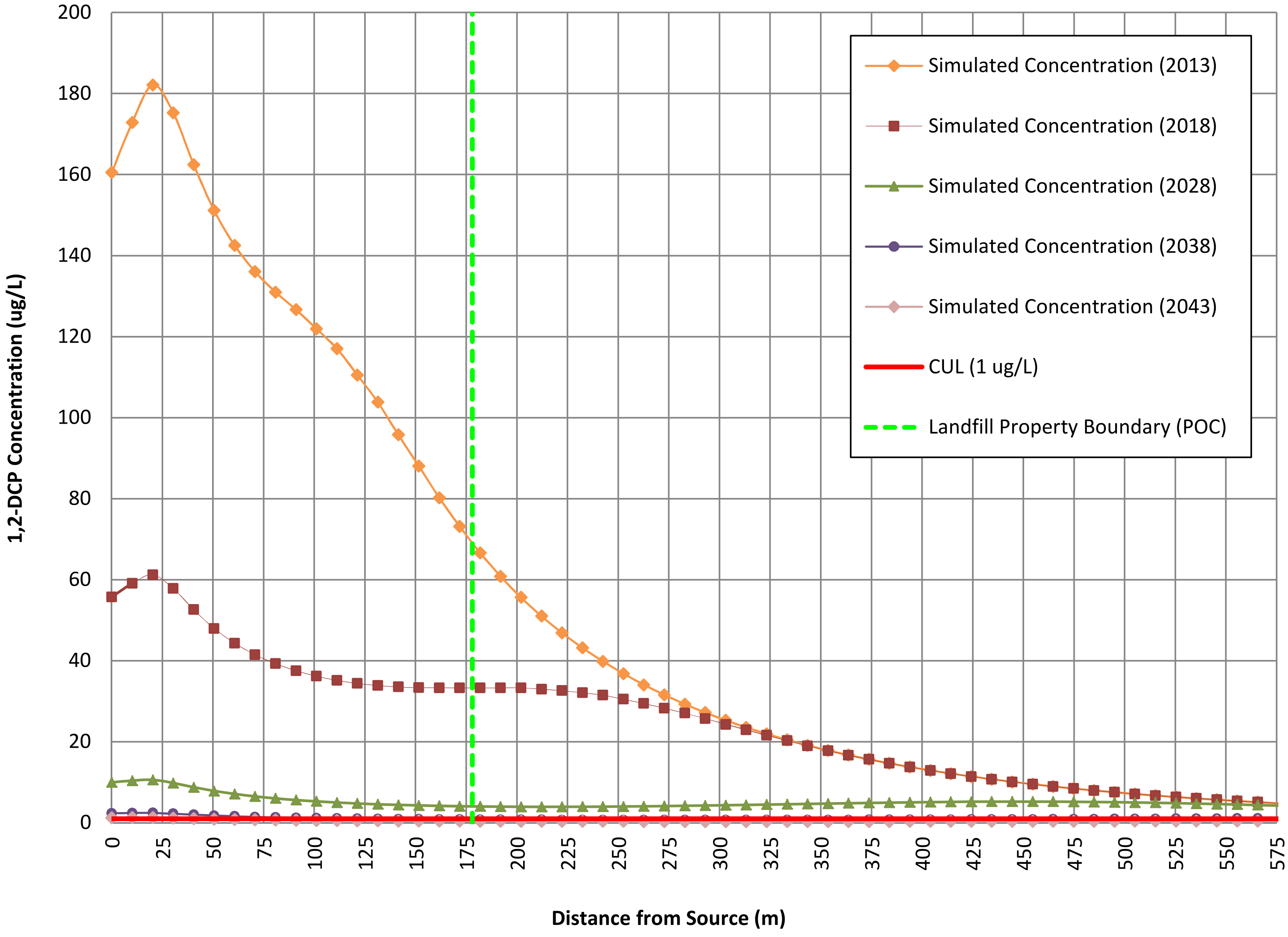


Figure 18

Simulated Future Vinyl Chloride Concentration Profiles - Roza Northerly Plume

(FS Component: P1 Long Term Groundwater Pumping)

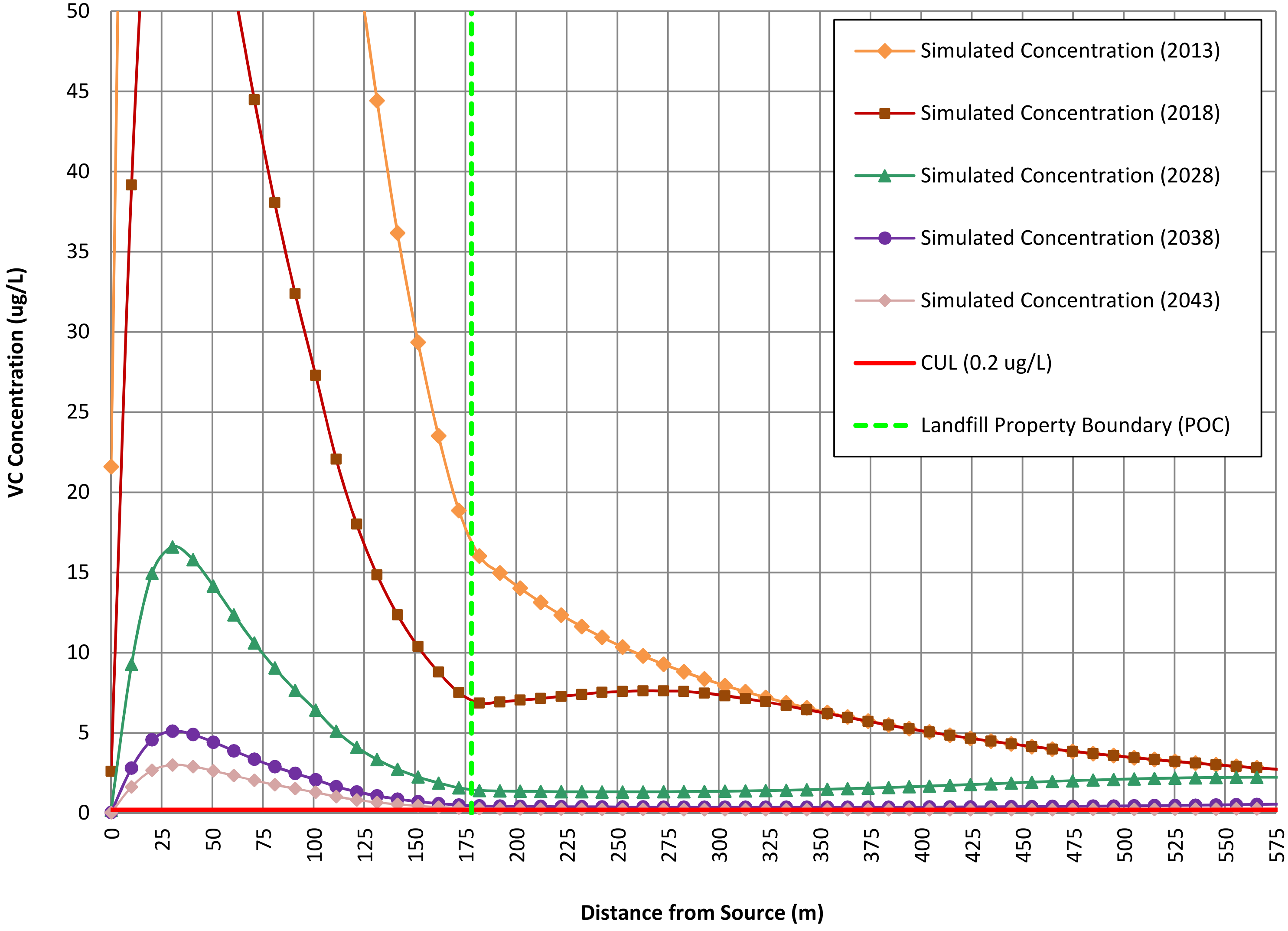


Figure 19
Simulated Future Benzene Concentration Profiles -Roza Northerly Plume
(FS Component: *P1 Long Term Groundwater Pumping*)

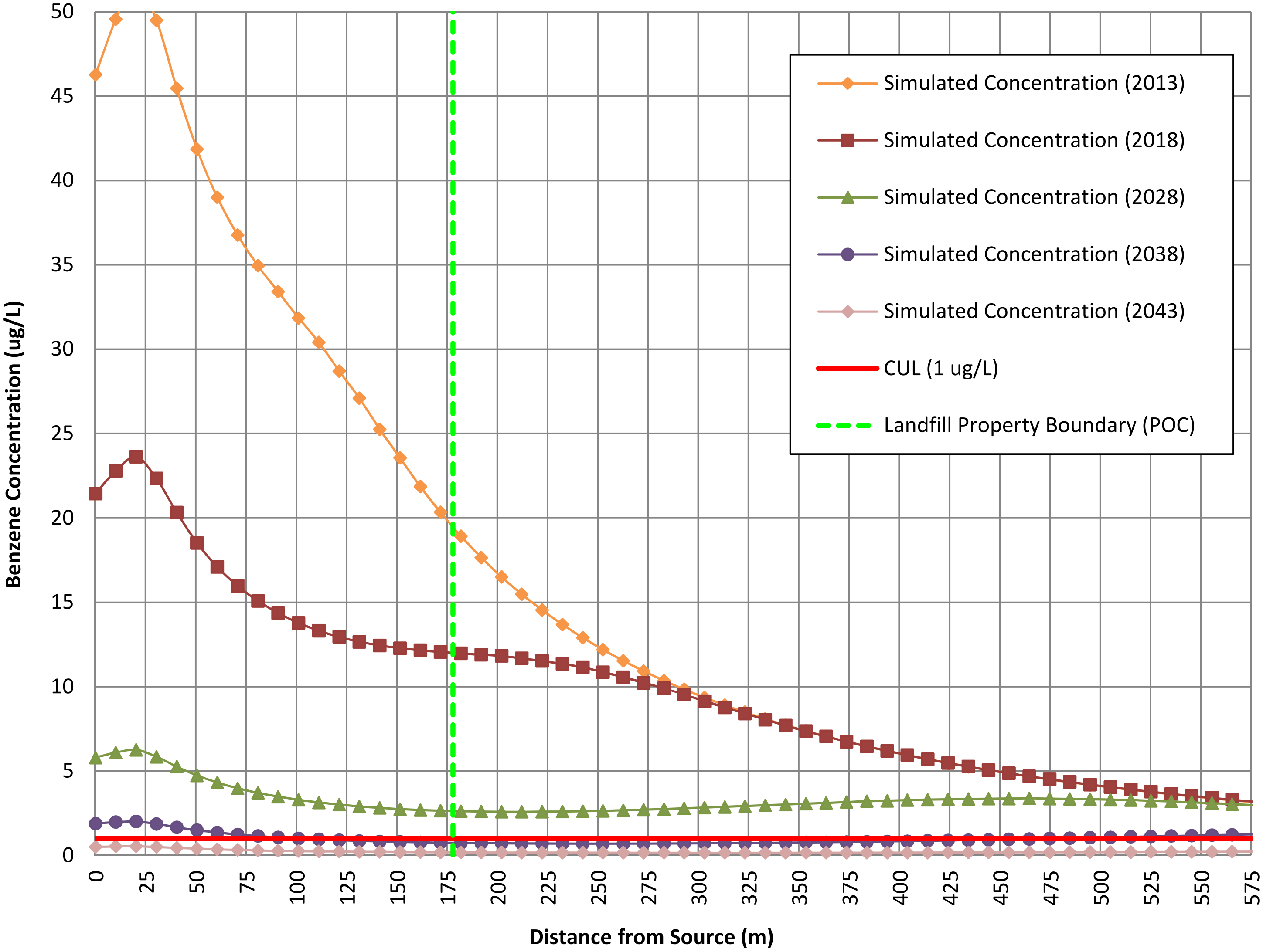
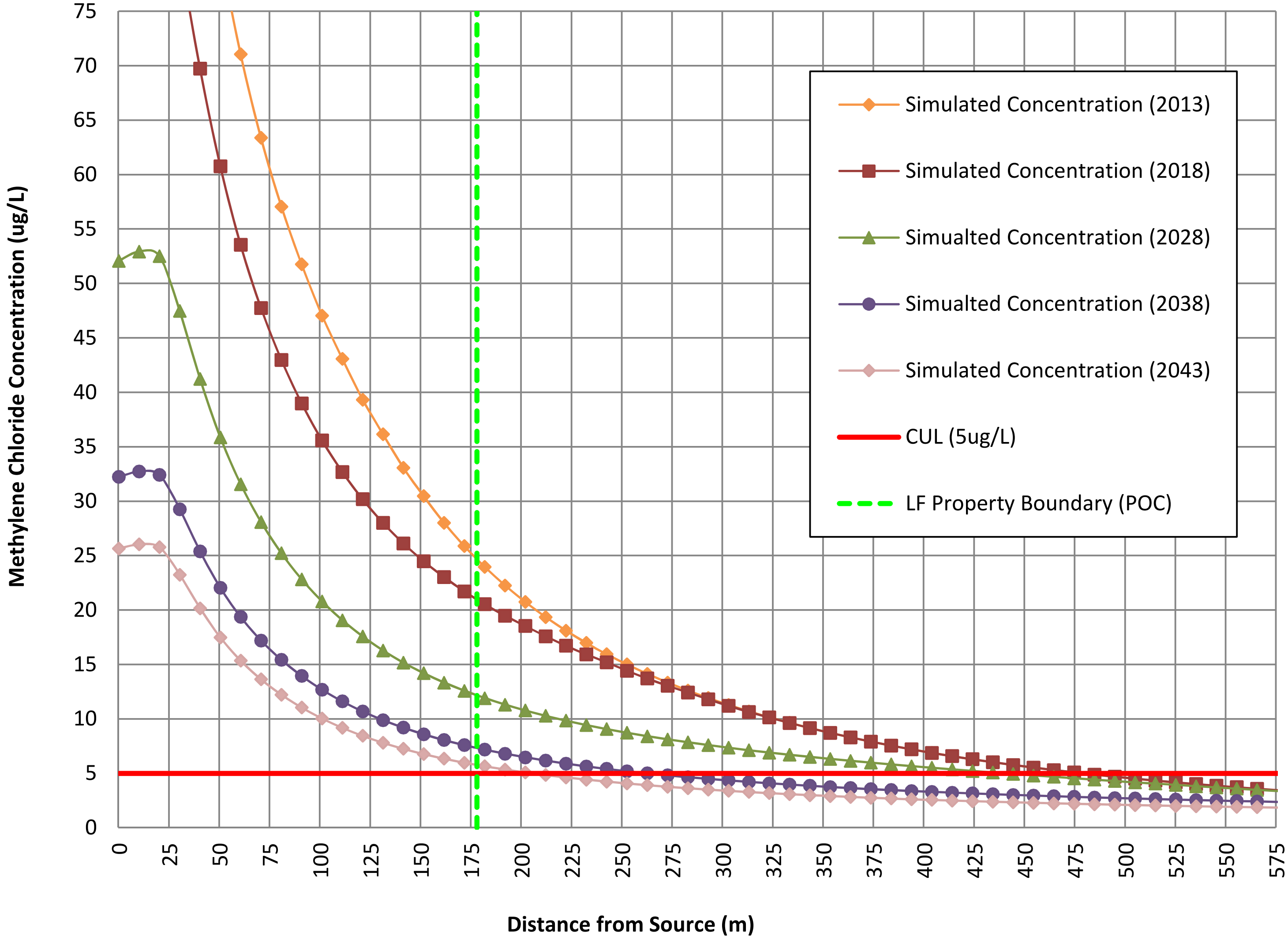


Figure 20

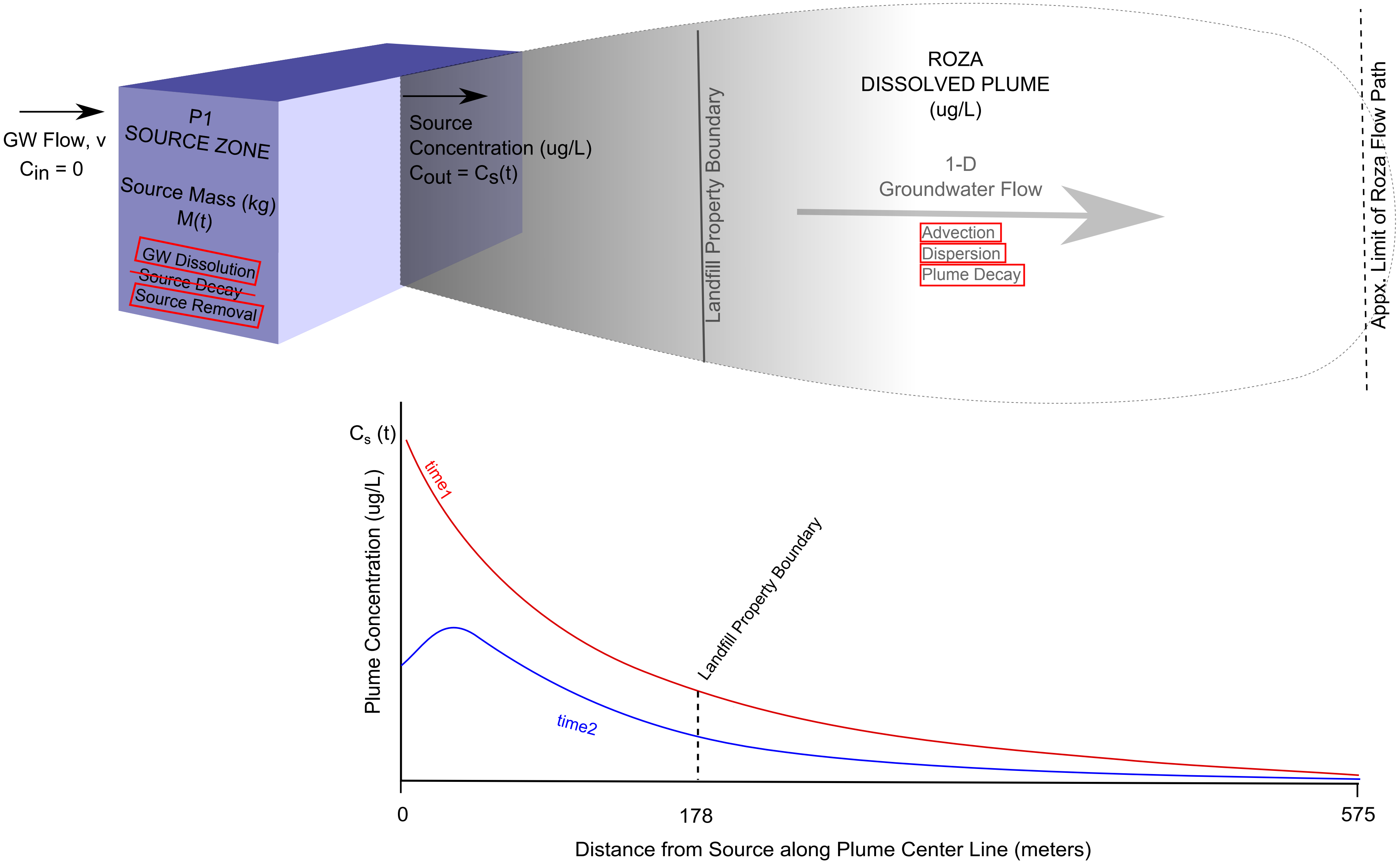
Simulated Future Methylene Chloride Concentration Profiles -Roza Northerly Plume

(FS Component: *P1 Long Term Groundwater Pumping*)



Source Mass/Source Concentration Relationship:

$$C_S(t)/C_o = [M(t)/M_o]^{Gamma}$$



Source and Plume processes used to simulate this component are outlined in red.
Processes not simulated are crossed out in red.

Figure 21 Conceptual REMChlor Model - Soil Vapor Extraction (SVE)

Ephrata Landfill RI/FS

Figure 22

Simulated Future 1,2-DCP Concentration Profiles - Roza Northerly Plume

(FS Component: SVE as 50% Source Removal)

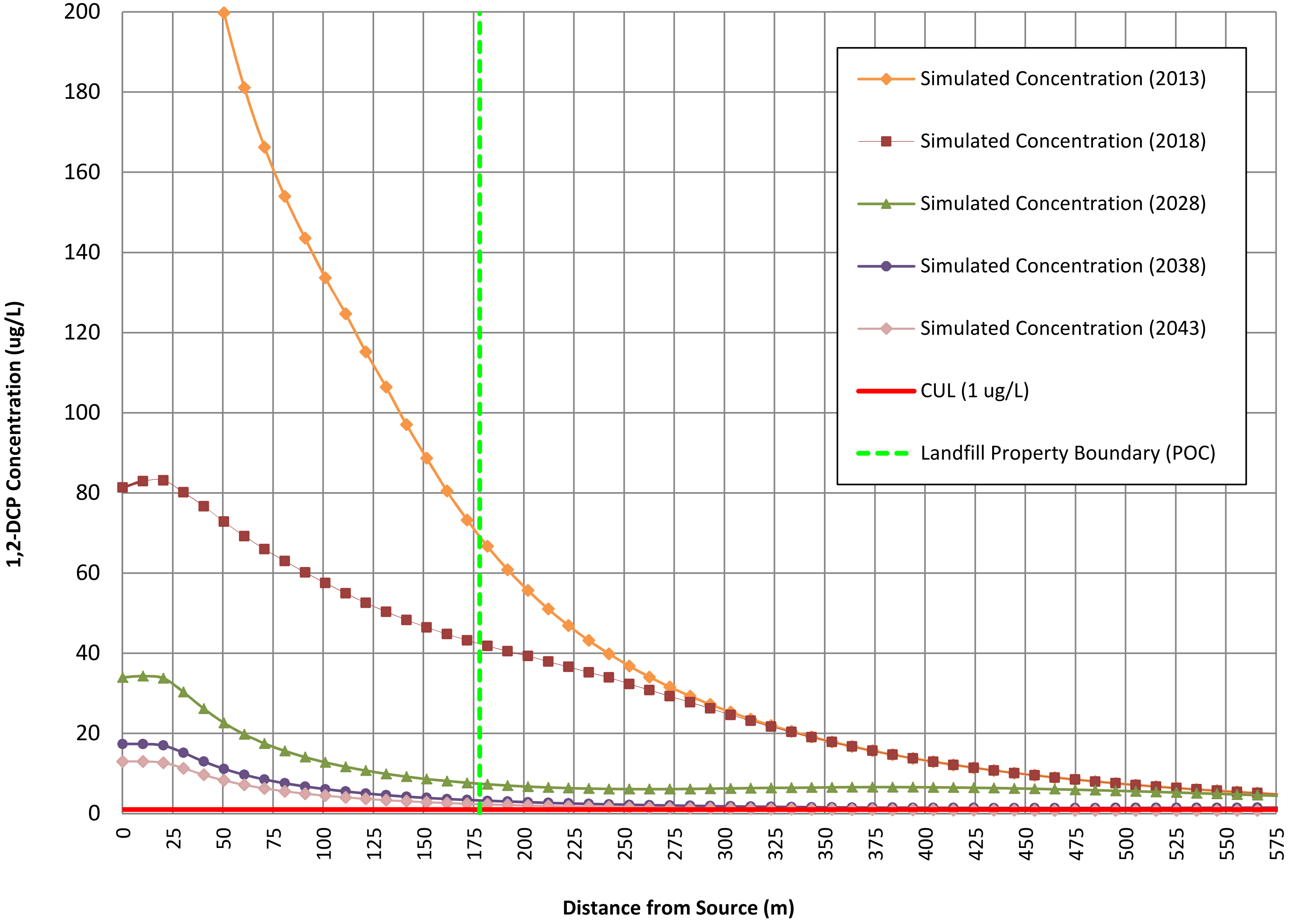


Figure 23

Simulated Future Vinyl Chloride Concentration Profiles - Roza Northerly Plume

(FS Component: SVE as 50% Source Removal)

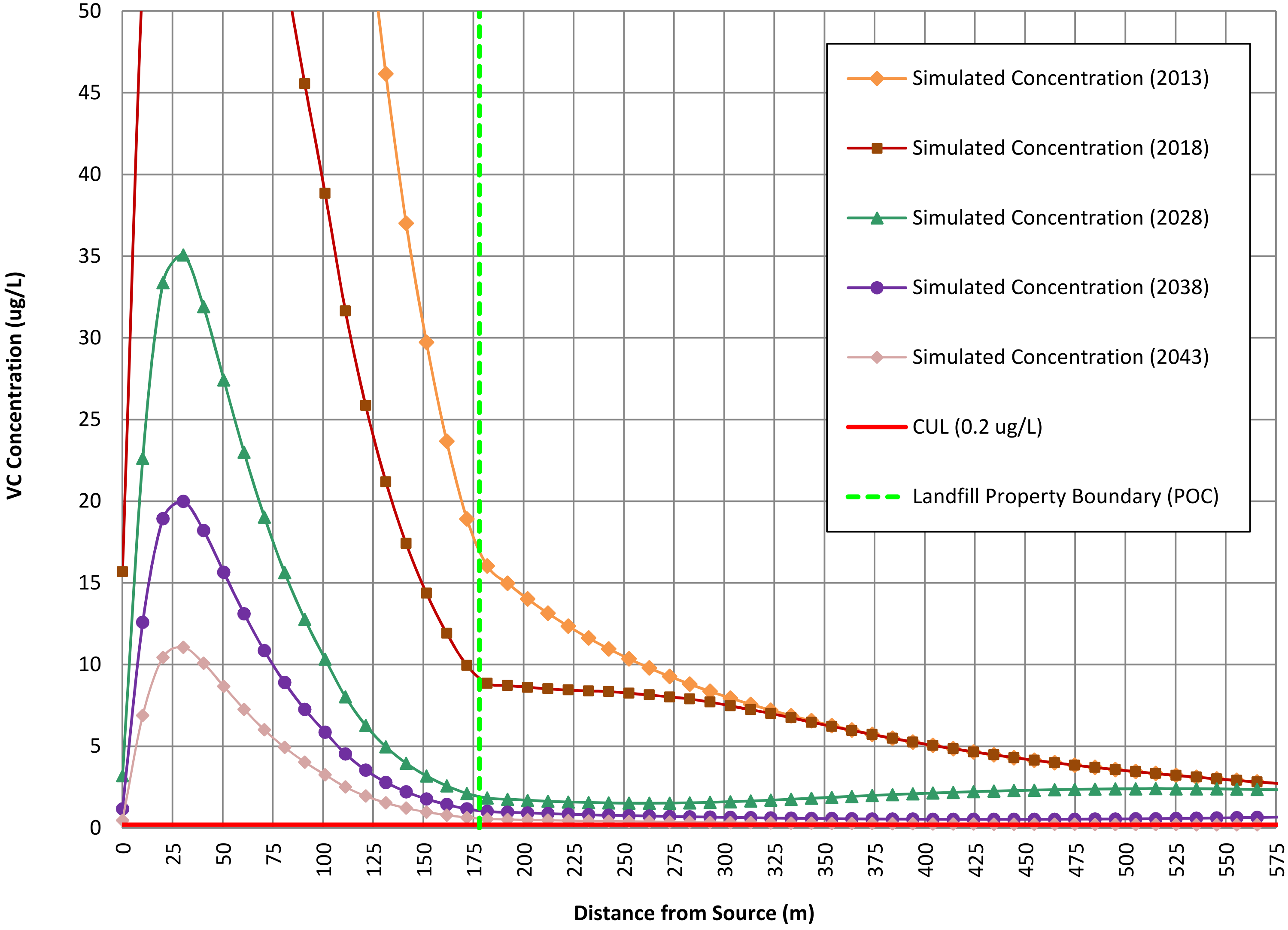


Figure 24

Simulated Future Benzene Concentration Profiles - Roza Northerly Plume

(FS Component: SVE as 50% Source Removal)

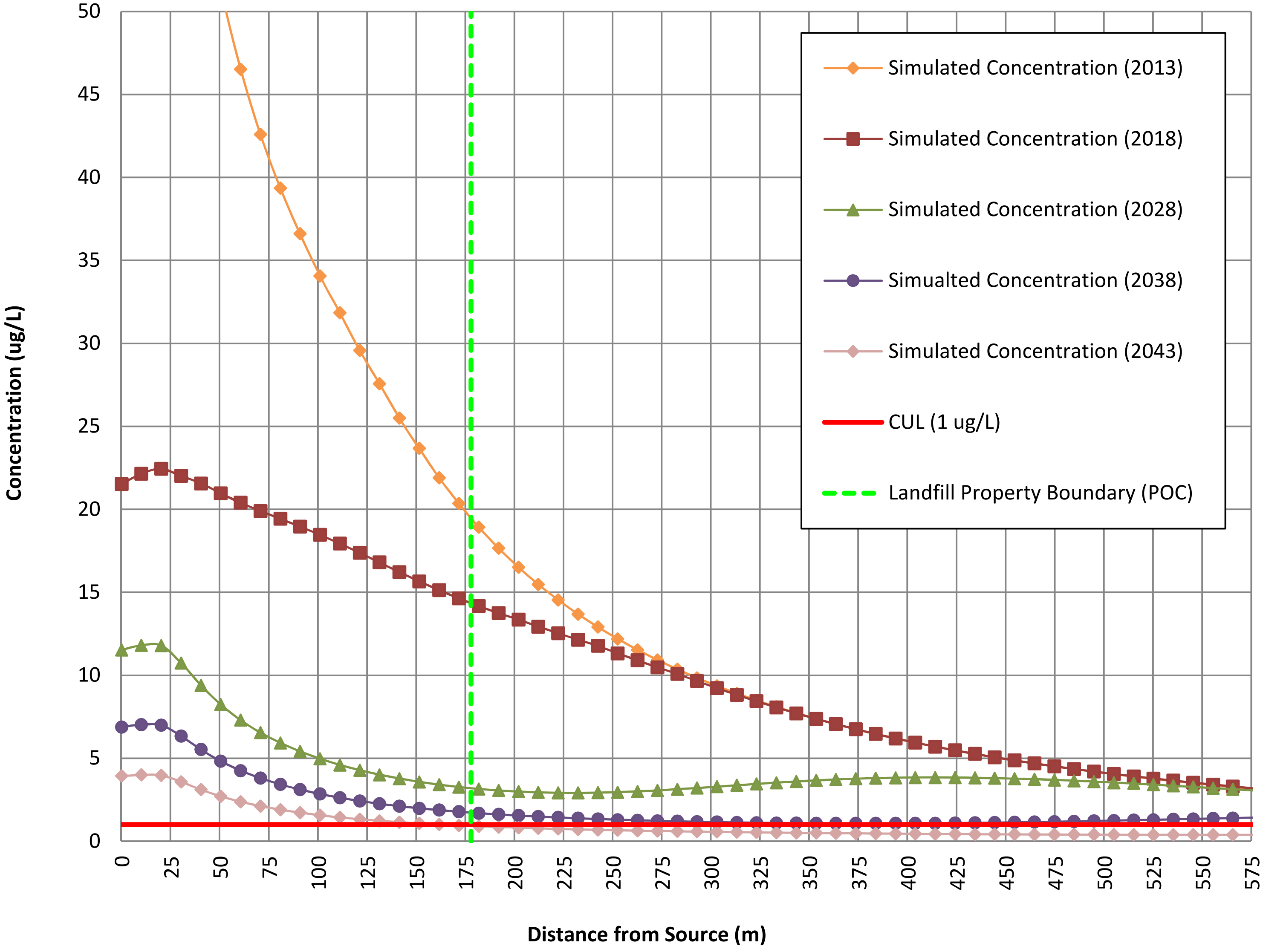
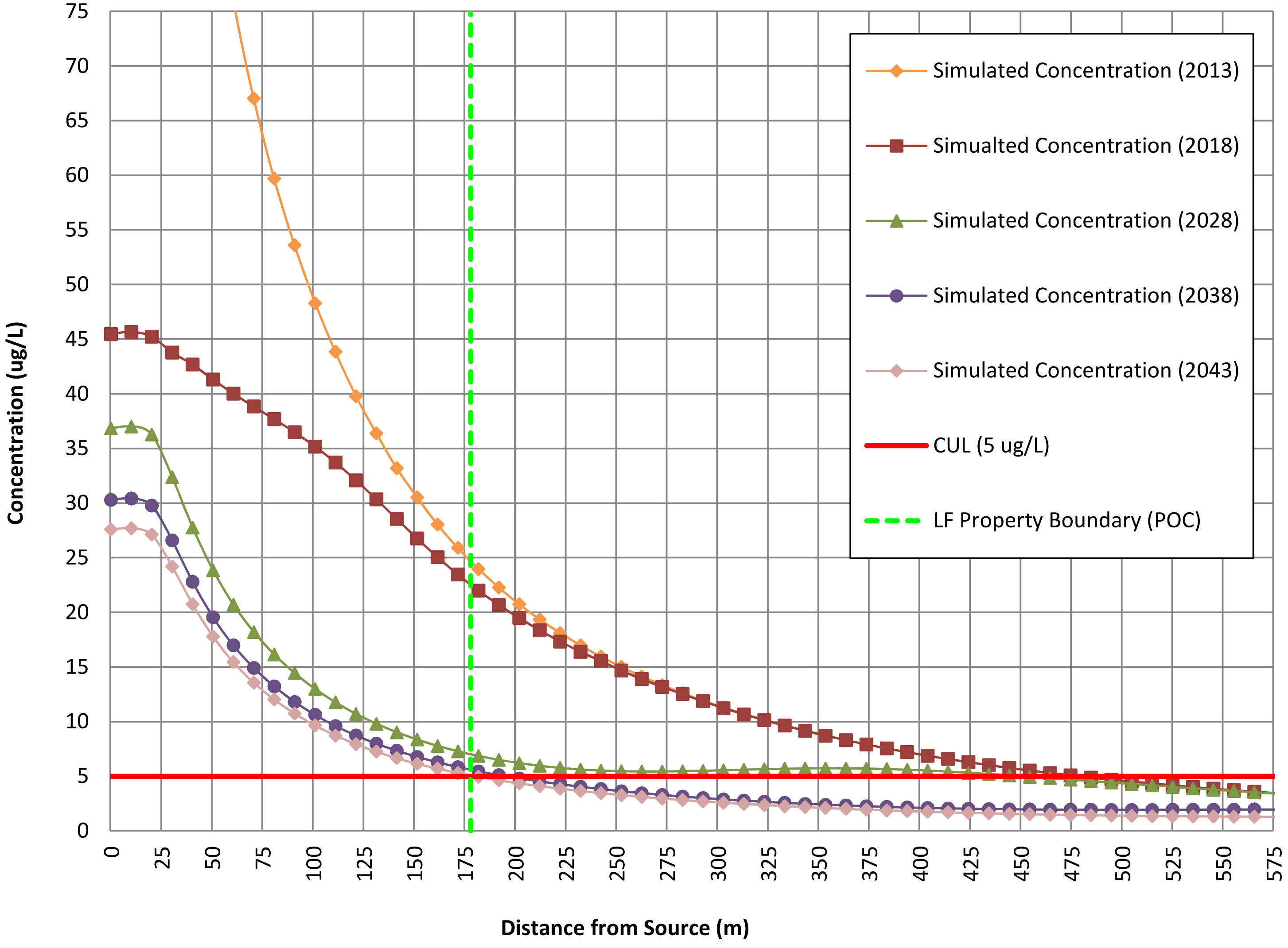


Figure 25

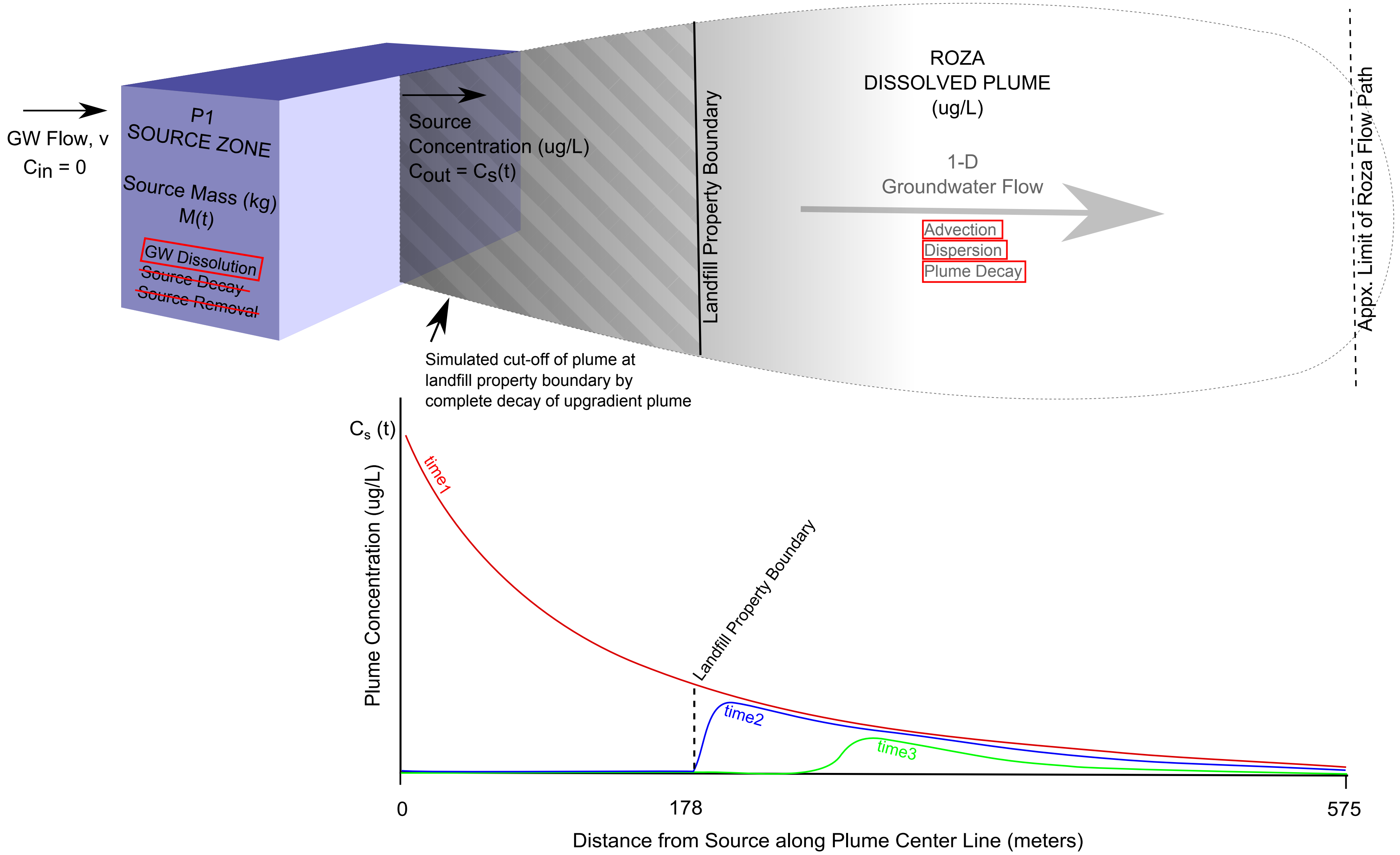
Simulated Future Methylene Chloride Concentration Profiles - Roza Northerly Plume

(FS Component: SVE as 50% Source Removal)



Source Mass/Source Concentration Relationship:

$$C_S(t)/C_o = [M(t)/M_o]^{Gamma}$$



Source and Plume processes used to simulate this component are outlined in red.
Processes not simulated are crossed out in red.

For this component the plume decay term was increased between 0 and 152 meters to simulate cut-off of plume at landfill property boundary (hatched area in plume above)

Figure 26 Conceptual REMChlor Model - Roza Plume Capture

Ephrata Landfill RI/FS

Figure 27

Simulated Future 1,2-DCP Concentration Profiles - Roza Northerly Plume

(FS Component: Roza Plume Capture at Landfill Property Boundary)

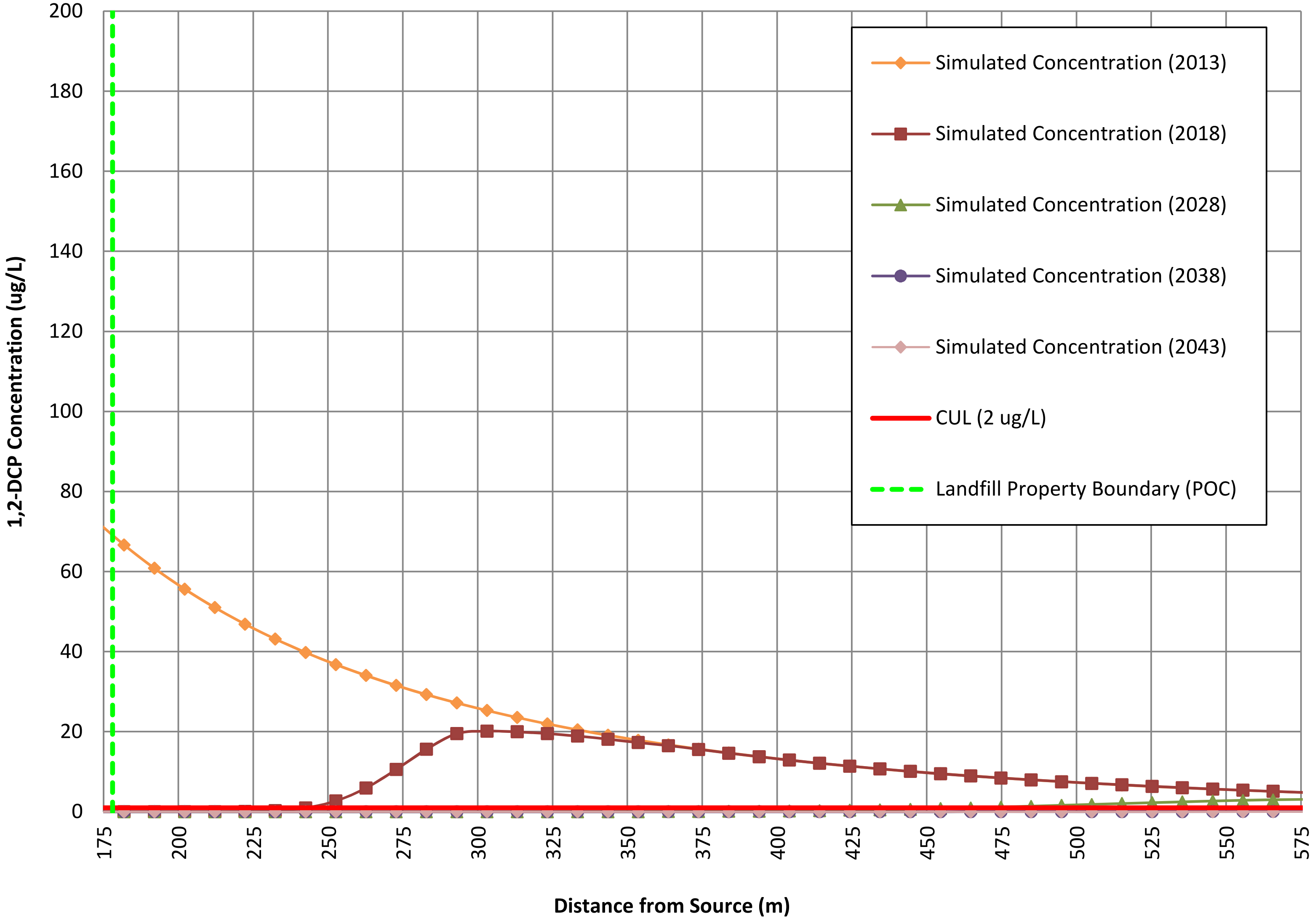


Figure 28

Simulated Future Vinyl Chloride Concentration Profiles - Roza Northerly Plume

(FS Component: Roza Plume Capture at Landfill Property Boundary)

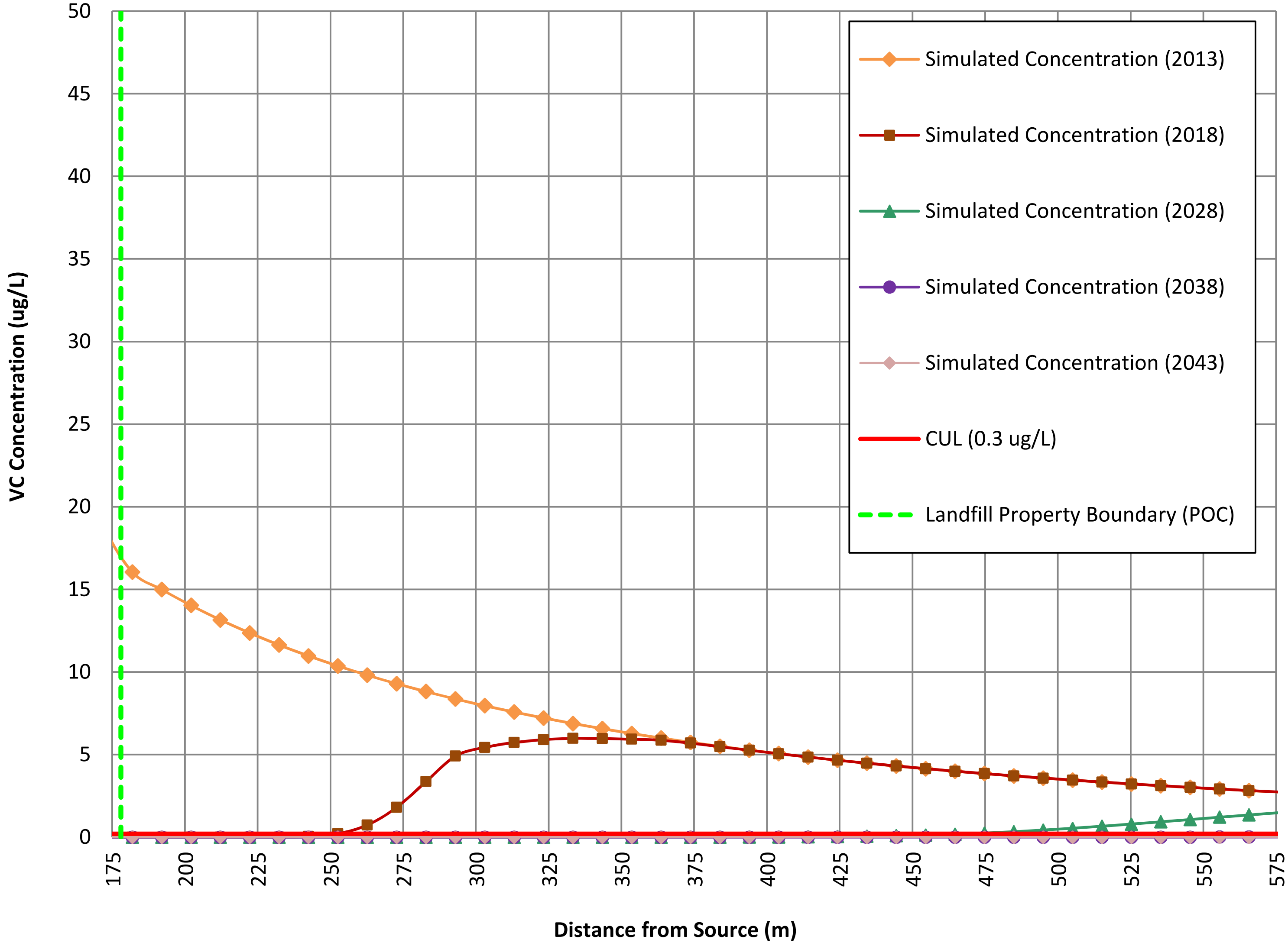


Figure 29

Simulated Future Benzene Concentration Profiles - Roza Northerly Plume

(FS Component: Roza Plume Capture at Landfill Property Boundary)

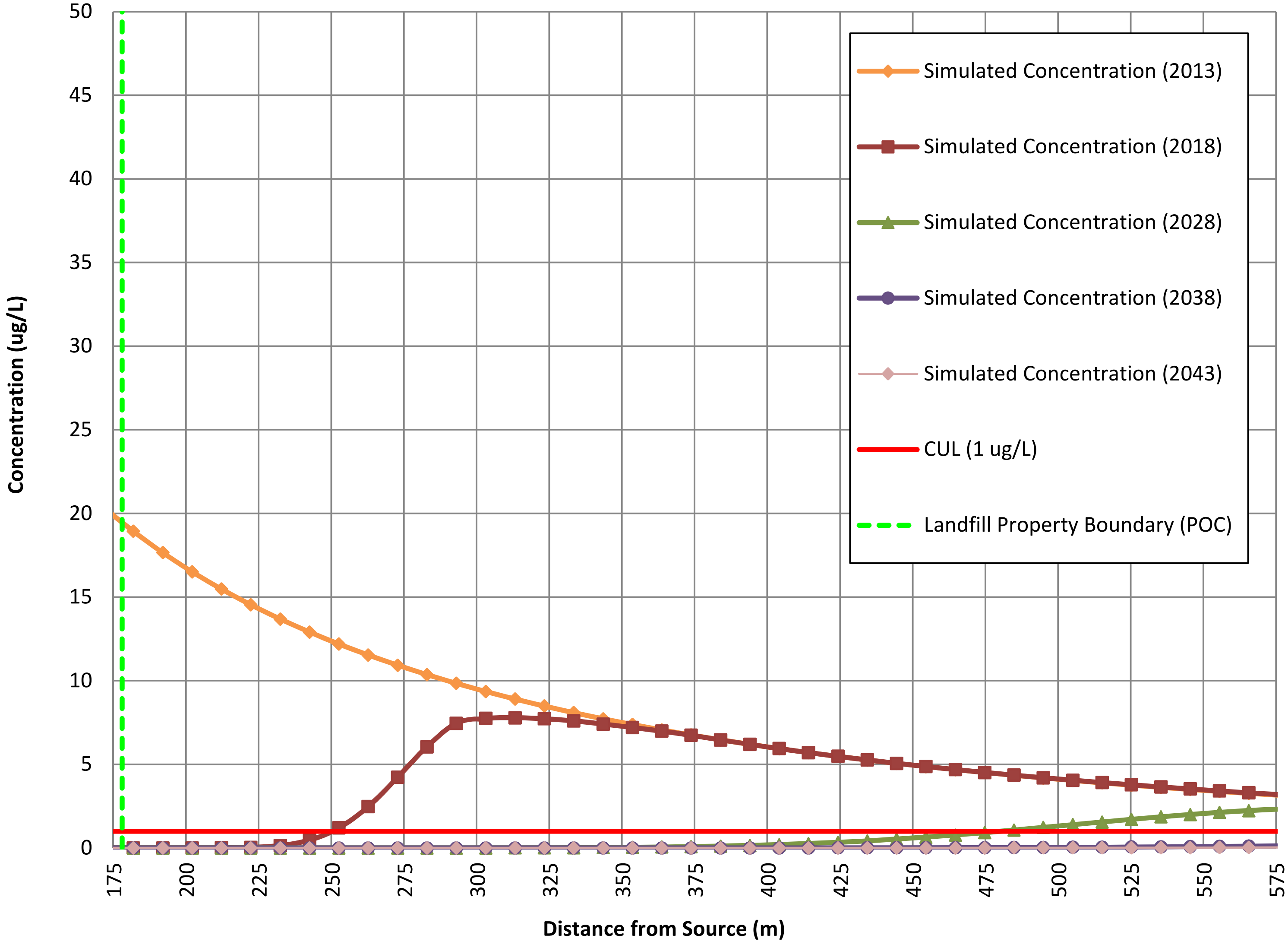


Figure 30

Simulated Future Methylene Chloride Concentration Profiles - Roza Northerly Plume

(FS Component: Roza Plume Capture at Landfill Property Boundary)

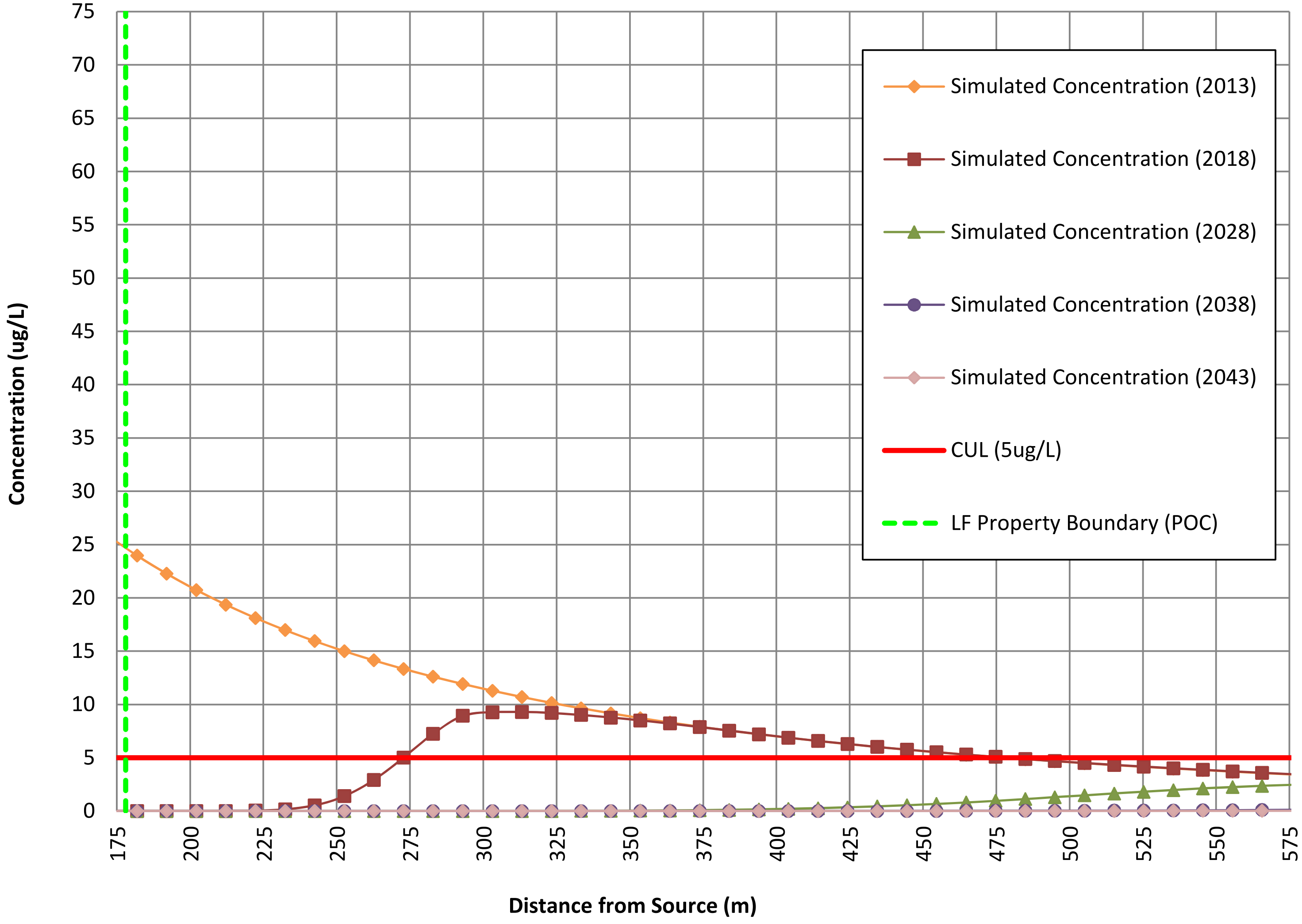
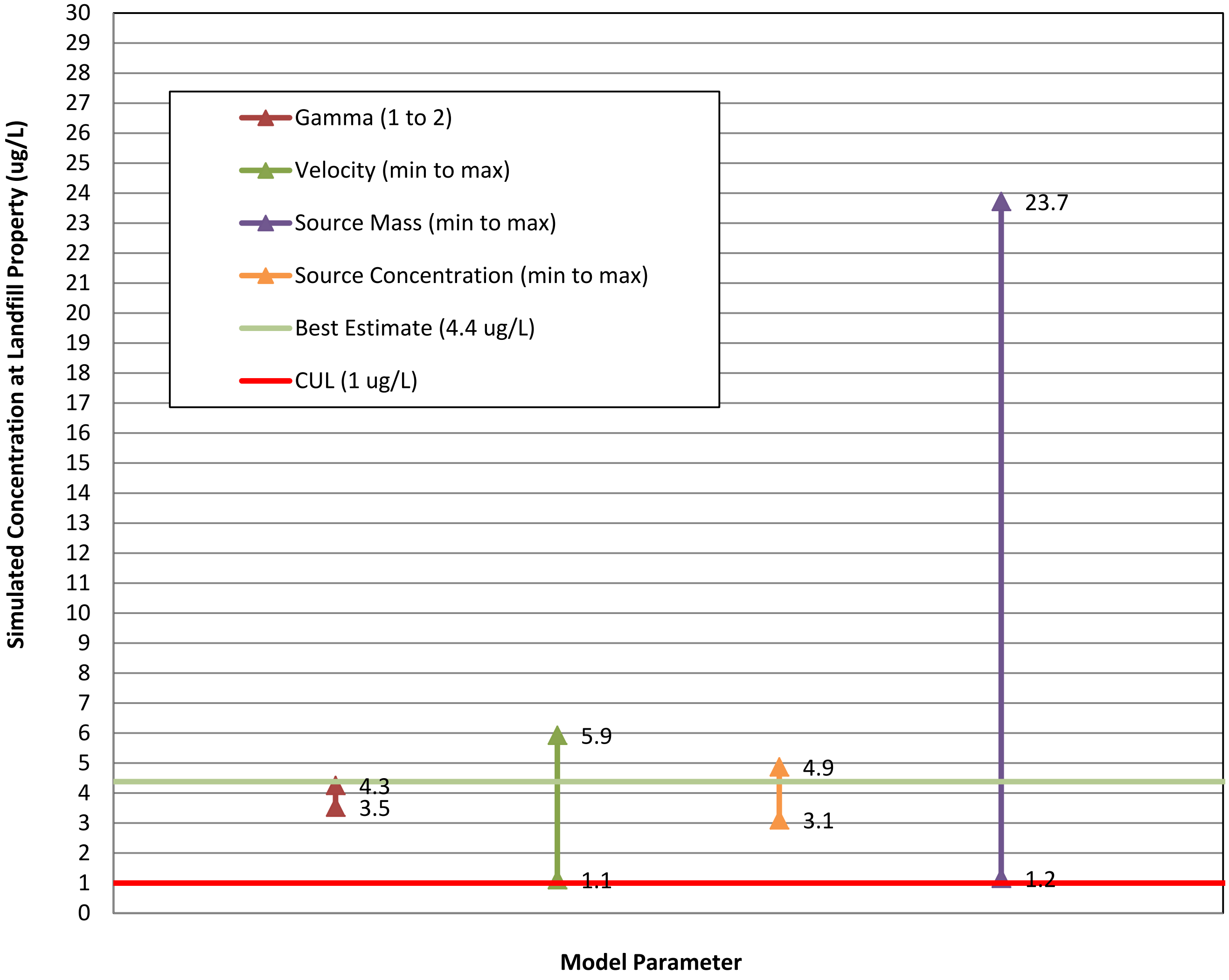


Figure 31

Model Sensitivity to Key Model Parameters

1,2-DCP Simulated Concentration under NA (2038)



APPENDIX B

REMChlor Fate and Transport Results in Support of POC Considerations Internal Technical Memorandum

PACIFIC groundwater GROUP

HYDROGEOLOGIC AND CONTAMINANT CALCULATIONS
FEASIBILITY STUDY SUPPORT
EPHRATA LANDFILL

August 29, 2012

HYDROGEOLOGIC AND CONTAMINANT CALCULATIONS
FEASIBILITY STUDY SUPPORT
EPHRATA LANDFILL

Prepared for:

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August 29, 2012
JE0714
CalculationSupportReport_AppendixFS_Report_Final.docx

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FIGURES

SIGNATURE

This report, and Pacific Groundwater Group's work contributing to this report, were reviewed by the undersigned and approved for release.

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Dawn Chapel

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Washington State Hydrogeologist No. 2651

1.0 INTRODUCTION

This report provides hydrogeologic and contaminant calculations performed in support of the cleanup actions being evaluated in the Feasibility Study (FS; Parametrix, 2012) for the Ephrata Landfill (Figure 1). Hydrogeologic calculations were performed to estimate groundwater extraction rates, extraction volumes, and number of wells for different cleanup action scenarios in the FS. Contaminant calculations were also performed to estimate source mass and source concentration used in the REMChlor fate and transport model of the northerly plume (PGG, 2012a), which also supports the FS. Additional contaminant calculations were also performed to estimate mass attenuation rates in the northerly plume.

Hydrogeologic calculations are presented below. Contaminant calculations are presented in the subsequent section.

Our professional services were performed, our findings obtained, and our report prepared in accordance with generally accepted hydrogeologic practices. This warranty is in lieu of all other warranties, expressed or implied.

2.0 HYDROGEOLOGIC CALCULATIONS

Hydrogeologic calculations were developed for the following scenarios in support of the FS:

1. Seasonal pumping of P1 source area groundwater (existing wells MW-34p1 and MW-36p1)
2. Long term (continuous) pumping of P1 source area groundwater
3. Long term (continuous) pumping of P2 source area groundwater
4. Seasonal pumping of groundwater in the Hole (existing well EW-1)
5. Dewatering of the Hole
6. Property boundary hydraulic containment (capture) of the northerly plume (Roza aquifer high transmissivity zone)
7. Property boundary hydraulic containment (capture) of the northerly plume (Roza aquifer low transmissivity zone)
8. End-of-plume hydraulic containment (capture) of the northerly plume (low transmissivity zone)

These scenarios correspond with certain cleanup action components described in the FS. The results of these calculations are presented as a range of estimated extraction rates and wells for each scenario based on uncertainty in input parameters. A single set of values (based on best-estimate input parameters) is recommended as the design basis for cleanup action components in the FS (Table 1). Calculations for each scenario are completed independent of other scenarios; however, some interference drawdown would be expected during simultaneous implementation of some scenarios. Aside from a few noted exceptions, the scenarios described herein correspond to cleanup action components in the FS (Parametrix 2012).

The following sections summarize the objectives and limitations for each of the above scenarios. The subsequent section then describes our technical approach and results of the calculations.

2.1 SCENARIO OBJECTIVES AND KEY ASSUMPTIONS

The objective and limitations of each scenario evaluated in these calculations are discussed below.

2.1.1 P1 Source Area – Seasonal Extraction

The objective of this scenario would be to remove source mass by seasonal pumping (approximately 200 days per year) in the P1 source area; an area immediately south of the drum removal area where light non-aqueous phase liquid (LNAPL) has been observed (Figure 1). The calculations assume the use of existing extraction wells (MW-34p1 and MW-36p1). Extraction rates in the P1 source area are limited by a maximum drawdown of about 2-ft in order to reduce the potential of pumping LNAPL. LNAPL would continue to be managed with absorbent socks under this scenario.

2.1.2 P1 Source Area – Long Term Extraction

The objectives of this scenario would be to remove source mass by continuous long term extraction of groundwater from the P1 source area. Continuous pumping would reduce vertical gradients, partially contain the source, and create an unsaturated zone for soil vapor extraction. For this calculation, we assume extraction rates are limited by a maximum drawdown of about 2-ft in order to reduce the potential of pumping LNAPL. However, the FS also contemplates pumping of total fluids (e.g. mixed phase) and *ex-situ* separation of LNAPL with long term pumping (Parametrix, 2012), which would support more drawdown.

2.1.3 P2 Source Area – Long Term Extraction

The P2 source area is present directly beneath the P1 source area, separated by about 10-ft of dense basalt. The objective of this scenario would be to remove source mass from the P2 source area; however, the extremely low transmissivity (T) of the P2 source area (0.2 ft^2/dy) limits the ability to do so.

P2 source area T (0.2 ft^2/dy) is about two orders of magnitude less than that of the overlying P1 (21 ft^2/dy). Continuous long-term pumping in such a low T zone is not technically feasible. To illustrate the technical challenge, groundwater sampling of the existing P2 source area wells (MW-33p2, MW-35p2, and MW-38p2) involves hand bailing the well dry and returning the next day, once the wells recover. Recovery the next day is still sometimes not sufficient to fill all sample bottles. Theoretically, a long-term sustainable pumping rate for this zone would be well below 0.1 gpm[1]. The low discharge rates achievable in the P2 source area would not provide for significant source removal. Based on these observations, we did not quantify extraction rates and volumes for this scenario, nor is it a component in the FS.

2.1.4 Groundwater from the Hole – Seasonal Extraction

The objective of this scenario would be to remove contaminant mass by resuming seasonal extraction (approximately 200 days per year) of groundwater from the Hole[2] (Figure 1) using the existing extraction well (EW-1). For this assessment, extraction rates were maximized while limiting the drawdown to 3-ft to 5-ft (available drawdown is about 5-ft in EW-1).

2.1.5 Groundwater from the Hole – Dewater

The objectives of this scenario would be to remove contaminant mass, reduce saturation of waste in the Hole, and to contain contaminant movement. Because the Hole is largely, if not completely, bounded by basalt, the dominant migration pathway is likely downward to the underlying Roza aquifer. The groundwater elevation in the underlying Roza aquifer is estimated[3] to be about 0.5 feet lower than the groundwater elevation in the Hole and the available drawdown in the Hole is about 5-ft. Thus, reversal of the vertical gradient appears to be a feasible option for containing contaminant movement. For this evaluation we assume complete dewatering of the Hole, but recognize complete dewatering may not be necessary for containment.

2.1.6 Northerly Plume – Property Boundary Hydraulic Containment in the Roza Aquifer Component

The objective of this scenario would be to hydraulically contain (capture) groundwater in the Roza aquifer along the northern landfill property boundary. This would stop or greatly reduce contaminant migration in the northerly plume beyond the landfill property boundary. The Roza aquifer is highly heterogeneous; however, based on aquifer tests of various Roza wells, there appears to be a much higher transmissivity area (high-T) near the northwest corner of the landfill (Figure 1). We have therefore divided the calculation into high-T and low-T area, as explained below.

Roza aquifer transmissivity in the vicinity of the landfill's maintenance shop (3,074 ft^2/dy) is orders of magnitude higher than Roza aquifer transmissivity measured elsewhere (2.8 ft^2/dy)[4]. The potential for groundwater extraction is therefore comparatively favorable in the high-T zone. Northerly plume hydraulic capture was evaluated along the property boundary in the high-T area and low-T area independently (Figure 1). However,

---

[1] The estimated transmissivity of the P2 zone (0.2 ft^2/dy) is about an order of magnitude lower than the low-T Roza area (2.8 ft^2/dy) and sustainable pumping rates in the low-T Roza area are calculated to be less than 0.1 gpm (see results for Roza containment in Low-T area).

[2] The Hole is a 20 ft deep depression in the basalt surface beneath the landfill. The lower 5 to 7 feet of soil/refuse within the Hole is saturated with groundwater over an area of about 1 acre (Figure 1).

[3] Based on measured water levels in Roza wells immediately northwest of the Hole (MW-3b, 7b, and 9b in Figure 1).

[4] Values based on geometric mean of measured values in the high-T zone and low-T zone.

pumping in the high-T area is expected to capture groundwater in both transmissivity zones (see Section 2.2.5 below).

2.1.7 Northerly Plume – End-of-Plume Hydraulic Containment in the Roza Aquifer Component

The objective of this scenario would be to hydraulically contain groundwater in the Roza aquifer component of the northerly plume near the location of the Whitson well (Figure 1) in order to stop contaminants from migrating further toward private wells. Groundwater in the Roza is believed to discharge laterally into alluvium within a bedrock draw just beyond the Whitson well (Figure 1). Some vertical migration to deeper aquifers may also occur near the Whitson well. This part of the Roza aquifer is thought to be a low T area based on the transmissivity measured in nearby well MW-44b (7 gpd/ft).

2.2 HYDROGEOLOGIC CALCULATIONS AND RESULTS

For each of the above scenarios we evaluated groundwater draw-down and capture associated with different combinations of wells and extraction rates. The software package AQTESOLV v4.5 (HydroSOLVE, Inc.) was used to predict drawdown associated with wells, pumping rates, and aquifer parameters for all but two of the above scenarios. The analytical model GFLOW (Haitjema Software) was used for the Roza high-T property boundary containment scenario. Seasonal P1 pumping was evaluated using estimates of sustainable pumping rates for MW-34p1 and MW-36p1 and prior pumping observations in MW-34p1. Generally, pumping rates were adjusted for each well until target drawdowns were achieved, based on hydrogeologic constraints in a particular area.

The results of this evaluation provide the basis for the number of wells, well spacing, extraction rates, and annual extraction volumes recommended for different cleanup action scenarios in the FS (Table 1). To capture some of the uncertainty in these calculations, we also include a range of values for each scenario (Table 2). Table 2 also provides an estimate of initial annual mass removed for each scenario based on the volume of extracted groundwater and the average groundwater concentrations measured in the target area. The initial annual mass removed is shown both for indicator hazardous substances (IHS) identified in the FS (Parametrix, 2012) and for total organic COCs[5]. Note that over 90% of the organic COC mass removal in the P1 source area is from the removal of toluene, ethylbenzene, and xylene (TEX) and ketone compounds[6].

The results for each scenario are discussed in detail below.

2.2.1 Seasonal P1 Pumping Results

For this scenario, extraction rates and volumes were based on estimates of sustainable pumping rates for MW-34p1 and MW-36p1 and observations of seasonal pumping already performed (PGG, 2011). Sustainable pumping rates for MW-34p1 and MW-36p1 (assuming no more than 2-ft of drawdown) are estimated to be 0.3 and 0.1 gpm respec-

---

[5] Contaminants of concern (COCs) are identified in the RI (PGG, 2010 and 2012b).
[6] Ketone compounds are 2-butanone, 2-hexanone, 4-methyl-2-pentanone, and acetone.

tively. The pumping duration is assumed to be 200 days. Based on these assumptions, the recommended design groundwater extraction was 115,000 gallons/year (Table 1).

2.2.2 Long-Term P1 Pumping Results

For this scenario, we used AQTESOLV to predict drawdown after 5 years of pumping. Extraction rates and number of wells were based on maintaining approximately 2-ft drawdown in numerous wells while also maximizing the drawdown between wells throughout the P1 source area.

For this evaluation, we considered a range of T-values in the P1 zone. T-values were varied between a minimum (10 ft^2/dy), geometric mean (21 ft^2/dy), and maximum (51 ft^2/dy) value based on measured values in MW-34p1, MW-36p1 and MW-37p1 (Figure 1). A range of extraction wells was also considered in the evaluation. Between 2 to 9 wells were spaced uniformly within the P1 source area (P1 source area is shown in Figure 1). The aquifer storage (S) value was assumed to be 0.1 (this value assumes unconfined conditions will be achieved with long term pumping and that the P1 zone is a porous medium – as described in boring logs). Extraction rates were adjusted in AQTESOLV until the maximum predicted drawdown was similar to the target drawdown. The results indicate an annual extraction volume ranging from about 75,000 to 550,000 gallons with the best-estimated (recommended design basis) value being about 250,000 gallons (Tables 1, 2 and 3).

We also estimated a range in the ambient groundwater flux through the P1 source area using the average groundwater gradient between wells MW-34p1, MW-36p1, and MW-37p1 (0.02) and the range of T values in these wells. Based on this calculation, the ambient flux ranged from 86,500 gallons/year to 445,600 gallons/year with a best estimated value (based on geometric mean T-value) of 183,500 gallons/year (Table 4).

The annual groundwater extraction recommended for design purposes for the FS was 250,000 gallons (Table 1). This is slightly higher than the best estimated ambient groundwater flux and accounts for additional flux due to pumping.

2.2.3 Long-Term P2 Pumping Results

As mentioned in the objectives and limitations section above, this component is considered technically infeasible and was therefore not assessed.

2.2.4 Groundwater Pumping from the Hole Results

Groundwater extraction from the Hole considers both seasonal pumping and dewatering. The seasonal extraction calculation assumes pumping from the existing extraction well (EW-1) and the dewatering calculation assumes two conditions; one using the existing well and another using four wells spaced uniformly throughout the area of saturation in the Hole (the location of the Hole is shown in Figure 1). A single transmissivity value of 700 ft^2/dy was used for the calculation. This value was based on an earlier aquifer test of EW-1 (PGG, 2002). The aquifer storage value was assumed to be 0.1 (unconfined porous medium). We set a target drawdown of 3 to 5-ft for seasonal pumping and 5-ft for dewatering (estimated saturated thickness of the Hole at EW-1). The pumping duration for seasonal extraction was assumed to be 200 days and the pumping duration for a single cycle of dewatering was assumed to be about 40 to 70 days.

These parameters were used in AQTESOLV until the maximum predicted drawdown was similar to the target drawdown. We used the no flow boundary option in AQTESOLV to simulate the boundary of the basalt surrounding groundwater in the Hole.

The results indicate an annual extraction volume ranging from about 290,000 gallons (based on 3-ft of drawdown) to 430,000 gallons (based on 5-ft of drawdown) for seasonal pumping and 390,000 gallons (based on one existing well) to 440,000 gallons (based on four wells) for dewatering (Tables 2 and 5). The final recommended design annual groundwater extraction is 290,000 gallons for seasonal pumping and 390,000 gallons for dewatering (Table 1). Although the AQTESOLV results indicate 1 well can achieve 390,000 gallons per year for dewatering, a total of 4 wells are recommended for the design basis.

The volume of water in the Hole is estimated to be about 320,000 gallons[7]. This value is based on an estimated saturation volume of 8000 cubic yards in the Hole (PGG, 2010) and a porosity of 0.2. The ambient groundwater flux through the Hole is estimated to be about 46,000 gallons/year (Table 6). Given the relatively low ambient flux, subsequent annual volumes necessary to maintain a dewatered state in the Hole may be less than the first-time volume extraction.

2.2.5 Northerly Plume Containment at Property Boundary – Roza High-T Area Results

For this scenario, we assessed capture using 2 wells which would be installed along the property boundary in the high-T area (Figure 1). We used previous estimates of sustainable pumping rates and transmissivity (PGG, 2002) and evaluated the required extraction rates to achieve capture in the high-T area.

Given the potentially much larger volume of extractable groundwater in the high-T Roza area compared to other scenarios and the effects of an adjacent low-T zone (boundary effects), we used the analytical model GFLOW and particle tracking to evaluate capture. GFLOW is a 2-D steady-state analytic element groundwater flow model that allows for heterogeneities in aquifer properties.

For the GFLOW evaluation, we considered a range of T-values for the high-T area under a range of bounded aquifer conditions. The range in T-values was based on a previous analyses of Roza wells in the high-T area (EW-2, MW-3b, MW-7b and MW-9b) from an aquifer pumping test of EW-2 (PGG, 2002). The reported range in T-values from this earlier work (Table 2 in PGG, 2022) was based on analyses of both drawdown and recovery in multiple wells. For this current evaluation we used the 25th percentile of this dataset as a minimum estimate (1,200 ft^2/dy), the 75th percentile as a maximum estimate (7,890 ft^2/dy), and the geometric mean as the best-estimate (3,074 ft^2/dy). These values

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[7] The recommended extraction volume (390,000 gallons) for dewatering the Hole (Table 1) is somewhat larger than the volume of saturation calculation (320,000 gallons). A larger volume is recommended in the design because an increased gradient in the Hole due to drawdown will likely increase the discharge rate of groundwater into the Hole and therefore a larger volume of extractable groundwater will be available

were used in a 2-D, steady-state, GFLOW simulation for the Roza high-T zone under three aquifer bounded conditions:

- Infinitely unbounded high-T aquifer
- High-T aquifer partially bounded by low-T zone
- High-T aquifer fully bounded by low-T zone

Under all three conditions we assigned a uniform groundwater gradient of 0.0007 ft/ft towards the north calculated from Roza wells in the high-T area (MW-3b, MW-7b, and MW-9b). The unbounded aquifer condition assumed the high-T Roza zone extends infinitely in all directions. The fully bounded aquifer condition assumed the high-T Roza zone (Figure 1) was fully bounded by a low-T zone (T-value of 35 ft^2/dy)[8]. The partially bounded aquifer condition is a hybrid condition and assumed a low-T boundary around all but the southern portion of the high-T zone.

The range of extraction rates resulting from the GFLOW analysis were compared to calculations of the ambient groundwater flux across the high-T boundary. We also evaluated drawdown in the adjacent low-T Roza area due to pumping in the high-T area using an analytical solution for 1-D flow with a sudden change at a boundary. The results are discussed below.

The GFLOW results indicate a large range of estimated annual extraction volumes (Table 7); about 300,000 gallons (under the fully bounded condition) to 16,000,000 gallons (under the infinitely unbounded condition and maximum T). For comparison, the ambient groundwater flux through the high-T Roza area of the property boundary is estimated to be 1,120,000 to 7,320,000 gallons per year - based on the range in T-values (Table 8). Using the results of these analyses we propose an uncertainty range of 500,000 to 8,000,000 gallons per year be considered for this scenario (Table 2) with a recommended design value of 3,500,000 gallons (Table 1). The recommended design value is based on the ambient groundwater flux through the high-T area using the geometric mean T-value (3,000,000 gallons) plus additional flux from capture of the low-T area.

As mentioned, we also evaluated capture of the surrounding low-T area from pumping in the high-T area using an analytical solution for 1-D flow with a sudden change at a boundary (Kresic, 1997):

$$\Delta H(x,t) = \Delta Ho*efc(\lambda)$$

Where

$\Delta H(x,t)$	is the change in head with time and distance from the boundary
ΔHo	is the change in head at the boundary
$efc(\lambda)$	is the complementary error function $1-erf(\lambda)$
$erf(\lambda)$	is approximated as $\sqrt{[1-e(-4\lambda^2/\pi)]}$
λ	$= x/2\sqrt{a*t}$

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[8] Value based on geometric mean of all Roza wells in both zones. Same value used in the REMChlor fate and transport simulation.

x	is the distance from the boundary
a	is the aquifer diffusivity T/S
t	is time since head change at boundary
T	is the low-T aquifer transmissivity (3 ft^2/dy)[9]
S	is the aquifer storage (0.000025)[10]

Assuming a drawdown of 5-ft at the boundary between the high-T and low-T zones (value for ΔHo in above equation) the drawdown in the low-T area 1500-ft away from this boundary after 365 days is about 4-ft. The 4-ft drawdown at this distance suggests pumping in the Roza high-T area may capture much of the Roza low-T area, depending on the hydraulic continuity between the two areas. Note that the available drawdown in the Roza aquifer is estimated to be about 20-ft, therefore the drawdown achieved at the boundary could actually be greater than 5-ft.

2.2.6 Northerly Plume Containment at Property Boundary – Roza Low-T Area Results

For this scenario, we assessed capture using a line of extraction wells which would be installed near the property boundary in the low-T area (Figure 1). We used a single T- value of 2.8 ft^2/dy based on the geometric mean of all Roza wells in the low-T area and a confined aquifer storage value of 2.5x10^{-5} (value reported in PGG, 2002).

AQTESOLV was used to predict drawdown after 365 days of pumping using 1 to 9 wells. Extraction rates were adjusted to maintain approximately 15-ft of drawdown. Because the drawdown predicted in AQTESOLV assumes a flat water table it cannot be used to assess capture when a natural gradient also exists. We therefore imported gridded drawdown results from AQTESOLV into the contouring software package SURFER v8.0 (Golden Software, Inc.) and subtracted the drawdown grid from a second grid representing a uniform groundwater gradient. The uniform groundwater gradient (0.0014 ft/ft) was calculated using groundwater elevation data from Roza monitoring wells in the target area. The resulting grid was then contoured and visually assessed to infer capture along the boundary.

The results of this assessment indicate at least 5 wells would be necessary to potentially achieve capture along the low-T boundary; however, long-term sustainable pumping rates would be less than 0.1 gpm per well (Table 9). Maintaining such low discharge rates long-term is not considered to be feasible, and this scenario is not evaluated in the FS.

The ambient groundwater flux through the low-T area of the property boundary is estimated to be 9,000 gallons per year (Table 10) – three orders of magnitude less than the ambient flux through the high-T area of the property boundary (Table 8).

2.2.7 Northerly Plume Containment Roza Aquifer Component at End-of-Plume Results

For this scenario, we assessed capture using a line of extraction wells near the end of the Roza aquifer component of the northerly plume, which is assumed to be in the low-T area based on the T-value measured in nearby well MW-44b (Figure 1). We used a single

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[9] Based on geometric mean of all Roza wells except those in the High-T zone.
[10] Based on value reported in PGG 2002.

transmissivity value of 2.8 ft^2/dy based on the geometric mean of all Roza wells in the low-T area and a confined aquifer storage value of $2.5x10^{-5}$ (value reported in PGG, 2002).

An analysis method similar to that used for the low-T Roza capture at the property boundary (Section 2.2.6) was applied to this evaluation. AQTESOLVE was used to predict drawdown after 365 days for a number of wells and extraction rates adjusted to maintain the target drawdown. Gridded drawdown results were imported into SURFER and subtracted from a uniform groundwater gradient grid. Note that the gradient near the end of the Roza northerly plume (0.018 ft/ft)[11] is greater than the low-T area near the landfill property boundary (0.0014 ft/ft). The resulting grid was contoured and visually assessed to infer capture along the boundary.

The results indicate at least 15 wells would be necessary to potentially achieve capture at the end of the Roza aquifer component of the northerly plume; however, similar to the low-T property boundary evaluation, long-term sustainable pumping rates are less than 0.1 gpm for individual wells, which is not considered feasible (Table 11).

The ambient groundwater flux at the end of the northerly plume in the Roza aquifer component is estimated to be 124,300 gallons per year (Table 12).

3.0 CONTAMINANT CALCULATIONS

The following section summarizes the calculations of source mass and source concentrations used in the REMChlor model (PGG, 2012a). The subsequent section summarizes calculations used to estimate northerly plume mass attenuation rates.

3.1 SOURCE CALCULATIONS FOR MODEL INPUT

Source area contaminant calculations were required for input to the fate and transport model developed for the northerly plume (PGG, 2012a). A REMChor fate and transport model was developed to evaluate plume response to a number of FS cleanup action scenarios. The model is based on average Roza aquifer parameters although the modeled flow path also includes short segments of the P1 and P2 zones near the source. Required source input parameters for the model are the initial source mass (Mo) and initial source concentration (Co). The source is assumed to be dominantly associated with leakage from the removed drums (Figure 1). This section provides calculations for estimating Mo and Co for the following seven volatile organic compounds (VOC) simulated using REMChlor (PGG, 2012a):

- 1,2-Dichloropropane (1,2-DCP)
- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- cis-12-Dichloroethene (cis-1,2-DCE)

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[11] Gradient at end of plume is based on groundwater elevation data from wells MW-44b, MW-48b and MW-51b.

- Vinyl Chloride (VC)
- Benzene
- Methylene Chloride

A range of values for Co and Mo (minimum, maximum, and best-estimate; Table 13) were estimated using data collected during the Remedial Investigation [12] (PGG, 2010 and 2012b). The ranges in values are based on uncertainty in parameters used to perform the source calculations. The ranges were used to conduct part of the model sensitivity analysis (PGG, 2012a). The following sections summarize our approach and results for calculation of source mass (Mo) and source concentration (Co).

3.1.1 Source Mass

The range in source mass for each simulated VOC is based on estimates of minimum, maximum, and best-estimates of VOC mass in residual LNAPL and soils in the source area (Table 14). As explained below, the range of uncertainty in the source mass is based on compounded uncertainty in parameter values such that the minimum and maximum may be too extreme. We therefore narrowed the range of values assessed in the model by using the 25th and 75th percentiles rather than the minimum and maximum source mass (Table 14). The results of these calculations show that most of the source mass is in LNAPL and not soils (Table 14). The approach and results for calculating residual LNAPL and soil source mass are described below.

3.1.1.1 LNAPL Source Mass

LNAPL source mass is based on estimates of LNAPL volume (Table 15) and the concentration of VOCs in LNAPL (Table 16).

<u>The LNAPL volume is calculated as:</u>

$\text{Vol}_{\text{LNAPL}} = (\text{Thickness}_{\text{LNAPL}}) \times (\text{Area}_{\text{LNAPL}}) \times (\text{Porosity}_{\text{P1}}) \times (\text{Residual Saturation}_{\text{LNAPL}})$

LNAPL has only been observed in the P1 source zone. Therefore the thickness of the residual LNAPL zone was estimated to range from 1-ft (seasonal fluctuation of water table in P1 source zone) to 3-ft (average thickness of the P1 source zone) with a best-estimated value of 2-ft (Table 15).

The LNAPL area is estimated to range from 5,000 ft^2 to 17,000 ft^2 with a best-estimated value of 10,000 ft^2 (Table 15). This range is based on locations (wells and borings) where LNAPL has and has not been observed in the P1 zone (Figure 1).

The P1 zone is a permeable weathered basalt interflow zone with characteristics of granular sediment. The porosity of the P1 zone was therefore estimated to range from 0.1 to 0.3 with a best-estimated value of 0.2 (Table 15).

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[12] Except for a more recent LNAPL sample collected in 2011, all analytical data used in the contaminant calculations were collected during the RI (2008 to 2010).

The LNAPL residual saturation is the fraction of P1 porosity filled with LNAPL. A recent study of LNAPL saturation was conducted at 11 British Petroleum (BP) sites with 338 samples collected at various locations throughout the full depth of LNAPL impacted soils (Adamski, 2011). The result of that study indicated most soils had relatively low LNAPL saturations with LNAPL confined mainly to macropores (Adamski, 2011). The average LNAPL saturation in the 338 samples was 6% and most samples (80%) had LNAPL saturations less than 10% (Adamski, 2011). Based on the results of the BP study we estimate the residual LNAPL saturation in the P1 zone to range from 3% to 10% of the P1 porosity with a best-estimated value of 6% (Table 15).

Using the equation above and the ranges in values of LNAPL residual saturation, LNAPL thickness, P1 source area, and P1 porosity, we estimate the LNAPL volume to range from a minimum of 112 gallons to a maximum of 11,446 gallons with a best-estimated value of 1,795 gallons (Table 15). Note that the minimum and maximum are based on compounding the range in input parameter values so that the minimum and maximum represent extreme values.

<u>The LNAPL VOC mass is calculated as:</u>

$\text{Source Mass}_{\text{LNAPL}} = (C_{\text{LNAPL}})\text{x}(\text{Vol}_{\text{LNAPL}})\text{x}(\text{Density}_{\text{LNAPL}})$

Estimated VOC concentrations in LNAPL (C_{LNAPL} in above equation) are based on an LNAPL sample collected from well MW-34p1 in September 2011[13] (Table 16). Concentrations for benzene, methylene chloride, trichloroethene, and vinyl chloride are based on ½ the laboratory reporting limits because these VOCs were not detected in the LNAPL sample.

Using the range of estimated LNAPL volumes (Table 15) in the equation above with estimated values for C_{LNAPL} and the LNAPL density (0.87 kg/L), we calculated a range of VOC mass in LNAPL (Table 16).

3.1.1.2 Soil Source Mass

Soil source mass is based on estimates of the average concentration of VOCs in the adsorbed soil phase (Table 17) and the bulk mass of residual soils (Table 18):

$\text{Source Mass}_{\text{soil}} = (C_{\text{soil}})*(\text{Bulk Mass}_{\text{soil}})*(0.000001 \text{ kg/mg})$

Where

$\text{Source Mass}_{\text{soil}}$	is the source VOC mass in soils (kg)
C_{soil}	is the concentration of VOC sorbed on soil (mg/kg)
$\text{Bulk Mass}_{\text{soil}}$	is the bulk mass of residual soils in the source area (kg)

<u>Adsorbed Soil Phase Concentration</u>

Residual soil samples were collected in the drum excavation following drum removal (PGG, 2010). Many of the samples were collected from areas where LNAPL was ob-

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[13] The LNAPL sample was analyzed for VOCs by EPA Method 8260C by Friedman and Bruya, Inc. in Seattle, WA.

served, so the results may be biased high and not representative of adsorbed soil phase concentrations. We therefore estimated adsorbed phase soil concentrations (C_{soil}) in the source area using equilibrium partitioning calculations from groundwater (C_{water}) to soil (Table 17):

$$C_{Soil} = Kd*C_{Water}$$

The partitioning coefficient (Kd) was calculated using default values for the octanol-water partition coefficient (Koc) and organic carbon fraction of aquifer solids (foc) in Ecology's Cleanup Levels and Risk Calculations (CLARC) database:

$$Kd = Koc*foc$$

Adsorption of contaminants in basalt aquifers is typically considered to be relatively insignificant due to the absence of organic material (Sorenson et al, 1998) and we expect using the MTCA default value for the organic carbon fraction (0.1%) may overestimate the soil adsorbed phase. However, we have not found definitive references on adsorption specifically for the Wanapum basalt and have therefore used the MTCA values for calculating C_{soil}.

Adsorbed phase soil concentrations were calculated for soils in the drum area and soils in the P1 source area (Table 17). Groundwater concentrations (C_{water}) in the drum area were based on average concentrations observed in interstitial liquids and seeps within the excavation (PGG, 2010) and groundwater concentrations in the P1 source area were based on average concentrations observed in MW-34p1[14] (Table 17).

Bulk Mass of Residual Soils

The bulk mass of residual soil was calculated as:

$$\text{Bulk Mass}_{soil} = (\text{Thickness}_{soil})*(\text{Area}_{soil})*(\text{Density}_{soil})$$

The bulk residual soil mass (i.e. those soils with adsorbed phase VOCs) was calculated separately for residual soils in the drum area and soils in the P1 source area. We estimated a range of bulk residual soil mass in both areas based on uncertainty in the thickness and area of residual soils (Table 18). The bulk density of soil in both locations was assumed to be 1.5 kg/L (MTCA default value).

Within the drum area, residual soil thickness was estimated to range from 0.05 to 0.5-ft with a best estimated value of 0.1-ft (Table 18). These relatively low values for thickness take into account that most residual soils in the drum excavation were removed to the top of bedrock; however some residual soils could not be excavated (PGG, 2010). The residual soil area in the drum area is estimated to be 7,000 ft^2 (based on survey of drum excavation).

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[14] Groundwater concentrations measured in the interstitial liquids, seeps, and MW-34p1 may include an oil-phase and therefore may overestimate the dissolved phase concentration.

Within the P1 source area, the residual soil thickness and area were estimated to range from 1 to 3-ft and 5,000 to 17,000 ft^2 respectively (Table 18). These values are based on the same ranges for residual LNAPL in the P1 source area (Table 15).

Source VOC Mass in Soils

Using the calculations of adsorbed phase soil concentrations (Table 17) and the range of estimated bulk residual soil mass (Table 18); we estimated a best-estimate, minimum and maximum value for the soil source mass for each VOC (Table 19).

3.1.2 Source Concentration

The source concentration in the P1 source area (Co) used in the REMChlor model (PGG, 2012a) represents the dissolved phase contaminant concentration in contact with the source mass (Mo).

Since groundwater concentrations measured in the P1 source area (MW-34p1) may overestimate the dissolved phase concentration due to the presence of LNAPL, we used northerly plume mass flux calculations to estimate Co. This approach assumes the mass flux of IHS in the source area is the same as[15] the mass flux some distance downgradient of the source and that minimum IHS degradation occurs between the source area and nearby plume. This approach tends to underestimate Co, because some degradation of IHS does occur. Note that the high degradation rate of total VOCs (Section 3.2.1) is dominated by non-IHS compounds, which were not simulated by REMChlor.

The mass flux (J) is calculated as:

$J\ (ug/dy) = Q*C$

Where

Q is the volumetric groundwater flux (L/dy)
C is the dissolved phase VOC concentration (ug/L)

And

$J_{plume} = J_{source}$

To use this approach we estimated mass flux in both the high-T and low-T zones of the Roza aquifer downgradient of the P1 source area near the northern boundary of the landfill property (Figure 1). VOC groundwater concentrations in nearby Roza wells were contoured and spatially averaged along the boundary in both the low-T and high-T zones. The spatially averaged groundwater concentrations were used as a single representative value in each zone (Table 20). The volumetric groundwater flux (Q) in the high-T and low-T zones is based on the average groundwater gradient (i), geometric mean of hydraulic conductivity (K), and cross-sectional area (A) in each zone (Table 20):

$Q_{High\text{-}T} = K*I*A = (307.5\ ft/dy)*(0.00068)*(500\text{-}ft)*(10\text{-}ft) = 1046\ ft^3/dy$

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[15] Long-term monitoring at the site indicates groundwater concentrations are fairly stable (PGG, 2010).

$Q_{Low\text{-}T}$ = K*I*A = (0.28 ft/dy)*(0.00143)*(840-ft)*(10-ft) = 3.4 ft^3/dy

The total plume mass flux (J) is the sum of the high-T and low-T plume mass flux (Table 20). Note that most of the plume mass flux is through the high-T area due to the much higher volumetric flux in this area.

The source area concentration (Co) is then calculated as:

Co = $J_{plume}/Q_{SourceArea}$

Where

$Q_{SourceArea}$ = K*I*A

And

K*I = User specified Simulated Darcy Velocity = 5.1 m/yr (PGG, 2012a)

Using the above equation, we estimated a range in Co values (Table 20) based on a minimum, maximum, and best-estimated value for the cross-section P1 source area (Figure 1).

The results of this analysis show that the values of Co (best estimates) for most of the simulated VOCs are in the same order of magnitude as the average concentrations measured in MW-34p1 (Table 20), suggesting the method of using mass flux results in a reasonable estimate of the source concentration. The best-estimate value of Co for vinyl chloride (1303 ug/L); however, is almost twice as high as concentrations measured in MW-34p1 (maximum concentration was 750 ug/L; Table 20). This observation, along with documented reductive dechlorination of chloro-ethenes, suggests additional vinyl chloride is being generated through degradation processes along this portion of the plume path. A value of 1303 ug/L would therefore likely over-estimate the Co term in REMChlor. Therefore, the maximum observed value in MW-34p1 (750 ug/L) was used as the best-estimate Co value for vinyl chloride in the model (PGG, 2012a). All other Co values were based on the Mass Flux estimated values in Table 20.

3.2 ESTIMATED NORTHERLY PLUME MASS ATTENUATION

Groundwater geochemical screening at the site indicates there is strong to adequate evidence for anaerobic degradation occurring in the P1 and P2 source area as well as the Roza component of the northerly plume (PGG, 2010 Section 9.4). In support of the FS, we have used two independent methods to estimate mass removal as a result of natural attenuation within the portion of the northerly plume between the P1 source area and the Roza aquifer high-T property boundary (Figure 1).

The first method is based on estimates of mass flux (Section 3.2.1). With the mass flux method, the total organic COC mass flux is calculated for the P1 source area and the Roza aquifer high-T property boundary. The annual total organic COC mass removal is then estimated as the difference in mass flux between the two locations. Because this method uses flux along two transects of the plume that are assumed to encompass the entire plume width, attenuation with this method should only be due to the removal of mass and not due to dispersion, although there are other assumptions associated with this method (see below).

The second method uses a first order bulk attenuation rate and then calculates the mass attenuation over a one year period (Section 3.2.2). This method incorporates all attenuation processes (dispersion, degradation, sorption, and volatilization) and therefore estimating mass reduction requires adjustment for the effects of dispersion (see below).

The combined results of the two methods indicate total annual organic COC mass removal ranging from 130 kg/yr (lower bound) to 260 kg/yr (upper bound) with a recommended value of 200 kg/yr to be used in the FS (the recommended value is based on the mass flux method). Both methods include significant uncertainty due to dependence on groundwater velocity, which may vary by an order of magnitude due to the heterogeneity of basalt aquifers.

Both methods estimate bulk attenuation rates for organic COCs. As described in the RI (PGG, 2010), mass attenuation along this portion of the plume is dominated by the removal of TEX and ketone compounds (over 90%), which are not IHS.

3.2.1 Mass Attenuation Estimate - Mass Flux Method

The mass flux method estimates the mass loss due to degradation processes as the difference in mass passing through two points along a flow path. The total organic COC mass flux was estimated for the P1 source area and high-T Roza aquifer at the landfill property boundary (Figure 1). Key assumptions included in this method are:

- Plume equilibrium (steady state)
- Steady uniform flow
- Mass flux through the Roza high-T boundary represents all of the mass flux originating from the P1 source area.

As described in Section 3.1.2, the mass flux (J) is:

J (ug/yr) = Q*C

Where

Q is the volumetric groundwater flux (L/yr)
C is the dissolved phase VOC concentration (ug/L)

The attenuation of mass between these two locations is then calculated as:

Mass attenuation (ug/yr) = $J_{p1} - J_{Roza}$

Mass fluxes at the P1 source area and Roza high-T landfill property boundary are estimated at 206 kg/yr and 2 kg/yr, respectively. The difference between these mass fluxes indicates approximately 200 kg/yr mass loss due to degradation in the groundwater plume between the P1 source area and the landfill property boundary. Most (97%) of the change in mass is from the attenuation of TEX and ketone compounds (Table 21)[16].

3.2.2 Mass Attenuation Estimate - First Order Bulk Attenuation Rate Method

This method estimates the annual total organic COC attenuation using a first order bulk attenuation rate constant (k). The method for estimating the k-value is described below. The subsequent section describes how the k-value is used to estimate the annual total organic COC mass attenuation.

3.2.2.1 First Order Bulk Attenuation Rate Calculation

A first order bulk attenuation rate constant (k) for total organic COCs was estimated for the portion of the northerly plume which extends from the P1 source area to the high-T Roza aquifer at the landfill property boundary (Figure 1). For this calculation we used the method of plotting concentration versus distance developed by Newell and others for estimating first order bulk k-values (Newell et al, 2002). With this method, the bulk k-value represents attenuation of dissolved constituents due to *all* attenuation processes including dispersion, degradation, sorption, and volatilization.

First order attenuation is defined by the following equation:

$Ct = Co*e^{-kt}$

Where Co = the initial dissolved phase concentration (ug/L)

Ct = the concentration at some time (t) in the future (ug/L)

t = time (years)

k = the bulk attenuation rate constant (yr^{-1})

The method for estimating the bulk k-value involves the following steps (Newell et al, 2002):

1. Plot natural log of concentration versus distance
2. Fit a linear regression line to the data
3. Multiply the absolute value of the slope of the line by the contaminant velocity (seepage velocity divided by the retardation factor R) to derive k

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[16] A mass flux approach was also used to estimate the initial source mass concentration (Co) for select VOCs simulated in REMChlor (IHS, see Section 3.1.2). Application of the mass flux method to estimate Co assumed no degradation between the P1 source area and the Roza high-T property boundary. Although some degradation is occurring between the two locations, as mentioned in section 3.1.2, the Co values for all IHS(with the exception of vinyl chloride) were the same order of magnitude as the average concentrations measured in MW-31p1, suggesting the mass flux method provided reasonable estimate of Co values. Also note that the mass flux approach used in the development of Co (Table 20) used contoured groundwater concentrations for IHS whereas the calculations presented in Table 21 used the average organic COC concentrations measured in wells MW-3b and MW-7b. The two methods produce similar but slightly different values for groundwater concentrations along the high-T boundary.

Average organic COC concentrations measured in wells at three locations within the northerly plume between the P1 source area and the Roza aquifer high-T boundary were used for concentration-distance plots (step 1) (Figures 1 and 2, and Table 22):

- P1 Source Area (MW-34p1); at the source[17].
- Roza Aquifer midway between Source Area and Roza High-T property boundary (MW-42b); approximately 120 meters from the source.
- Roza Aquifer at the High-T property boundary (MW-3b and MW-9b); approximately 240 meters from the source.

Figure 2 shows a plot of the natural log of total organic COC concentration versus distance. A linear regression line (step 2) fitted to the data indicates a slope of -0.031.

The average contaminant velocity within this area of the northerly plume is estimated to be 100 m/yr[18]. This estimate is based on seepage velocities calculated for the P1 source area and the Roza aquifer high-T area as follows:

Seepage velocity = K*i/n

Where K = the hydraulic conductivity (ft/dy)

i = groundwater gradient

n = effective porosity (assumed to be 0.2)

P1 Source Area Seepage velocity = (7 ft/dy)*(0.02)/(0.2) = 0.7 ft/dy = 78 m/yr

Roza High-T Aquifer Seepage Velocity = (307 ft/dy)*(0.0007)/(0.2) = 1.1 ft/dy = 120 m/yr

For this calculation we assume a single average seepage velocity of 100 m/yr for the northerly plume between these two areas. Given the low organic content expected in basalt aquifers, we assume a retardation factor (R) of 1. Thus, the contaminant velocity (v_c) is also 100 m/yr.

Finally, the bulk attenuation rate (k) is calculated as (step 3):

k = absolute value of slope*vc = 0.031*100 = 3.1 yr^{-1}

A k-value of 3.1 corresponds to a half-life of 0.22 years:

$t_{½}$ = ln(0.5)/(-k) = ln(0.5)/(-3.1) = 0.22 years

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[17] Although the concentrations measured in MW-34p1 may over-estimate the dissolved phase concentration of some VOCs (due to the presence of LNAPL), the average concentrations measured in this well were deemed a reasonable approximation for the calculation.

[18] This value for contaminant velocity (100 m/yr) is higher than the value used in the REMChlor fate and transport model (25.5 m/yr). The value used in the REMChlor model is based on the average K-value measured in all Roza wells, including those located in the low-T area (PGG, 2012a).

This half-life suggests rapid degradation of COCs in the dissolved phase plume.

3.2.2.2 Annual Mass Attenuation Calculation

This section describes the method used to estimate the annual mass attenuation rate for total organic COCs using the rate constant discussed above. Two concentration profiles were developed assuming a unit cross section area (flow tube) using the first-order decay rate equation[19] (Section 3.2.2.1): a steady state concentration profile under current conditions; and the same steady state curve translated forward one-year (100 m) assuming no degradation. The area between the two curves represents the mass loss due to attenuation over the one year period (Figure 3). The mass loss along the flow tube is then multiplied by the cross-sectional area of the source area (45 m^2) to estimate the mass attenuation within the dissolved-phase plume[20].

This method yields a mass attenuation rate of 257 kg/year for organic COCs as an upper bound of the expected degradation rate (mass removal). This result is an upper bound because the method does not distinguish between change in concentration due to degradation and change in concentration due other processes (namely dispersion). The mass loss due to degradation decreases to approximately 130 kg/yr if dilution due to dispersion is assumed to account for 50% of the change in concentration; simulations of chloride attenuation suggest an approximately 50% decrease in concentration due to dispersion 240 meters downgradient of the landfill in the northerly plume (Figure 3 in PGG, 2012a).

4.0 REFERENCES

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[19] $C_t = C_o*e^{-kt}$.

[20] Plume cross sectional area (45 m^2), is consistent with the cross-sectional area used in the mass flux calculation at the P1 source area.

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Table 1. Recommended Groundwater Extraction Rates, Volumes, and Wells for FS Design

	Cleanup Action Scenarios Evaluated							
Parameter	Pump MW-34p1 and MW-36p1 (Seasonal Extraction)[1]	Long Term Exraction P1[2]	Long-Term Extraction P2	Pump EW-1 [Hole] (seasonal Extraction)[3]	Dewater Hole[4]	Roza High T (Property Boundary Capture)[5]	Roza Low T (Property Boundary Capture)[6]	Roza Low T (EOP Capture)[7]
Total Groundwater Discharge Rate (gpm)	0.4	0.5	Not Feasible (see text)	1	4	6	Not Feasible (see text)	
Pumping Duration (days)[8]	200	Infinite		200	70	Infinite		
Extraction Volume (gallons/year)	115,000	250,000		290,000	390,000	3,500,000		
Wells Required	2 Existing	5		1 Existing	4	2		
Well Spacing (ft)	90	50		NA	NA	160		

Notes

1. Based on seasonal pumping of P1 source zone for 200 days with 2-ft of drawdown in well. Sustainable pumping rates in MW-34p1 and MW-36p1 are estimated to be 0.3 and 0.1 gpm respectively

2. Based on long term sustainable pumping of P1 source zone (2-ft drawdown in well).

3. Based on seasonal pumping of the Hole for 200 days with 3 to 5-ft of drawdown in well (Existing well).

4. Although the calculations indicate 1 well can achieve the dewatering extraction volume (Table 5), a total of 4 wells are recommended for the design basis.

Long term sustainable pumping rates may be less depending on the recharge rate to Hole.

Ambient Darcy Flux in Hole = 46,000 gallons/year (minimum sustainable pumping rate). Given the Darcy flux, it may not be possible to dewater the Hole more than once per year.

5. Based on hydraulic containment by capture along High T boundary near landfill property boundary.

6. Based on hydraulic containment by capture along Low T boundary near landfill property boundary. Well discharge rate not likely feasible (very low).

7. Based on hydraulic containment by capture along Low T end of plume (EOP) boundary near Whitson well. Well discharge rate not likely feasible (very low).

8. Pumping duration (days) is per year.

Table 2. Summary of Groundwater Extraction Rates, Volumes, and Wells for Cleanup Action Scenarios

	Cleanup Action Scenarios Evaluated							
Parameter	Pump MW-34p1 and MW-36p1 (Seasonal Extraction)[1]	Long Term Exraction P1[2]	Long-Term Extraction P2	Pump EW-1 [Hole] (seasonal Extraction)[3]	Dewater Hole[4]	Roza High T (Property Boundary Capture)[5]	Roza Low T (Property Boundary Capture)	Roza Low T (EOP Capture)
Range of Total Groundwater Discharge Rate (gpm)	NA	0.15 to 1	Not Feasible (see text)	1 to 1.5	4 to 8	1 to 15	Not Feasible (see text)	Not Feasible (see text)
Recommended Design Total Groundwater Discharge Rate (gpm)	0.4	0.5		1	4	6		
Range of Groundwater Discharge Per well (gpm)	NA	0.1 to 0.4		1	2 to 4	0.5 to 7.5		
Pumping Duration (days)[6]	200	Infinite		200	40 to 70	Infinite		
Range Total Extracton Volume (gallons/year)	NA	75,000 - 550,000		290,000 - 430,000	390,000 - 440,000	500,000 - 8,000,000		
Recommended Design Total Water Extraction Volume (gallons/year)	115,000	250,000		290,000	390,000	3,500,000		
Range of Wells Required	2 Existing	2 to 10		1	1 to 4	2		
Well Spacing (ft)	90	30 to 90		NA	50 to 100	160		
Estimated VOC IHS Mass Removal[7]								
Avg Concentration of 1,2-DCP observed in component area (ug/L)	480	480		1.5	1.5	10		
Estimated 1,2-DCP Mass Removal (kg/yr)	0.2	0.5		0.002	0.002	0.1		
Avg Concentration of Benzene observed in component area (ug/L)	140	140		2.5	2.5	2		
Estimated Benzene Mass Removal (kg/yr)	0.1	0.1		0.003	0.004	0.03		
Avg Concentration of Methylene Chloride observed in component area (ug/L)	400	400		1	1	2		
Estimated Methylene Chloride Mass Removal (kg/yr)	0.2	0.4		0.001	0.001	0.03		
Avg Concentration of PCE observed in component area (ug/L)	13	13		0.05	0.05	0.5		
Estimated PCE Mass Removal (kg/yr)	0.01	0.01		0.0001	0.0001	0.01		
Avg Concentration of TCE observed in component area (ug/L)	11	11		1	1	1		
Estimated TCE Mass Removal (kg/yr)	0.005	0.01		0.001	0.001	0.01		
Avg Concentration of cis-1,2-DCE observed in component area (ug/L)	2440	2440		30	30	25		
Estimated cis-1,2-DCE Mass Removal (kg/yr)	1.1	2.3		0.03	0.04	0.3		
Avg Concentration of Vinyl Chloride observed in component area (ug/L)	355	355		75	75	25		
Estimated Vinyl Chloride Mass Removal (kg/yr)	0.2	0.3		0.1	0.1	0.3		
Avg Concentration of 1,1,1-TCA observed in component area (ug/L)	2,220	2,220		0.00	0.00	0.00		
Estimated 1,1,1-TCA Mass Removal (kg/yr)	1.0	2.1		0.00	0.00	0.00		
Avg Concentration of 1,1-DCE observed in component area (ug/L)	30	30		0.40	0.40	1.00		
Estimated 1,1-DCE Mass Removal (kg/yr)	0.01	0.03		0.0004	0.0006	0.01		
Avg Concentration of 1,2-DCA observed in component area (ug/L)	525	525		0.60	0.60	2.00		
Estimated 1,2-DCA Mass Removal (kg/yr)	0.2	0.5		0.001	0.001	0.03		
Avg Concentration of Chloroform observed in component area (ug/L)	34	34		0.00	0.00	0.00		
Estimated Chloroform Mass Removal (kg/yr)	0.01	0.03		0.00	0.00	0.00		
Avg Concentration of Toluene observed in component area (ug/L)	62,000	62,000		0.20	0.20	0.00		
Estimated Toluene Mass Removal (kg/yr)	27	59		0.0002	0.0003	0.00		
TOTAL MASS REMOVAL OF IHS VOCs (kg/yr)	30	65		0.12	0.17	0.91		
Estimated Total organic COC Mass Removal[9]								
Avg Concentration of Total organic COCs in component area (ug/L)	289,000	289,000		150	150	165		
TOTAL ORGANIC COC REMOVAL (kg/yr)	126	273		0.2	0.2	2.2		

Notes

1. Based on seasonal pumping of P1 source zone for 200 days with 2-ft of drawdown in well (maintain 2-ft head above pump). Sustainable pumping rates in MW-34p1 and MW-36p1 are estimated to be 0.3 and 0.1 gpm respectivel
2. Based on long term sustainable pumping of P1 source zone and potential mobilization of LNAPL towards wells (2-ft drawdown in well is assumed for current evaluation)
3. Based on seasonal pumping of the Hole for 200 days with 3 to 5-ft of drawdown in well (Existing well)
4. Based on dewatering Hole over 40 to 70 day period. Long term sustainable pumpig rates may be less depending on recharge rate to Hole. Ambient Darcy Flux through Hole = 46,000 gallons/year (min. sustainable pumping rate).
   Given Darcy flux, not likely possible to dewater Hole more than once per year
5. Based on hydraulic containment by capture along High T boundary near landfill property boundary
6. The pumping duration (days) is per year.
7. Mass Removal (kg) is calculated as the recommended design extracted groundwater (vol.) multiplied by the average groundwater concentration (mass/vol).
   Average concentrations based on data collected during the RI. P1 data from MW-34p1. Roza data from MW-3b and MW-7b. Hole data from 2008 extraction season (PGG, 2010
   Note that extracted groundwater may be diluted with cleaner groundwater over time as cleaner portions of the aquifer contribute to extracted groundwater. Thus the annual mass removal may be less than calculated above
9. Total VOC mass removal in the P1 source zone would be dominated by BTEX and Ketones

Table 3. P1 Source Area Long Term Groundwater Extraction - Aqtesolv Results

Parameters	Aqtesolve Input/Output	Geometric Mean T[7]			Max T				Min T		
		2 Wells	5 Wells	7 Wells	2 Wells	5 Wells	7 Wells	9 Wells	2 Wells	5 Wells	7 Wells
Target Area[1]	Input	160x80-ft	160x80-ft	160x80-ft	160x80-ft	160x80-ft	160x80-ft	160x80-ft	160x80-ft	160x80-ft	160x80-ft
Discharge/well (gpm)	Input	0.15	0.10	0.07	0.40	0.2	0.15	0.12	0.07	0.05	0.04
Transmissivity (ft^2/dy)[2]	Input	21	21	21	51	51	51	51	10	10	10
Target DD in well (ft)	Input	2	2	2	2	2	2	2	2	2	2
Predicted DD in Well (ft)[3]	Output	2.1	2.4	2.0	2.5	2.2	2.2	2.2	1.9	2.2	2.3
Predicted DD in Source Area (ft)[4]	Output	1-2.1	1.6-2.4	1.6 to 2.2	1.3-2.5	1.6 to 2.2	1.7-2.2	1.7-2.2	0.8 to 1.9	1.4-2.2	1.6 to 2.3
Extraction Duration (days)	Input	5 yr	5 yr	5 yr	5 yr	5 yr	5 yr	5 yr	5 yr	5 yr	5 yr
Number of Wells	Input	2	5	7	2	5	7	9	2	5	7
Well Spacing (ft)[5]	Input	Existing 90-ft	80x50	50x50	Existing 90-ft	80x50	50x50	30x50	Existing 90-ft	80x50	50x50
Total Discharge Rate (gpm)	Input	0.3	0.5	0.49	0.8	1	1.05	1.08	0.14	0.25	0.28
Extracted Water Volume (gallons/yr)	Input	157,680	262,800	257,544	420,480	525,600	551,880	567,648	73,584	131,400	147,168
Aqtesolve Solution	Input	Neuman	Neuman	Neuman	Neuman	Neuman	Neuman	Neuman	Neuman	Neuman	Neuman
S or Sy[6]	Input	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Aquifer Sat Thickness (ft)	Input	3	3	3	3	3	3	3	3	3	3

Notes

1. Based on an approximation of estimated LNAPL Extent in P1 Source Area (Figure 1)
2. Based on geometric mean, min, and max of MW-34p1, MW-36p1, and MW-37p1
3. Drawdown in well as predicted by Aqtesolv
4. Range of Drawdown predicted by Aqtesolv
5. Wells spaced uniformly in target area
6. Storage or Specific Yield (depending on if confined or unconfined)
7. Geometric mean calculated with MS Excel formula

Table 4. Estimated Ambient Groundwater Flux through P1 Source Area

Parameter Values	Geomean K	Min K	High K
K (ft/dy)	7	3.3	17
I (ft/ft)	0.02	0.02	0.02
A (160-ft long x 3-ft thickness)	480	480	480
Q (ft^3/dy) = KIA	67	32	163
Q (gpm)	0.35	0.16	0.85
Q (gallons/yr)	183,494	86,504	445,628

I = groundwater gradient based on average gradient measured in wells MW-34p1, MW-36p1, and MW-37p1

A = Estimated cross-sectional Source Area

Q = Groundwater Flux

Table 5. Groundwater Extraction from the Hole - Aqtesolv Results

Parameter	Aqtesolve Input/Output	Seasonal Pumping (EW-1)	Seasonal Pumping (EW-1)	Dewater (EW-1)	Dewater (4- wells)
Target Area[1]	250x250-ft	250x250-ft	250x250-ft	250x250-ft	250x250-ft
Discharge/well (gpm)[1]	Input	1.0	1.5	4.0	2.0
Transmissivity (ft^2/dy)[2]	Input	700	700	700	700
Target DD in well (ft)	Input	3	5	5	5
Predicted DD in Well (ft)	Output	3	5	5	5
Predicted DD in Hole (ft)	Output	3 to 3.3	4.5 to 5	4 to 5	4.5 to 5
Extraction Duration (days)	Input	200	200	67	38
Number of Wells	Input	1	1	1	4
Well Spacing (ft)	Input	NA	NA	NA	NA
Total Discharge Rate (gpm)	Input	1	1.5	4	8
Extraction Water Volume/Duration (gallons)	Input	288,000	432,000	385,920	437,760
Aqtesolve Solution[3]	Input	Neuman/NF Boundary	Neuman/NF Boundary	Neuman/NF Boundary	Neuman/NF Boundary
S or Sy	Input	0.1	0.1	0.1	0.1
Aquifer Sat Thickness (ft)	Input	5	5	5	5

Notes

1. Based on approximate area of saturation in Hole (1.5 acres)

1. PGG (2002) Extraction Report states a sustainable pumping rate rate of 1 to 2 gpm for EW-1

2. Transmissivity from 2002 Extraction Report (PGG, 2002)

3. A no flow boundary was used in Aqtesolve to simulate the boundary of the basalt surrounding groundwater in the Hole.

Table 6. Estimated Ambient Groundwater Flux through the Hole

Parameter	Value
K (ft/dy)	15
I (ft/ft)	0.0009
Area (250-ft long x 5-ft thickness)	1250
Q (ft^3/dy) = KIA	17
Q (gpm)	0.09
Q (gallons/year)	46,078

I = groundwater gradient based on average gradient measured in wells EW-1, W-9 and W-12

A = Estimated cross-sectional Source Area

Q = Groundwater Flux

Table 7. Northerly Plume Capture at Property Boundary (Roza High-T zone) - GFLOW Results

	Unbounded High T Zone			Partly Bounded High T Zone			Fully Bounded High T Zone		
Parameters	Geomean T	Max T	Min T	Geomean T	Max T	Min T	Geomean T	Max T	Min T
Length of High T Boundary	500	500	500	500	500	500	500	500	500
Discharge/well (gpm)	5	15	2.5	2.5	5	1	0.25	0.25	0.25
Transmissivity (ft^2/dy)[1]	3074	7890	1200	3074	7890	1200	3074	7890	1200
Extraction Duration (days)	Indefinite	Indefinite	Indefinite	Indefinite	Indefinite	Indefinite	Indefinite	Indefinite	Indefinite
Number of Wells	2	2	2	2	2	2	2	2	2
Well Spacing (ft)	166	166	166	166	166	166	166	166	166
Total Discharge Rate (gpm)	10	30	5	5	10	2	0.5	0.5	0.5
Extracted Water Volume (gallons/yr)[2]	5,256,000	15,768,000	2,628,000	2,628,000	5,256,000	1,051,200	262,800	262,800	262,800
Aquifer Sat Thickness (ft)	10	10	10	10	10	10	10	10	10

Notes

1. Based on previous aquifer pumping tests in high-T area (PGG, 2002).

2. GFLOW calculated extraction rates are those necessary to achieve capture (see text).

Table 8. Estimated Ambient Groundwater Flux through Roza High-T Area of Property Boundary

Parameter Values	Geomean K	Low K	High K
K (ft/dy)	307	120	789
I (ft/ft)	0.00068	0.00068	0.00068
A (500-ft long x 10-ft thickness)	5000	5000	5000
Q (ft^3/dy) = KIA	1,045	409	2,681
Q (gpm)	5	2	14
Q (gallons/yr)	2,854,300	1,116,900	7,321,900

I = groundwater gradient based on average gradient measured in wells MW-3b, MW-7b and MW-9b

A = Estimated cross-sectional High-T Area

Q = Groundwater Flux

Table 9. Northerly Plume Capture at Property Boundary (Roza Low-T zone) - ATESOLV Results

Parameters	Aqtesolve Input/Output	5 Wells (Geomean T)	9 Wells (Geomean T)
Length of Boundary	Input	840	840
Discharge/well (gpm)[1]	Input	0.065	0.040
Transmissivity (ft^2/dy)[2]	Input	2.8	2.8
Target DD in well (ft)	Input	15.0	15.0
Predicted DD in Well (ft)[3]	Output	16	18
Predicted DD along boundary (ft)[4]	Output	11 to 16	13 to 18
Extraction Duration (days)	Input	365	365
Number of Wells	Input	5	9
Well Spacing (ft)[5]	Input	200	100
Total Discharge Rate (gpm)	Input	0.33	0.36
Extraction Water Volume/Duration (gallons)	Input	170,820	189,216
Aqtesolve Solution	Input	Theis Confined	Theis Confined
S or Sy[6]	Input	2.50E-05	2.50E-05
Aquifer Sat Thickness (ft)	Input	10	10

Notes

1. Maintaining such low rates long term would be very difficult and is below our recommended threshold for pumping.
2. Based on geometric mean of all Roza wells in low-T area.
3. Drawdown in well as predicted by Aqtesolv
4. Range of Drawdown predicted by Aqtesolv
5. Wells spaced uniformly in target area
6. Storage or Specific Yield (depending on if confined or unconfined)

Table 10. Estimated Ambient Groundwater Flux through Roza Low-T Area of Property Boundary

Parameter Values	Value
K (ft/dy)	0.28
I (ft/ft)	0.0014
A (840-ft long x 10-ft thickness)	8400
Q (ft^3/dy) = KIA	3
Q (gpm)	0.017
Q (gallons/yr)	8,991

K-value based on geometric mean in low-T area

I = groundwater gradient based on average gradient measured in wells MW-3b, MW-7b and MW-9b

A = Estimated cross-sectional High-T Area

Q = Groundwater Flux

Table 11. Northerly Plume Capture at Roza End of Plume (Low-T zone) - ATESOLV Results

Parameters	Aqtesolve Input/Output	15 Wells (Geomean T)	30 wells (Geomean T)
Length of Boundary	Input	900	900
Discharge/well (gpm)[1]	Input	0.025	0.015
Transmissivity (ft^2/dy)[2]	Input	2.8	2.8
Target DD in well (ft)	Input	15.0	15.0
Predicted DD in Well (ft)[3]	Output	17	20
Predicted DD along boundary (ft)[4]	Output	14 to 17	17 to 20
Extraction Duration (days)	Input	365	365
Number of Wells	Input	15	30
Well Spacing (ft)[5]	Input	60	30
Total Discharge Rate (gpm)	Input	0.38	0.45
Extraction Water Volume/Duration (gallons)	Input	197,100	236,520
Aqtesolve Solution	Input	Theis Confined	Theis Confined
S or Sy[6]	Input	2.50E-05	2.50E-05
Aquifer Sat Thickness (ft)	Input	10	10

Notes

1. Maintaining such low rates long term would be very difficult and is below our recommended threshold for pumping
2. Based on geometric mean of all Roza wells in low-T area.
3. Drawdown in well as predicted by Aqtesolv
4. Range of Drawdown predicted by Aqtesolv
5. Wells spaced uniformly in target area
6. Storage or Specific Yield (depending on if confined or unconfined

Table 12. Estimated Ambient Groundwater Flux through Roza Low-T Area near Roza End of Plume

Parameter Values	Value
K (ft/dy)	0.28
I (ft/ft)	0.018
A (900-ft long x 10-ft thickness)	9000
Q (ft^3/dy) = KIA	46
Q (gpm)	0.24
Q (gallons/yr)	124,301

K-value based on geometric mean in low-T area

I = groundwater gradient based on average gradient measured in wells MW-44b, MW-48b, and MW-51b (Figure 1)

A = Estimated cross-sectional High-T Area

Q = Groundwater Flux

Table 13. Initial Source Mass and Source Concentrations for Model Input

VOC[1]	Initial Source Mass (Mo) Best-Esimate (kg)	Max (kg)	Min (kg)	Initial Source Concentration (Co) Best-Esimate (ug/L)	Max (ug/L)	Min (ug/L)
Tetrachloroethene (PCE)	0.66	2.4	0.3	24	35	21
1,2-Dichloropropane	0.96	3.5	0.5	597	869	516
cis-1,2-Dichloroethene	3.50	12.8	1.9	1409	2050	1219
Benzene	0.30	1.1	0.2	113	164	98
Methylene chloride	1.51	5.5	0.8	154	224	133
Trichloroethene (TCE)	0.31	1.1	0.2	65	94	56
Vinyl chloride	0.30	1.1	0.2	750	1091	649

1. Seven volatile organic compounds simulated in REMChlor fate and transport model (PGG, 2012)

Table 14. Estimated Source Mass, Mo

VOC[1]	Best Estimate[2]			Minimum Estimate[2]			Maximum Estimate[2]			Alt. Min[3]	Alt. Max[3]
	LNAPL (kg)	Soil (Kg)	Total (kg)	LNAPL (kg)	Soil (Kg)	Total (kg)	LNAPL (kg)	Soil (Kg)	Total (kg)	25th Perc.	75th Perc.
Tetrachloroethene (PCE)	0.65	0.0075	0.66	0.04	0.00	0.04	4.14	0.03	4.17	0.4	2.4
1,2-Dichloropropane	0.94	0.0198	0.96	0.06	0.01	0.06	6.02	0.05	6.07	0.5	3.5
cis-1,2-Dichloroethene	3.42	0.0758	3.50	0.21	0.02	0.23	21.83	0.20	22.03	1.9	12.8
Benzene	0.30	0.0082	0.30	0.02	0.00	0.02	1.88	0.02	1.90	0.2	1.1
Methylene chloride	1.48	0.0315	1.51	0.09	0.01	0.11	9.41	0.15	9.56	0.8	5.5
Trichloroethene (TCE)	0.30	0.0133	0.31	0.02	0.01	0.02	1.88	0.06	1.95	0.2	1.1
Vinyl chloride	0.30	0.0059	0.30	0.02	0.00	0.02	1.88	0.02	1.90	0.2	1.1

Notes

1. Seven volatile organic compounds simulated in REMChlor fate and transport model (PGG, 2012)
2. Best estimated, minimum, and maximum based on range of parameters values used in source mass calculations (see text)
3. Alternative minimum and maximum based on 25th and 75th percentile of best-estimate, min, and max total.
   As explained in text, the min and max represent compounded uncertainty and extreme end members, therefore range narrowed with 25ht and 75th percentiles

Table 15. Estimated Residual LNAPL Volume in P1 Source Area

Range	LNAPL Residual Saturation (%)[1]	LNAPL Thickness (ft)[2]	P1 Source Area (ft^2)[3]	P1 Zone Porosity[4]	Estimated LNAPL Volume (gallons)[5]
Best-Estimate	6%	2	10,000	0.2	1,795
Minimum	3%	1	5,000	0.1	112
Maximum	10%	3	17,000	0.3	11,446

Notes

1. Residual LNAPL as a fraction of P1 porosity.
   Range based on analysis from 338 samples collected from 11 British Petroleum LNAPL sites (Adamski, 2011)
2. Range in thickness based on seasonal fluctuation of P1 water levels and the average thickness of P1 zone (see text)
3. P1 source area based on observations of LNAPL (see text)
4. Porosity range based on observation that the weathered P1 zone is similar to unconsolidated sediments
5. LNAPL Volume = (Thickness)*(Area)*(Porosity)*(Residual Saturation)*(7.481 gallons/ft^3)

Table 16. Estimated Residual LNAPL Mass in P1 Source Area

VOC	LNAPL Density (kg/L)	VOC Concentration in LNAPL (mg/kg)[1], (C_{LNAPL})	Best Estimate		Minimum Estimate		Maximum Estimate	
			LNAPL Volume (gallons), (Vol_{LNAPL})	VOC Mass in LNAPL (kg)[2], (Source $Mass_{LNAPL}$)	LNAPL Volume (gallons), (Vol_{LNAPL})	VOC Mass in LNAPL (kg)[2], (Source $Mass_{LNAPL}$)	LNAPL Volume (gallons), (Vol_{LNAPL})	VOC Mass in LNAPL (kg)[2], (Source $Mass_{LNAPL}$)
Tetrachloroethene (PCE)	0.87	110	1,795	0.65	112	0.04	11,446	4.14
1,2-Dichloropropane	0.87	160	1,795	0.94	112	0.06	11,446	6.02
cis-1,2-Dichloroethene	0.87	580	1,795	3.42	112	0.21	11,446	21.83
Benzene	0.87	50	1,795	0.30	112	0.02	11,446	1.88
Methylene chloride	0.87	250	1,795	1.48	112	0.09	11,446	9.41
Trichloroethene (TCE)	0.87	50	1,795	0.30	112	0.02	11,446	1.88
Vinyl chloride	0.87	50	1,795	0.30	112	0.02	11,446	1.88

Notes

1. Based on results from LNAPL sample collected in September 2011.
   Results for Benzene, Methylene Chloride, TCE and Vinyl Chloride based on 1/2 the detection limit (VOC was not detected in sample)
2. VOC Mass = (LNAPL Concentration)*(LNAPL Density)*(LNAPL Volume)*(3.78 L/gallon)*(0.000001 kg/mg)

Table 17. Estimated Adsorbed Phase Soil Concentrations (based on equilbrium partitioning)

	MTCA Kd Calculation[1]			Estimated Groundwater Concentration in Contact with Residual Soils[2] , (C_{gw})		Estimated Adsorbed Phase Soil Concentration[3] , (C_{soil})	
VOC	Koc (L/kg)	foc	Kd (L/kg)	Former Drum Excavation (ug/L)	P1 Area (ug/L)	Former Drum Excavation (mg/kg)	P1 Area (mg/kg)
Tetrachloroethene (PCE)	265	0.001	0.27	564	13	0.149	0.004
1,2-Dichloropropane	47	0.001	0.05	429	482	0.020	0.023
cis-1,2-Dichloroethene	35.5	0.001	0.04	2,086	2,441	0.074	0.087
Benzene	62	0.001	0.06	419	141	0.026	0.009
Methylene chloride	10	0.001	0.01	94,541	398	0.945	0.004
Trichloroethene (TCE)	94	0.001	0.09	4,435	11	0.417	0.001
Vinyl chloride	18.6	0.001	0.02	448	355	0.008	0.007

Notes

1. Partitioning coefficient (Kd) calculated with default values for octanol-water partition coefficient (Koc) and organic carbon fraction of aquier solids (foc) in Ecology's Cleanup Levels and Risk Calculations (CLARC) database.
   Kd = Koc*foc
2. Groundwater concentrations in former drum excavation based on average concentrations in interstital liquids and seeps collected during drum and soil removal (PGG, 2010)
   Groundwater concentrations in P1 Area bawsed on average concentrations measured in well MW-34p1 (Figure 1)
3. Adsorbed Phase Soil Concentration = (Kd)*(Groundwater Concentration)*(0.001 mg/ug)

Table 18. Estimated Bulk Mass of Residual Soil

Range	Soil Thickness (ft)[1] Former Drum Excavation	Soil Thickness (ft)[1] P1 Area	Soil Area (ft^2)[2] Former Drum Excavation	Soil Area (ft^2)[2] P1 Area	Soil Density (kg/L)[3]	Estimated Bulk Mass of Residual Soil (kg)[4] Former Drum Excavation	Estimated Bulk Mass of Residual Soil (kg)[4] P1 Area
Best-Estimate	0.1	2	7000	10,000	1.5	29,733	849,504
Minimum	0.05	1	7000	5,000	1.5	14,866	212,376
Maximum	0.5	3	7000	17,000	1.5	148,663	2,166,235

Notes

1. Residual soils in former drum excavation were removed to the extent possible. The residual soil thickness is thus estimated to be less than 0.5-ft.
   Thickness of residual soils in P1 area estimated to have the same range as estimated LNAPL thickness (see Table 15).
2. Area of residual soils in former drum area based on estimated footprint of excavated contaminated soils.
3. Bulk density based on MTCA default value.
4. Mass of Soil = (Soil Thickness)*(Soil Area)*(Soil Density)*(28.32 ft^3/L)

Table 19. Estimated Adsorbed Phase Contaminant Mass in Residual Soils

A. Best-Estimated Adsorbed Phase Contamiant Mass[1]

	Soils in Former Drums			Soils in P1 Area			Total Soils
VOC	Soil Concentration (mg/kg)	Mass of Soil (kg)	Contaminant Mass (kg)	Soil Concentration (mg/kg)	Mass of Soil (kg)	Contaminant Mass (kg)	Total VOC Mass in Soils (Kg)
Tetrachloroethene (PCE)	0.149	29,733	0.004	0.004	849,504	0.003	0.007
1,2-Dichloropropane	0.020	29,733	0.001	0.023	849,504	0.019	0.020
cis-1,2-Dichloroethene	0.074	29,733	0.002	0.087	849,504	0.074	0.076
Benzene	0.026	29,733	0.001	0.009	849,504	0.007	0.008
Methylene chloride	0.945	29,733	0.028	0.004	849,504	0.003	0.031
Trichloroethene (TCE)	0.417	29,733	0.012	0.001	849,504	0.001	0.013
Vinyl chloride	0.008	29,733	0.000	0.007	849,504	0.006	0.006

B. Minimum-Estimated Adsorbed Phase Contamiant Mass[1]

	Soils in Former Drums			Soils in P1 Area			Total Soils
VOC	Soil Concentration (mg/kg)	Mass of Soil (kg)	Contaminant Mass (kg)	Soil Concentration (mg/kg)	Mass of Soil (kg)	Contaminant Mass (kg)	Total VOC Mass in Soils (Kg)
Tetrachloroethene (PCE)	0.149	14,866	0.002	0.004	212,376	0.001	0.003
1,2-Dichloropropane	0.020	14,866	0.000	0.023	212,376	0.005	0.005
cis-1,2-Dichloroethene	0.074	14,866	0.001	0.087	212,376	0.018	0.020
Benzene	0.026	14,866	0.000	0.009	212,376	0.002	0.002
Methylene chloride	0.945	14,866	0.014	0.004	212,376	0.001	0.015
Trichloroethene (TCE)	0.417	14,866	0.006	0.001	212,376	0.000	0.006
Vinyl chloride	0.008	14,866	0.000	0.007	212,376	0.001	0.002

C. Maximum-Estimated Adsorbed Phase Contamiant Mass[1]

	Soils in Former Drums			Soils in P1 Area			Total Soils
VOC	Soil Concentration (mg/kg)	Mass of Soil (kg)	Contaminant Mass (kg)	Soil Concentration (mg/kg)	Mass of Soil (kg)	Contaminant Mass (kg)	Total VOC Mass in Soils (Kg)
Tetrachloroethene (PCE)	0.149	148,663	0.022	0.004	2,166,235	0.008	0.030
1,2-Dichloropropane	0.020	148,663	0.003	0.023	2,166,235	0.049	0.052
cis-1,2-Dichloroethene	0.074	148,663	0.011	0.087	2,166,235	0.188	0.199
Benzene	0.026	148,663	0.004	0.009	2,166,235	0.019	0.023
Methylene chloride	0.945	148,663	0.141	0.004	2,166,235	0.009	0.149
Trichloroethene (TCE)	0.417	148,663	0.062	0.001	2,166,235	0.002	0.064
Vinyl chloride	0.008	148,663	0.001	0.007	2,166,235	0.014	0.016

Notes

1. Contaminant Mass = (Soil Concentration)*(Mass of Soil)*(0.000001 kg/mg)

Table 20. Estimated VOC Mass Flux and Source Concentration, Co

																		Measured Concentrations in P1 Source Area			
	Low-T Area			High-T Area			Total Area	Darcy V[4]	Best Estimate[5]			Maximum Estimate[5]			Minimum Estimate[5]			MW-34p1			B-22-p1
VOC	GW. Conc.[1] (ug/L) (C)	GW Flux[2] (ft^3/dy) (Q)	VOC Mass Flux[3] (ug/dy) (J)	GW. Conc.[1] (ug/L) (C)	GW Flux[2] (ft^3/dy) (Q)	VOC Mass Flux[3] (ug/dy) (J)	Total Plume Mass Flux (ug/dy) (J)	(m/yr)	X-Sec Source Area (ft^2) (A)	GW Flux through Source Area[6] (ft^3/dy) (Q)	Source Conc.[7] (ug/L) (Co)	X-Sec Source Area (ft^2) (A)	GW Flux through Source Area[6] (ft^3/dy) (Q)	Source Conc.[7] (ug/L) (Co)	X-Sec Source Area (ft^2) (A)	GW Flux through Source Area[6] (ft^3/dy) (Q)	Source Conc.[7] (ug/L) (Co)	Avg Conc. (ug/L)	Max Conc (ug/L)	Min Conc. (ug/L)	P1 sample collected during drilling of MW-30b / Equivalent to MW-36p1 (ug/L)
Tetrachloroethene (PCE)	2.49	3.4	237	0.5	1046	14,679	14,916	5.10	480	22.00	24	330	15.12	35	555	25.44	21	13	21	5.8	700
1,2-Dichloropropane	40.37	3.4	3841	12.4	1046	368,154	371,995	5.10	480	22.00	597	330	15.12	869	555	25.44	516	482	810	160	360
cis-1,2-Dichloroethene	21.90	3.4	2084	29.6	1046	875,995	878,079	5.10	480	22.00	1,409	330	15.12	2,050	555	25.44	1,219	2441	5200	690	3000
Benzene	17.60	3.4	1675	2.3	1046	68,660	70,335	5.10	480	22.00	113	330	15.12	164	555	25.44	98	141	250	32	220
Methylene chloride	13.00	3.4	1237	3.2	1046	94,702	95,939	5.10	480	22.00	154	330	15.12	224	555	25.44	133	398	780	16	2800
Trichloroethene (TCE)	1.31	3.4	125	1.4	1046	40,130	40,255	5.10	480	22.00	65	330	15.12	94	555	25.44	56	11	20	1.9	580
Vinyl chloride[8]	7.50	3.4	714	27.4	1046	810,886	811,600	5.10	480	22.00	1,303	330	15.12	1,895	555	25.44	1,127	355	750	54	550

Notes

1. Based on estimated average groundwater concentration at property boundary using contoured groundwater data

2. Groundwater volumetric flux based on average gradient, geometric mean of hydraulic conductivity and cross-sectional area in Low-T and High-T area near landfill property boundary

3. $J = C*Q*(28.32 L/ft^3)$

4. Simualted Darcy velocity (see PGG, 2012)

5. Min, max, and best-estimate values of Co based on min, max, and best-estimate of source cross-section (x-sec) area (Figure 1)

6. Groundwater flux through source area = (Darcy Velocity)*(X-Sec Area)*(3.28 ft/m)*(1 yr/365 dy)

7. Source Concentration, Co = (Total Mass Flux)/(X-Sec Area)*(1 ft^3/28.32 L)

8. The predicted source concentration for vinyl chloride based on Mass Flux (1303 ug/L) is almost twice as high as concentrations measured in the P1 source area (750 ug/L max)
This is likely due to additional vinyl chloride being generated through degradation processes along the plume flow path.
The shaded values of Co for vinyl chloride are therefore likely to be over-estimated. We therefore used the maximum concentration measured in the P1 source area (750 ug/L) as our best estimate of Co for vinyl chloride in the REMChlor model (PGG, 2012a)
Since the maximum and minimum Co values for the other VOCs are 1.45 and 0.86 times the best-estimate value respectively; the maximum and minimum Co values for vinyl chloride are estimated to be 1091 and 649 ug/L respectively.

Table 21. Total Organic COC Mass Flux Change Calculation - Northerly Plume (P1 source area to Roza high-T property boundary)

			P1 Source (MASS FLUX)				High T Roza Property Boundary (MASS FLUX)						MASS FLUX CHANGE
Organic Chemical of Concern (COC)	Units	Group	MW-34p1 Average (ug/L)	Horizontal Darcy Velocity[1] (m/yr)	Approx. Cross Section Area[2] (m^2)	Mass Flux based on Avg of MW-34p1 (g/yr)	MW-3b	MW-7b	Roza Average of Wells (ug/L)	Horizontal Darcy Velocity[3] (m/yr)	Appox. Cross-Section Area[4] (m^2)	Mass Flux (g/yr)	P1 - Roza Mass Flux (g/yr)
1,2-Dichloropropane	ug/L	12-DCP	482.00	16.00	44.62	344.08	10.22	9.07	9.65	24	464.75	107.59	236.49
Benzene	ug/L	BTEX	141.00	16.00	44.62	100.65	2.78	1.66	2.22	24	464.75	24.79	75.86
Ethylbenzene	ug/L	BTEX	4,614.29	16.00	44.62	3,293.96	0.20	0.10	0.15	24	464.75	1.67	3292.28
o-Xylene	ug/L	BTEX	3,900.00	16.00	44.62	2,784.06	0.26	0.23	0.25	24	464.75	2.75	2781.31
Toluene	ug/L	BTEX	61,714.29	16.00	44.62	44,055.41	0.10	0.10	0.10	24	464.75	1.12	44054.29
Xylene Isomers, M+P	ug/L	BTEX	10,585.71	16.00	44.62	7,556.73	0.20	0.20	0.20	24	464.75	2.23	7554.50
1,1,1-Trichloroethane	ug/l	Ethane	2,217.14	16.00	44.62	1,582.73	0.10	0.10	0.10	24	464.75	1.12	1581.62
1,1,2-Trichloroethane	ug/L	Ethane	33.00	16.00	44.62	23.56	0.10	0.10	0.10	24	464.75	1.12	22.44
1,1-Dichloroethane	ug/L	Ethane	2,728.57	16.00	44.62	1,947.82	10.49	17.00	13.75	24	464.75	153.32	1794.50
1,2-Dichloroethane (EDC)	ug/L	Ethane	526.00	16.00	44.62	375.49	1.45	2.07	1.76	24	464.75	19.65	355.84
Chloroethane	ug/L	Ethane	73.00	16.00	44.62	52.11	57.27	75.30	66.29	24	464.75	739.35	-687.24
1,1-Dichloroethene	ug/L	Ethenes	29.50	16.00	44.62	21.06	0.71	0.82	0.77	24	464.75	8.57	12.49
cis-1,2-Dichloroethene	ug/L	Ethenes	2,441.43	16.00	44.62	1,742.84	34.64	19.09	26.86	24	464.75	299.64	1443.20
Tetrachloroethene (PCE)	ug/L	Ethenes	13.40	16.00	44.62	9.57	0.17	0.34	0.26	24	464.75	2.85	6.71
Trichloroethene (TCE)	ug/L	Ethenes	10.95	16.00	44.62	7.82	1.33	0.92	1.13	24	464.75	12.59	-4.77
Vinyl Chloride	ug/L	Ethenes	354.67	16.00	44.62	253.18	30.58	16.92	23.75	24	464.75	264.91	-11.73
2-Butanone	ug/L	Ketone	39,366.67	16.00	44.62	28,102.32	1.25	1.25	1.25	24	464.75	13.94	28088.38
2-Hexanone	ug/L	Ketone	585.00	16.00	44.62	417.61	1.25	1.25	1.25	24	464.75	13.94	403.67
4-Methyl-2-Pentanone (MIBK)	ug/L	Ketone	21,500.00	16.00	44.62	15,348.01	1.25	1.25	1.25	24	464.75	13.94	15334.06
Acetone	ug/L	Ketone	136,000.00	16.00	44.62	97,085.07	8.05	4.27	6.16	24	464.75	68.69	97016.38
Methylene Chloride	ug/l	MC	398.00	16.00	44.62	284.12	1.95	2.88	2.41	24	464.75	26.92	257.19
1,2,4-Trimethylbenzene	ug/L	TMB	665.00	16.00	44.62	474.72	0.10	0.10	0.10	24	464.75	1.12	473.60
1,3,5-Trimethylbenzene	ug/L	TMB	253.33	16.00	44.62	180.84	0.10	0.10	0.10	24	464.75	1.12	179.73
1,3-Dichlorobenzene	ug/L	Other	5.65	16.00	44.62	4.03	0.30	0.23	0.27	24	464.75	2.97	1.06
4-Isopropyltoluene	ug/L	Other	0.50	16.00	44.62	0.36	0.10	0.10	0.10	24	464.75	1.12	-0.76
Bromobenzene	ug/L	Other	7.30	16.00	44.62	5.21	0.28	0.50	0.39	24	464.75	4.37	0.84
Chloroform	ug/L	Other	34.00	16.00	44.62	24.27	0.10	0.10	0.10	24	464.75	1.12	23.16
Chloromethane	ug/L	Other	0.50	16.00	44.62	0.36	0.10	0.10	0.10	24	464.75	1.12	-0.76
Naphthalene	ug/L	Other	200.00	16.00	44.62	142.77	0.60	0.25	0.43	24	464.75	4.74	138.03
n-Butylbenzene	ug/L	Other	8.30	16.00	44.62	5.93	0.10	0.10	0.10	24	464.75	1.12	4.81
sec-Butylbenzene	ug/L	Other	6.60	16.00	44.62	4.71	0.20	0.10	0.15	24	464.75	1.67	3.04
Bis(2-ethylhexyl) Phthalate	ug/L	SVOC	22.00	16.00	44.62	15.70	0.50	2.40	1.45	24	464.75	16.17	-0.47
2-Methylphenol	ug/L	SVOC	NS	16.00	44.62	NS	0.50	0.50	0.50	24	464.75	5.58	NS in P1
4-Methylphenol	ug/L	SVOC	NS	16.00	44.62	NS	0.50	0.50	0.50	24	464.75	5.58	NS in P1
SUM ORGANIC COC MASS FLUX (g/yr)						206,247						1,828	204,430
SUM ORGANIC COC MASS FLUX (kg/yr)						206						2	204
Percentage of change assoicated with TEX and Ketones													97%

Notes

1. P1 horizontal velocity based on geometric mean hydraulic conductivity (7 ft/dy) and groundwater gradient (0.02) associated with wells MW-34p1, MW-36p1, and MW-37p1.
2. Plume cross sectional area based on estimate of P1 source area: 160-ft by 3-ft
3. Roza high-T velocity based on geometric mean hydraulic conductivity (307 ft/dy) and groundwater gradient (0.0007) associated with wells MW-3b, MW-7b, and MW-9b
4. Plume cross sectional area based on estimate of high-T property boundary area: 500-ft by 10-ft

Shaded values uses 1/2 DL as the Concentration

NS = not sampled

Table 22. Concentration Data used for Bulk Attenuation Rate Calcualtion

VOC Chemical of Concern (COC)	Units	Group	MW-34p1 Average	MW-42b Average	Roza High T Average
1,2-Dichloropropane	ug/L	12-DCP	482.00	21.75	9.65
Benzene	ug/L	BTEX	141.00	1.60	2.22
Ethylbenzene	ug/L	BTEX	4,614.29	0.45	0.20
o-Xylene	ug/L	BTEX	3,900.00	0.50	0.25
Toluene	ug/L	BTEX	61,714.29	0.10	0.10
Xylene Isomers, M+P	ug/L	BTEX	10,585.71	0.50	0.20
1,1,1-Trichloroethane	ug/l	Ethane	2,217.14	0.10	0.10
1,1,2-Trichloroethane	ug/L	Ethane	33.00	0.10	0.10
1,1-Dichloroethane	ug/L	Ethane	2,728.57	43.00	13.75
1,2-Dichloroethane (EDC)	ug/L	Ethane	526.00	5.18	1.76
Chloroethane	ug/L	Ethane	73.00	260.00	66.29
1,1-Dichloroethene	ug/L	Ethenes	29.50	3.55	0.77
cis-1,2-Dichloroethene	ug/L	Ethenes	2,441.43	32.50	26.86
Tetrachloroethene (PCE)	ug/L	Ethenes	13.40	3.23	0.26
Trichloroethene (TCE)	ug/L	Ethenes	10.95	1.70	1.13
Vinyl Chloride	ug/L	Ethenes	354.67	7.75	23.75
2-Butanone	ug/L	Ketone	39,366.67	2.50	1.25
2-Hexanone	ug/L	Ketone	585.00	2.50	1.25
4-Methyl-2-Pentanone (MIBK)	ug/L	Ketone	21,500.00	2.50	1.25
Acetone	ug/L	Ketone	136,000.00	7.20	6.16
Methylene Chloride	ug/l	MC	398.00	5.98	2.41
1,2,4-Trimethylbenzene	ug/L	TMB	665.00	0.20	0.10
1,3,5-Trimethylbenzene	ug/L	TMB	253.33	0.10	0.10
1,3-Dichlorobenzene	ug/L	Other	5.65	0.40	0.27
4-Isopropyltoluene	ug/L	Other	0.50	0.10	0.10
Bromobenzene	ug/L	Other	7.30	0.45	0.39
Chloroform	ug/L	Other	34.00	0.10	0.10
Chloromethane	ug/L	Other	0.50	0.25	0.10
Naphthalene	ug/L	Other	200.00	0.25	0.60
n-Butylbenzene	ug/L	Other	8.30	0.10	0.10
sec-Butylbenzene	ug/L	Other	6.60	0.25	0.20
Bis(2-ethylhexyl) Phthalate	ug/L	SVOC	22.00	0.50	2.40
2-Methylphenol	ug/L	SVOC	NS	1.00	0.50
4-Methylphenol	ug/L	SVOC	NS	1.00	0.50
TOTAL	ug/L		288,918	407	165
TOTAL (natural log)			12.6	6.0	5.1

Notes
Shaded values represent non-detections and values are set to 1/2 lab detection limit
NS = not sampled
ug/L = micrograms per liter
Average concentration data based on data collected during the RI (PGG, 2010 and 2012b)
Roza High-T average based data from wells MW-3b and MW-7b

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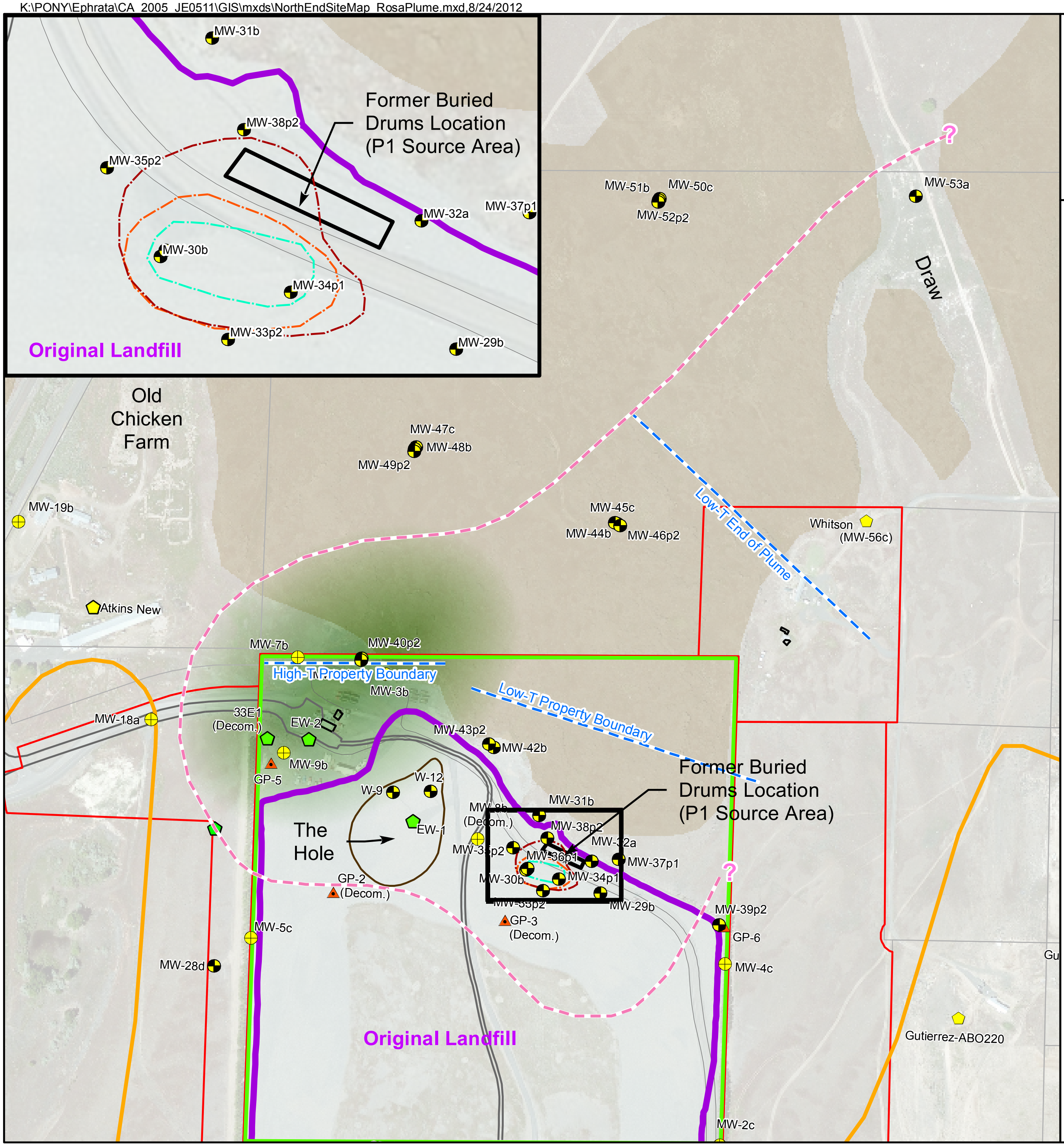


Figure 1

Ephrata Landfill North End Site Map

Ephrata Landfill
RI/FS

⊕ Quarterly Monitoring Well (MW)

● Remedial Investigation Monitoring Well (MW)
Locations A-G (Phase 2 RI Wells)

▲ Gas Probe (GP)

⬟ Other Wells

⬟ Sampled Off-site Wells

⬠ Other Off-site Wells

— Outwash Water Table / Top of Basalt Contact

▨ Basalt Outcrops

☐ Extent of Refuse

☐ Permitted Landfill Property Boundary

☐ County Owned Parcels

Approximate Extent of Groundwter Contamination
(VOCs' Above RI Screening Levels)

- - - Northerly Plume - Roza Aquifer

▨ Approximate Area of High-Transmissivity in Roza

- - - Evaluated Roza Capture Boundaries

Approximate P1 Source Area

☐ Max

☐ Best Estimate

☐ Min

0 Feet 500

N

Figure 2

Total Organic COC Concentration vs. Distance - Northerly Plume

(Beteween Source Area and Roza Aquifer High-T Area at Property Boundary)

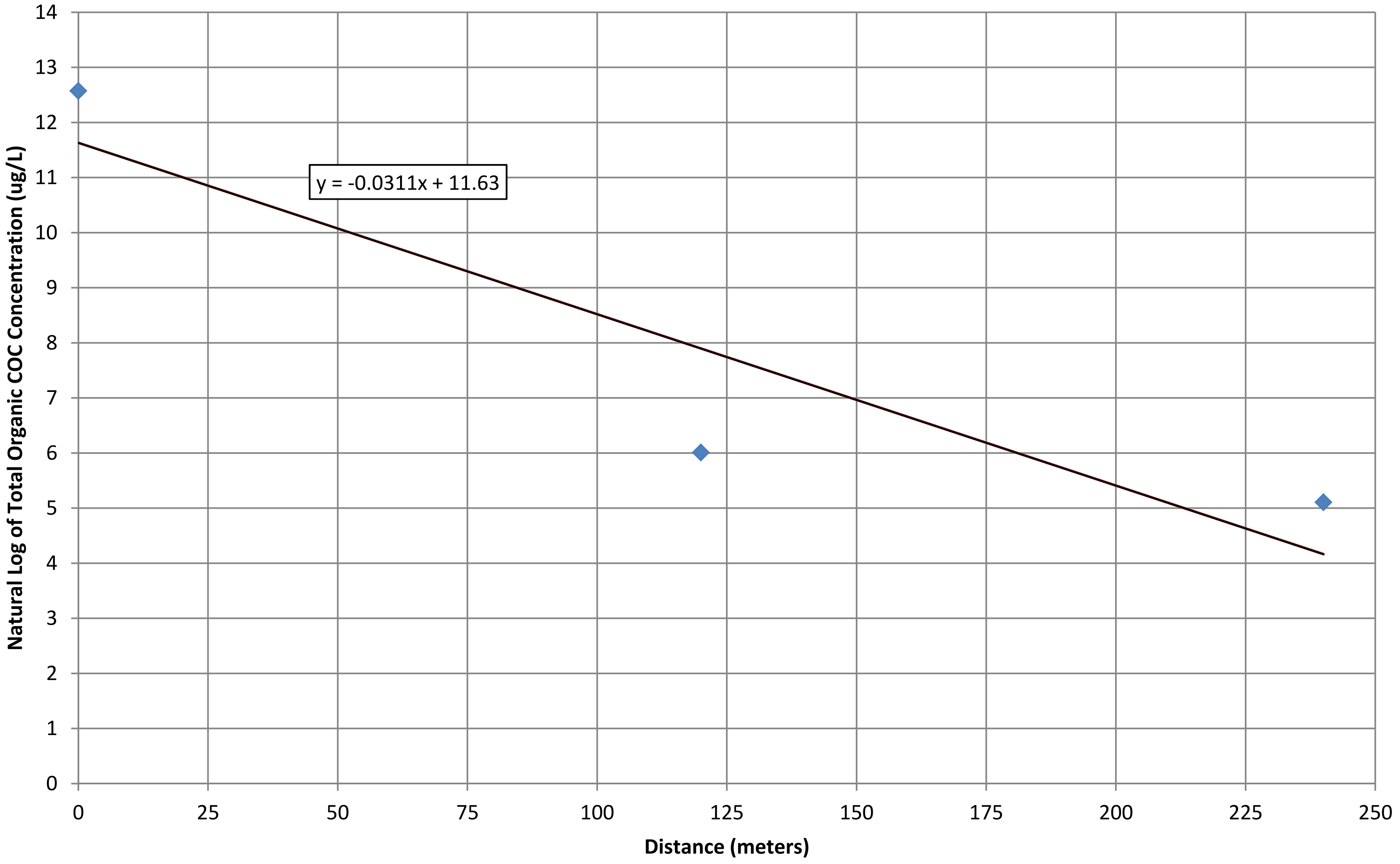
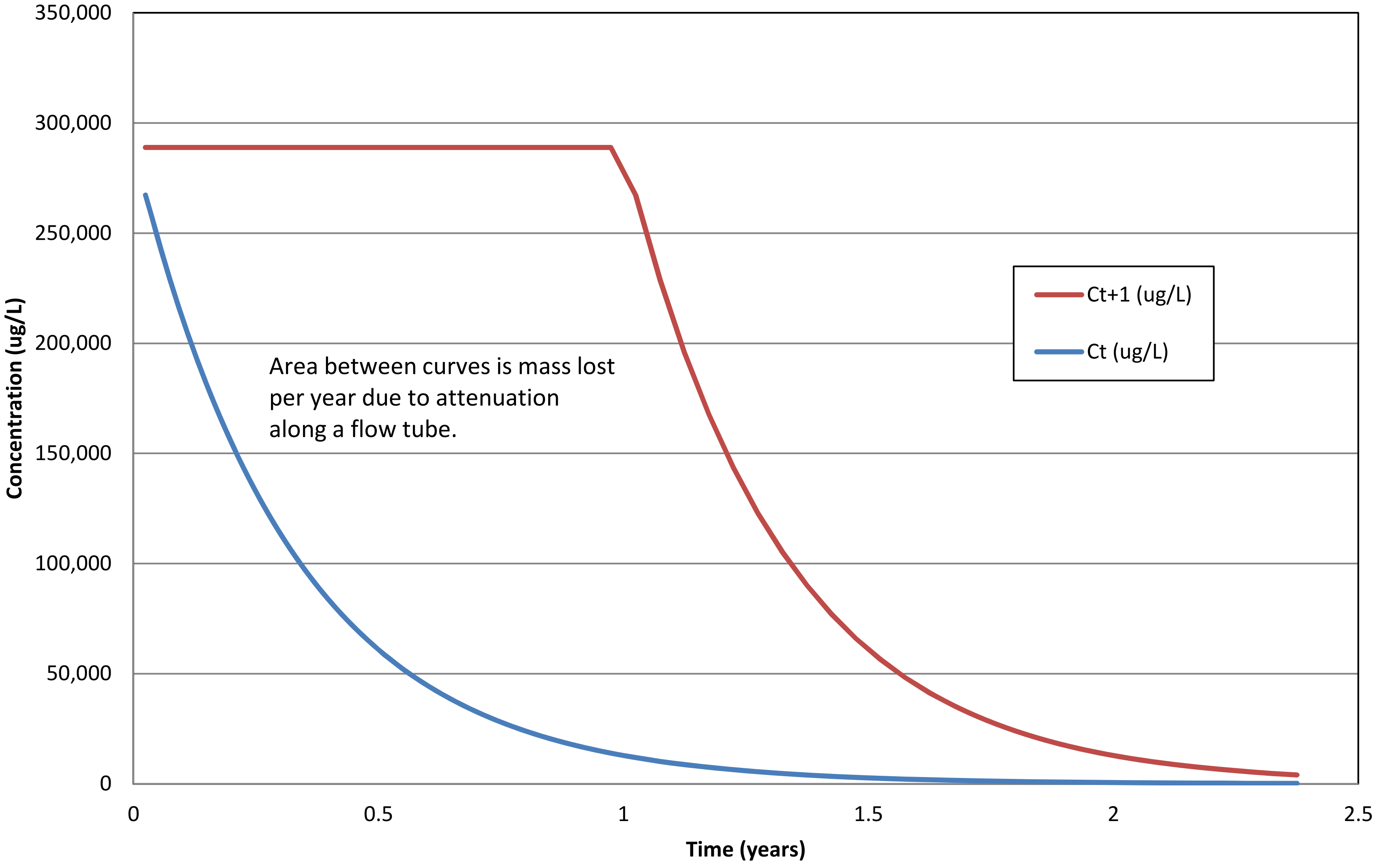


Figure 3

Annual Bulk Attenuation Rate Calculation

(Calculated concentration vs. time at current condition (t) and time step one year in future (t+1) with no attenuation)



Area between curves is mass lost per year due to attenuation along a flow tube.

APPENDIX C

Summary of Data Used for Identification of Indicator Hazardous Substances and Development of Cleanup Levels

APPENDIX C

Summary of Data and Screening Values Used for Identification of Indicator Hazardous Substances and Development of Cleanup Levels

This appendix describes the data used for identifying indicator hazardous substances (IHSs) and developing cleanup levels (CULs) for complete, major exposure pathways discussed in Section 4 of the Feasibility Study (FS).

CONTAMINANT DATA

The contaminant data used for this evaluation reflect current Site conditions, including the new scale and maintenance shop and completed and ongoing interim actions (FS Section 1.4, Interim Remedial Actions). Only groundwater and soils data were collected during the RI; no outdoor or indoor air samples were collected.

Plume Component Groundwater Data

RI groundwater samples collected from 2008 through June 2010 were analyzed for contaminants of concern (COCs), and these data were used to identify plume component and source area groundwater IHSs and develop CULs. RI data obtained from July 2010 to through September 2010 have since been evaluated by PGG and are not sufficiently different from data through June 2010 to warrant new calculations (PGG 2012). 2-Methylphenol and 4-methylphenol are the only exceptions, since these two COCs were detected in groundwater samples collected from two source area wells (MW-35p2 and MW-38p2) in September 2010 after having not been detected in groundwater samples collected from source area wells in 2008.

For the northerly plume components, data from the following monitoring wells were used:

- Roza aquifer component – MW-44b
- Whitson well component – Whitson well
- Interflow aquifer component – Abrams, Pashkovsky-ACX157, Pashkovsky-ABX965, and Perez
- Saturated alluvium component – MW-53a

For the landfill plume components, data from the following monitoring wells were used:

- Outwash aquifer component – MW-14a and MW-6a
- Frenchman Springs aquifer component – MW-28d

Contaminated shallow groundwater below the landfill could be a source for COCs to volatilize, migrate through the vadose (unsaturated) zone, and accumulate in the indoor air of the new scale and maintenance shop. Data from monitoring wells MW-1a and MW-26a were used to characterize risk for this location (FS Figure 2). These wells are completed in the uppermost aquifer, are the closest monitoring points to the new facilities, and represent groundwater below the buildings.

Statistics for the groundwater data are included Tables C-1 through C-8.

Source Area Groundwater Data

In addition to evaluating the plume components described above, source area groundwater contamination was also characterized for FS development using the collective data from 29 monitoring wells from multiple aquifers and locations:

- The P1 and P2 zones, the Hole, and the Roza aquifer at the north end of the original landfill

- The Interflow aquifer along the west, east, and south boundaries of the original landfill[1]
- The Outwash aquifer at the south end of the landfill

The 29 wells used to characterize source area groundwater are EW-1, EW-2, MW-1a, MW-2c, MW-3b, MW-5c, MW-6c, MW-7b, MW-9b, MW-10a, MW-11a, MW-16d, MW-22c, MW-23a, MW-24a, MW-25a, MW-29b, MW-30b, MW-31b, MW-32a, MW-33p2, MW-35p2, MW-37p1, MW-38p2, MW-39p2, MW-40p2, MW-41a, MW-42b, and MW-43p2. Statistics for the source area groundwater data are included in Table C-9.

North End Soils Data

During Phase 1 RI work performed in 2007 and 2009, soil samples were collected from test pits and a borehole located in the soil overlying known groundwater contamination in the old scale and maintenance shop area. Samples were analyzed for the original COCs identified in the RI Work Plan (PGG and Parametrix 2006). Statistics for the soil data used to calculate potential human health risk and whether north end soils could contribute to groundwater contamination are included in Table C-10.

GROUNDWATER RISK-BASED SCREENING VALUES

Washington State Department of Ecology's (Ecology's) Cleanup Levels and Risk Calculation (CLARC) Database was used to obtain risk-based screening values and other standards (i.e., maximum contaminant levels [MCLs]) for screening groundwater COCs to identify IHS and develop CULs for complete and major groundwater and indoor air exposure pathways. This section describes what risk-based screening values were used for the different the exposure pathways.

The CLARC Database was extensively updated in April 2011 to reflect current toxicity information. According to the CLARC web site, "*Toxicity values were updated consistent with the hierarchy of information specified in the MTCA rule.*" MTCA Method B standard formula values (SFVs) for several groundwater COCs and exposure pathways were affected by the update (increased, decreased, added, or dropped), and these changes also slightly affected the RI report and the list of COCs (PGG 2012).

Where MTCA Method B SFVs for COCs were dropped from the CLARC Database, MTCA's hierarchy in WAC 173-340-708 (7) and (8)) were first checked directly for applicable toxicity values: Integrated Risk Information System (IRIS), Health Effects Assessment Summary Tables (HEAST), and National Center for Environmental Assessment (NCEA) databases (NCEA maintains EPA's IRIS database and Provisional Peer Reviewed Toxicity Values [PPRTVs]).

If those databases did not yield applicable toxicity value(s) for a specific COC and exposure pathway, then EPA's Tier 3 sources for human health toxicity values in Superfund risk assessments (memorandum dated December 5, 2003, and available at www.epa.gov/oswer/riskassessment/pdf/hhmemo.pdf) were searched. The following databases are listed as Tier 3 sources in EPA's hierarchy:

- California Environmental Protection Agency (CalEPA) toxicity values at http://www.oehha.ca.gov/risk/chemicalDB//index.asp
- Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs) at http://www.atsdr.cdc.gov/mrls.html
- EPA's HEAST document at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2877 (note that this source was searched as part of MTCA's hierarchy)

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[1] Wells used to characterize the landfill plume were excluded from this group.

For the Ephrata Landfill site, the Tier 3 sources identified above were searched for each groundwater COC and exposure pathway for which CLARC Database MTCA Method B SFVs were dropped as a result of the April 2011 update. In evaluating the toxicity values reported in these databases, only effects that were observed after chronic exposure periods were selected. Additionally, toxicity values derived from studies of chemical effects resulting from non-standard exposure methods (e.g., gavage, intravenous, intraperitoneal, subcutaneous, or intramuscular) were not used.

Using the appropriate standard formulas provided in MTCA (Table C-11), risk-based screening values were calculated from those toxicity values found in the Tier 3 sources and determined to be applicable for use in MTCA risk-based calculations. Table C-11 lists the COCs that had one or more exposure-pathway-based MTCA Method B groundwater SFVs dropped from the CLARC Database and any available toxicity values and calculated risk-based screening.

Revised toxicity values for tetrachloroethene (PCE) and trichloroethene (TCE) were published in EPA's IRIS database on February 10, 2012, and September 28, 2011, respectively. In June 2012, Ecology distributed new SFVs for Method B and C groundwater and air, as well as an updated TCE guidance that included revised soil and surface water SFVs (Ecology 2012). The Method B groundwater and air SFVs distributed by Ecology were used for the identification of IHSs and calculation of CULs. For north end soils, the revised cancer potency factors and reference doses published in IRIS were used in MTCA's modified Method C equations (WAC 173-340-745) to evaluate risks to landfill workers.

Calculation of Screening Levels for Identifying Indicator Hazardous Substances for Indoor Air Exposure Pathways

Air risk-based SFVs obtained from Ecology's CLARC Database (Ecology 2011) or calculated from Tier 3 toxicity values were back-calculated to groundwater screening levels using the equation and methods provided in Ecology's draft guidance for evaluating risks associated with vapor intrusion as part of the MTCA cleanup regulation (Ecology 2009). For residential exposures, the groundwater screening levels for indoor air were calculated directly from the acceptable indoor air concentrations in the CLARC database (i.e., SFVs calculated from MTCA Method B standard equations). For landfill workers, the MTCA Method B groundwater screening levels were adjusted to reflect the limited exposure of landfill workers (i.e., based on MTCA Method C). Because Henry's Law constants are temperature-dependent, the values available from the CLARC database (25°C) were adjusted to an average temperature of 13°C for Washington shallow groundwater. Groundwater screening levels calculated to generate acceptable indoor air concentrations are presented in Table C-12.

REFERENCES

Ecology (Washington Department of Ecology). 2009. Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action. Washington State Department of Ecology Toxics Cleanup Program, Review Draft. October 2009. Publication No. 09-09-047.

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PGG (Pacific Groundwater Group) and Parametrix. 2006. Final Remedial Investigation/Feasibility Study (RI/FS) Work Plan Ephrata Landfill Corrective Action. Prepared for Grant County Public Works and City of Ephrata.

PGG. 2012. Addendum to Remedial Investigation Ephrata Landfill (Agency Draft). Technical Memorandum prepared by PGG. August 28, 2012.

Table C-1. Data Used to Identify Indicator Hazardous Substances and Develop Cleanup Levels for the Ephrata Landfill

Evaluated Medium	Representative Wells/Locations	Sampling Date Ranges First	Sampling Date Ranges Last	Number of Sampling Events
Groundwater				
Northerly Plume - Roza Aquifer Component	MW-44b	September 23, 2009	June 16, 2010	3
Northerly Plume - Whitson Well Component	Whitson	July 9, 2009	June 17, 2010	4
Northerly Plume - Interflow Aquifer Component	Abrams, Pashkovsky-ACX157, Pashkovsky-ABX965, Perez	July 14, 2009	October 13, 2009	1*
Northerly Plume - Saturated Alluvium Component	MW-53a	December 29, 2009	June 17, 2010	3
Landfill Plume - Frenchman Springs Aquifer Component	MW-28d	April 1, 2008	March 25, 2009	3
Landfill Plume - Outwash Aquifer Component	MW-14a and MW-6a	March 5, 2008	June 29, 2010	10
New Scale and Maintenance Shop (Vapor Intrusion Pathway)	MW-1a and MW-26a	March 5, 2008	June 29, 2010	15
Source Area	EW-1, EW-2, MW-1a, MW-2c, MW-3b, MW-5c, MW-6c, MW-7b, MW-9b, MW-10a, MW-11a, MW-16d, MW-22c, MW-23a, MW-24a, MW-25a, MW-29b, MW-30b, MW-31b, MW-32a, MW-33p2, MW-35p2, MW-37p1, MW-38p2, MW-39p2, MW-40p2, MW-41a, MW-42b, MW-43p2	March 5, 2008	June 30, 2010	195
North End Soils				
Uncapped Contaminated Soils and Refuse in the Area of the Old Scale and Maintenance Shop, Sampled at Varying Depths	B-8, T-3, T-4, T-5, T-6, T-7, T-8, T-9, T-10, T-11, T-12, T-13	August 14, 2007	September 18, 2007	18**

* The Abrams well was sampled twice during this sampling period.

** The number of samples exceeds the number of sampling locations because samples were collected from multiple depths at some locations.

Table C-2. Northerly Plume - Roza Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STDEV	COV
1,1,1,2-Tetrachloroethane	3	µg/L	0%	-	-	-	-
1,1,1-Trichloroethane	3	µg/L	0%	-	-	-	-
1,1,2,2-Tetrachloroethane	3	µg/L	0%	-	-	-	-
1,1,2-Trichloroethane	3	µg/L	0%	-	-	-	-
1,1,2-Trichlorotrifluoroethane	3	µg/L	0%	-	-	-	-
1,1-Dichloroethane	3	µg/L	100%	64	52	12.5	24%
1,1-Dichloroethene	3	µg/L	100%	0.86	0.77	0.1	11%
1,1-Dichloropropene	3	µg/L	0%	-	-	-	-
1,2,3-Trichlorobenzene	3	µg/L	0%	-	-	-	-
1,2,3-Trichloropropane	3	µg/L	0%	-	-	-	-
1,2,4-Trichlorobenzene	3	µg/L	0%	-	-	-	-
1,2,4-Trimethylbenzene	3	µg/L	33%	1.7	1.7	-	-
1,2-Dibromo-3-chloropropane	3	µg/L	0%	-	-	-	-
1,2-Dichlorobenzene	3	µg/L	100%	21	20	1.000	5%
1,2-Dichloroethane (EDC)	3	µg/L	100%	3.8	2.93	0.76	26%
1,2-Dichloropropane	3	µg/L	100%	36	28	7.55	27%
1,3,5-Trimethylbenzene	3	µg/L	0%	-	-	-	-
1,3-Dichlorobenzene	3	µg/L	67%	1.1	1.1	0.000	0%
1,3-Dichloropropane	3	µg/L	0%	-	-	-	-
1,4-Dichlorobenzene	3	µg/L	100%	9.4	9.2	0.3	3%
2,2-Dichloropropane	3	µg/L	0%	-	-	-	-
2-butanone	3	µg/L	0%	-	-	-	-
2-Chloroethylvinylether	3	µg/L	0%	-	-	-	-
2-Chlorotoluene	3	µg/L	0%	-	-	-	-
2-Hexanone	3	µg/L	0%	-	-	-	-
4-Chlorotoluene	3	µg/L	0%	-	-	-	-
4-Isopropyltoluene	3	µg/L	0%	-	-	-	-
4-Methyl-2-pentanone (MIBK)	3	µg/L	0%	-	-	-	-
Acetone	3	µg/L	67%	12	8.9	4.384	49%
Acrolein	3	µg/L	0%	-	-	-	-
Acrylonitrile	3	µg/L	0%	-	-	-	-
Alkalinity (as CaCO3)	3	mg/L	100%	655	629	23.90	4%
Arsenic, Dissolved	3	µg/L	100%	4.3	3.97	0.31	8%
Benzene	3	µg/L	100%	39	35.33	3.21	9%
Bicarbonate As CaCO3	3	mg/L	100%	655	629	23.90	4%
Bromobenzene	3	µg/L	100%	4	3.4	0.49	14%
Bromochloromethane	3	µg/L	0%	-	-	-	-
Bromodichloromethane	3	µg/L	0%	-	-	-	-
Bromoethane	3	µg/L	67%	0.3	0.3	0.000	0%
Bromoform	3	µg/L	0%	-	-	-	-
Bromomethane	3	µg/L	0%	-	-	-	-
Calcium, Total	2	mg/L	100%	266	265.5	0.707	0%
Carbon dioxide	1	mg/L	100%	80	80	-	-
Carbon Disulfide	3	µg/L	0%	-	-	-	-
Carbon Tetrachloride	3	µg/L	0%	-	-	-	-
Carbonate as CaCO3	3	mg/L	0%	-	-	-	-
Chloride	3	mg/L	100%	484	453	27.622	6%
Chlorobenzene	3	ug/L	100%	2.2	2.1	0.100	5%

Table C-2. Northerly Plume - Roza Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STDEV	COV
Chloroethane	3	µg/L	100%	450	443.3	5.774	1%
Chloroform	3	µg/L	0%	-	-	-	-
Chloromethane	3	µg/L	0%	-	-	-	-
cis-1,2-Dichloroethene	3	µg/L	100%	8.2	7.03	1.387	20%
cis-1,3-Dichloropropene	3	µg/L	0%	-	-	-	-
Depth to Water	5	feet	100%	33.74	33.378	0.435	1%
Dibromochloromethane	3	µg/L	0%	-	-	-	-
Dibromomethane	3	µg/L	0%	-	-	-	-
Dissolved Oxygen	3	mg/L	100%	1	0.53	0.404	76%
Ethane	2	µg/L	100%	31.7	18.25	19.021	104%
Ethylbenzene	3	µg/L	67%	2.1	1.7	0.566	33%
Ethylene Dibromide (EDB)	3	µg/L	0%	-	-	-	-
Hexachlorobutadiene	3	µg/L	0%	-	-	-	-
Hexane	1	µg/L	0%	-	-	-	-
Hydroxide (as CaCO3)	3	mg/L	0%	-	-	-	-
Iron, Dissolved	3	µg/L	100%	820	583.3	269.506	46%
Iron, Total	1	µg/L	300%	830	830	-	-
Isopropylbenzene (Cumene)	3	µg/L	67%	2.6	1.85	1.061	57%
Magnesium, Total	2	mg/L	100%	124	121.5	3.536	3%
Manganese, Dissolved	3	µg/L	100%	3120	2960	138.924	5%
Manganese, Total	1	µg/L	200%	2780	2780	-	-
Methane	1	µg/L	100%	5760	5760	-	-
Methyl iodide	3	µg/L	0%	-	-	-	-
Methyl tert-Butyl Ether	1	µg/L	0%	-	-	-	-
Methylene Chloride	3	µg/L	100%	14	12.67	1.155	9%
Naphthalene	3	µg/L	0%	-	-	-	-
n-Butylbenzene	3	µg/L	33%	0.2	0.2	-	-
Nitrate as Nitrogen	3	mg/L as N	0%	-	-	-	-
Nitrate+Nitrite as Nitrogen	3	mg/L as N	0%	-	-	-	-
Nitrite as Nitrogen	3	mg/L as N	0%	-	-	-	-
n-Propylbenzene	3	µg/L	67%	0.7	0.45	0.354	79%
Oxidation Reduction Potential	2	mV	100%	37	-14	72.125	-515%
o-Xylene	3	µg/L	67%	0.7	0.55	0.212	39%
pH	3	std. units	100%	7.12	6.88	0.357	5%
Potassium, Total	2	mg/L	100%	15	14.75	0.354	2%
sec-Butylbenzene	3	µg/L	67%	0.7	0.7	0.000	0%
Sodium, Total	2	mg/L	100%	49.3	45.45	5.445	12%
Specific Conductance @ 25C	3	umhos/cm	100%	2730	2640	122.882	5%
Styrene	3	µg/L	0%	-	-	-	-
Sulfate	3	mg/L	100%	34.2	30.17	3.620	12%
Temperature, 0 F	2	0 F	100%	60.1	56.49	5.105	9%
tert-Butylbenzene	3	µg/L	67%	0.4	0.35	0.071	20%
Tetrachloroethene (PCE)	3	µg/L	0%	-	-	-	-
Toluene	3	µg/L	67%	0.4	0.35	0.071	20%
Total Dissolved Solids	3	mg/L	100%	1460	1390	60.828	4%
Total Kjeldahl Nitrogen	1	mg/L as N	100%	1.96	1.96	-	-
Total Organic Carbon	3	mg/L	100%	40.9	39.63	1.484	4%
trans-1,2-Dichloroethene	3	µg/L	100%	2.4	1.97	0.379	19%

Table C-2. Northerly Plume - Roza Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STDEV	COV
trans-1,3-Dichloropropene	3	µg/L	67%	0.4	0.4	-	-
trans-1,4-Dichloro-2-butene	3	µg/L	0%	-	-	-	-
Trichloroethene (TCE)	3	µg/L	67%	0.1	0.092	0.011	12%
Trichlorofluoromethane	3	µg/L	0%	-	-	-	-
Vinyl Acetate	3	µg/L	0%	-	-	-	-
Vinyl Chloride	3	µg/L	100%	2.5	2.1	0.361	17%
Xylene Isomers, M+P	3	µg/L	33%	0.6	0.6	-	-

N = Sample size
%FOD = Percent Frequency of Detection
Max = Maximum value detected
Mean = Mean value detected
STDEV = Standard deviation of detected values
COV = Coefficient of Variation of detected values

Table C-3. Northerly Plume - Interflow Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STDEV	COV
1,1,1,2-Tetrachloroethane	5	µg/L	0%	-	-	-	-
1,1,1-Trichloroethane	5	µg/L	0%	-	-	-	-
1,1,2,2-Tetrachloroethane	5	µg/L	0%	-	-	-	-
1,1,2-Trichloroethane	5	µg/L	0%	-	-	-	-
1,1,2-Trichlorotrifluoroethane	5	µg/L	0%	-	-	-	-
1,1-Dichloroethane	5	µg/L	100%	2.1	0.9	0.7	78%
1,1-Dichloroethene	5	µg/L	0%	-	-	-	-
1,1-Dichloropropene	5	µg/L	0%	-	-	-	-
1,2,3-Trichlorobenzene	5	µg/L	0%	-	-	-	-
1,2,3-Trichloropropane	5	µg/L	0%	-	-	-	-
1,2,4-Trichlorobenzene	5	µg/L	0%	-	-	-	-
1,2,4-Trimethylbenzene	5	µg/L	0%	-	-	-	-
1,2-Dibromo-3-chloropropane	5	µg/L	0%	-	-	-	-
1,2-Dichlorobenzene	5	µg/L	0%	-	-	-	-
1,2-Dichloroethane (EDC)	5	µg/L	20%	0.2	0.2	-	-
1,2-Dichloropropane	5	µg/L	100%	2.9	1.2	1.1	89%
1,3,5-Trimethylbenzene	5	µg/L	0%	-	-	-	-
1,3-Dichlorobenzene	5	µg/L	0%	-	-	-	-
1,3-Dichloropropane	5	µg/L	0%	-	-	-	-
1,4-Dichlorobenzene	5	µg/L	0%	-	-	-	-
2,2-Dichloropropane	5	µg/L	0%	-	-	-	-
2-butanone	5	µg/L	0%	-	-	-	-
2-Chloroethylvinylether	5	µg/L	0%	-	-	-	-
2-Chlorotoluene	5	µg/L	0%	-	-	-	-
2-Hexanone	5	µg/L	0%	-	-	-	-
4-Chlorotoluene	5	µg/L	0%	-	-	-	-
4-Isopropyltoluene	5	µg/L	0%	-	-	-	-
4-Methyl-2-pentanone (MIBK)	5	µg/L	0%	-	-	-	-
Acetone	5	µg/L	0%	-	-	-	-
Acrolein	5	µg/L	0%	-	-	-	-
Acrylonitrile	5	µg/L	0%	-	-	-	-
Alkalinity (as CaCO3)	4	mg/L	100%	184.0	167.3	13.6	8%
Arsenic, Dissolved	4	µg/L	100%	2.9	2.4	0.5	20%
Benzene	5	µg/L	0%	-	-	-	-
Bicarbonate As CaCO3	4	mg/L	100%	184.0	167.3	13.6	8%
Bromobenzene	5	µg/L	0%	-	-	-	-
Bromochloromethane	5	µg/L	0%	-	-	-	-
Bromodichloromethane	5	µg/L	0%	-	-	-	-
Bromoethane	5	µg/L	0%	-	-	-	-
Bromoform	5	µg/L	0%	-	-	-	-
Bromomethane	5	µg/L	0%	-	-	-	-
Calcium, Total	4	mg/L	100%	67.5	60.2	6.7	11%
Carbon Disulfide	5	µg/L	0%	-	-	-	-
Carbon Tetrachloride	5	µg/L	0%	-	-	-	-
Carbonate as CO3	4	mg/L	0%	-	-	-	-
Chloride	4	mg/L	100%	44.4	31.4	9.5	30%
Chlorobenzene	5	µg/L	0%	-	-	-	-
Chloroethane	5	µg/L	0%	-	-	-	-
Chloroform	5	µg/L	0%	-	-	-	-
Chloromethane	5	µg/L	0%	-	-	-	-
cis-1,2-Dichloroethene	5	µg/L	40%	0.8	0.6	0.3	47%

Table C-3. Northerly Plume - Interflow Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STDEV	COV
cis-1,3-Dichloropropene	5	µg/L	0%	-	-	-	-
Dibromochloromethane	5	µg/L	0%	-	-	-	-
Dibromomethane	5	µg/L	0%	-	-	-	-
Ethylbenzene	5	µg/L	0%	-	-	-	-
Ethylene Dibromide (EDB)	5	µg/L	0%	-	-	-	-
Hexachlorobutadiene	5	µg/L	0%	-	-	-	-
Hexane	4	µg/L	0%	-	-	-	-
Hydroxide (as CaCO3)	4	mg/L	0%	-	-	-	-
Iron, Dissolved	4	µg/L	0%	-	-	-	-
Isopropylbenzene (Cumene)	5	µg/L	0%	-	-	-	-
Magnesium, Total	4	mg/L	100%	24.6	21.7	2.9	14%
Manganese, Dissolved	4	µg/L	0%	-	-	-	-
Methyl iodide	5	µg/L	0%	-	-	-	-
Methyl tert-Butyl Ether	4	µg/L	0%	-	-	-	-
Methylene Chloride	5	µg/L	0%	-	-	-	-
Naphthalene	5	µg/L	0%	-	-	-	-
n-Butylbenzene	5	µg/L	0%	-	-	-	-
Nitrate as Nitrogen	4	mg/L as N	100%	10.0	7.3	2.1	29%
Nitrate+Nitrite as Nitrogen	4	mg/L as N	100%	10.0	7.3	2.1	29%
Nitrite as Nitrogen	4	mg/L as N	100%	0.0	0.0	0.0	17%
n-Propylbenzene	5	µg/L	0%	-	-	-	-
o-Xylene	5	µg/L	0%	-	-	-	-
pH	5	std. units	100%	8.0	7.6	0.4	5%
Potassium, Total	4	mg/L	100%	5.4	4.7	0.9	19%
sec-Butylbenzene	5	µg/L	0%	-	-	-	-
Sodium, Total	4	mg/L	100%	25.3	22.0	2.4	11%
Specific Conductance @ 25C	5	umhos/cm	100%	751.0	616.0	82.2	13%
Styrene	5	µg/L	0%	-	-	-	-
Sulfate	4	mg/L	100%	72.8	61.8	14.0	23%
Temperature, 0 F	5	0 F	100%	60.1	58.7	2.2	4%
tert-Butylbenzene	5	µg/L	0%	-	-	-	-
Tetrachloroethene (PCE)	5	µg/L	0%	-	-	-	-
Toluene	5	µg/L	0%	-	-	-	-
Total Dissolved Solids	4	mg/L	100%	414.0	378.8	43.8	12%
trans-1,2-Dichloroethene	5	µg/L	0%	-	-	-	-
trans-1,3-Dichloropropene	5	µg/L	0%	-	-	-	-
trans-1,4-Dichloro-2-butene	5	µg/L	0%	-	-	-	-
Trichloroethene (TCE)	5	µg/L	0%	-	-	-	-
Trichlorofluoromethane	5	µg/L	0%	-	-	-	-
Vinyl Acetate	5	µg/L	0%	-	-	-	-
Vinyl Chloride	5	µg/L	0%	-	-	-	-
Xylene Isomers, M+P	5	µg/L	0%	-	-	-	-

N = Sample size

%FOD = Percent Frequency of Detection

Max = Maximum value detected

Mean = Mean value detected

STDEV = Standard deviation of detected values

COV = Coefficient of Variation of detected values

Table C-4. Northerly Plume - Whitson Well Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STD	COV
1,1,1,2-Tetrachloroethane	4	µg/L	0%	-	-	-	-
1,1,1-Trichloroethane	4	µg/L	0%	-	-	-	-
1,1,2,2-Tetrachloroethane	4	µg/L	0%	-	-	-	-
1,1,2-Trichloroethane	4	µg/L	0%	-	-	-	-
1,1,2-Trichlorotrifluoroethane	4	µg/L	0%	-	-	-	-
1,1-Dichloroethane	4	µg/L	100%	7.5	6.58	0.74	11%
1,1-Dichloroethene	4	µg/L	100%	0.2	0.20	0.00	0%
1,1-Dichloropropene	4	µg/L	0%	-	-	-	-
1,2,3-Trichlorobenzene	4	µg/L	0%	-	-	-	-
1,2,3-Trichloropropane	4	µg/L	0%	-	-	-	-
1,2,4-Trichlorobenzene	4	µg/L	0%	-	-	-	-
1,2,4-Trimethylbenzene	4	µg/L	0%	-	-	-	-
1,2-Dibromo-3-chloropropane	4	µg/L	0%	-	-	-	-
1,2-Dichlorobenzene	4	µg/L	100%	0.3	0.28	0.05	18%
1,2-Dichloroethane (EDC)	4	µg/L	100%	0.7	0.60	0.08	14%
1,2-Dichloropropane	4	µg/L	100%	5.3	4.90	0.32	6%
1,3,5-Trimethylbenzene	4	µg/L	0%	-	-	-	-
1,3-Dichlorobenzene	4	µg/L	0%	-	-	-	-
1,3-Dichloropropane	4	µg/L	0%	-	-	-	-
1,4-Dichlorobenzene	4	µg/L	0%	-	-	-	-
2,2-Dichloropropane	4	µg/L	0%	-	-	-	-
2-butanone	4	µg/L	0%	-	-	-	-
2-Chloroethylvinylether	4	µg/L	0%	-	-	-	-
2-Chlorotoluene	4	µg/L	0%	-	-	-	-
2-Hexanone	4	µg/L	0%	-	-	-	-
4-Chlorotoluene	4	µg/L	0%	-	-	-	-
4-Isopropyltoluene	4	µg/L	0%	-	-	-	-
4-Methyl-2-pentanone (MIBK)	4	µg/L	0%	-	-	-	-
Acetone	4	µg/L	25%	6	6.00	-	-
Acrolein	4	µg/L	0%	-	-	-	-
Acrylonitrile	4	µg/L	0%	-	-	-	-
Alkalinity (as CaCO3)	3	mg/L	100%	129	128.33	1.15	1%
Arsenic, Dissolved	3	µg/L	67%	0.8	0.80	0.00	0%
Benzene	4	µg/L	100%	1	0.83	0.15	18%
Bicarbonate As CaCO3	3	mg/L	100%	129	128.33	1.15	1%
Bromobenzene	4	µg/L	0%	-	-	-	-
Bromochloromethane	4	µg/L	0%	-	-	-	-
Bromodichloromethane	4	µg/L	0%	-	-	-	-
Bromoethane	4	µg/L	0%	-	-	-	-
Bromoform	4	µg/L	0%	-	-	-	-
Bromomethane	4	µg/L	0%	-	-	-	-
Calcium, Total	3	mg/L	100%	46.3	42.80	3.45	8%
Carbon Disulfide	4	µg/L	0%	-	-	-	-
Carbon Tetrachloride	4	µg/L	0%	-	-	-	-
Carbonate as CaCO3	3	mg/L	0%	-	-	-	-
Chloride	3	mg/L	100%	97.5	86.37	11.74	14%
Chlorobenzene	4	µg/L	0%	-	-	-	-
Chloroethane	4	µg/L	100%	2.7	2.40	0.24	10%
Chloroform	4	µg/L	0%	-	-	-	-
Chloromethane	4	µg/L	0%	-	-	-	-
cis-1,2-Dichloroethene	4	µg/L	100%	3.2	2.73	0.40	15%

Table C-4. Northerly Plume - Whitson Well Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STD	COV
cis-1,3-Dichloropropene	4	µg/L	0%	-	-	-	-
Dibromochloromethane	4	µg/L	0%	-	-	-	-
Dibromomethane	4	µg/L	0%	-	-	-	-
Ethylbenzene	4	µg/L	0%	-	-	-	-
Ethylene Dibromide (EDB)	4	µg/L	0%	-	-	-	-
Hexachlorobutadiene	4	µg/L	0%	-	-	-	-
Hexane	1	µg/L	0%	-	-	-	-
Hydroxide (as CaCO3)	3	mg/L	0%	-	-	-	-
Iron, Dissolved	3	µg/L	0%	-	-	-	-
Iron, Total	1	µg/L	0%	-	-	-	-
Isopropylbenzene (Cumene)	4	µg/L	0%	-	-	-	-
Magnesium, Total	3	mg/L	100%	30.8	28.77	2.55	9%
Manganese, Dissolved	3	µg/L	0%	-	-	-	-
Methyl iodide	4	µg/L	0%	-	-	-	-
Methyl tert-Butyl Ether	1	µg/L	0%	-	-	-	-
Methylene Chloride	4	µg/L	100%	1	0.70	0.22	31%
Naphthalene	4	µg/L	0%	-	-	-	-
n-Butylbenzene	4	µg/L	0%	-	-	-	-
Nitrate as Nitrogen	3	mg/L as N	100%	5.81	3.92	1.68	43%
Nitrate+Nitrite as Nitrogen	3	mg/L as N	100%	5.83	3.94	1.69	43%
Nitrite as Nitrogen	3	mg/L as N	67%	0.018	0.02	0.00	8%
n-Propylbenzene	4	µg/L	0%	-	-	-	-
o-Xylene	4	µg/L	0%	-	-	-	-
pH	4	std. units	100%	8.07	7.68	0.50	6%
Potassium, Total	3	mg/L	100%	11.9	11.27	0.85	8%
sec-Butylbenzene	4	µg/L	0%	-	-	-	-
Sodium, Total	3	mg/L	100%	21.9	21.23	0.59	3%
Specific Conductance @ 25C	4	umhos/cm	100%	734	621.50	79.44	13%
Styrene	4	µg/L	0%	-	-	-	-
Sulfate	3	mg/L	100%	32.3	28.27	5.35	19%
Temperature, 0 F	4	0 F	100%	62.2	60.21	2.99	5%
tert-Butylbenzene	4	µg/L	0%	-	-	-	-
Tetrachloroethene (PCE)	4	µg/L	100%	0.5	0.43	0.05	12%
Toluene	4	µg/L	0%	-	-	-	-
Total Dissolved Solids	4	mg/L	100%	376	274.09	181.47	66%
trans-1,2-Dichloroethene	4	µg/L	0%	-	-	-	-
trans-1,3-Dichloropropene	4	µg/L	0%	-	-	-	-
trans-1,4-Dichloro-2-butene	4	µg/L	0%	-	-	-	-
Trichloroethene (TCE)	4	µg/L	100%	0.4	0.33	0.05	15%
Trichlorofluoromethane	4	µg/L	0%	-	-	-	-
Vinyl Acetate	4	µg/L	0%	-	-	-	-
Vinyl Chloride	4	µg/L	100%	5.1	4.68	0.46	10%
Xylene Isomers, M+P	4	µg/L	0%	-	-	-	-

N = Sample size
%FOD = Percent Frequency of Detection
Max = Maximum value detected
Mean = Mean value detected
STDEV = Standard deviation of detected values
COV = Coefficient of Variation of detected values

Table C-5. Northerly Plume - Saturated Alluvium Groundwater Data Statistics

Constituent	N	Units	% FOD	Max	Mean	STDEV	COV
1,1,1,2-Tetrachloroethane	3	µg/L	0%	-	-	-	-
1,1,1-Trichloroethane	3	µg/L	33%	0.40	0.40	-	-
1,1,2,2-Tetrachloroethane	3	µg/L	0%	-	-	-	-
1,1,2-Trichloroethane	3	µg/L	0%	-	-	-	-
1,1,2-Trichlorotrifluoroethane	3	µg/L	0%	-	-	-	-
1,1-Dichloroethane	3	µg/L	100%	1.40	1.20	0.26	22%
1,1-Dichloroethene	3	µg/L	0%	-	-	-	-
1,1-Dichloropropene	3	µg/L	0%	-	-	-	-
1,2,3-Trichlorobenzene	3	µg/L	0%	-	-	-	-
1,2,3-Trichloropropane	3	µg/L	0%	-	-	-	-
1,2,4-Trichlorobenzene	3	µg/L	0%	-	-	-	-
1,2,4-Trimethylbenzene	3	µg/L	0%	-	-	-	-
1,2-Dibromo-3-chloropropane	3	µg/L	0%	-	-	-	-
1,2-Dichlorobenzene	3	µg/L	0%	-	-	-	-
1,2-Dichloroethane (EDC)	3	µg/L	0%	-	-	-	-
1,2-Dichloropropane	3	µg/L	100%	0.40	0.37	0.06	16%
1,3,5-Trimethylbenzene	3	µg/L	0%	-	-	-	-
1,3-Dichlorobenzene	3	µg/L	0%	-	-	-	-
1,3-Dichloropropane	3	µg/L	0%	-	-	-	-
1,4-Dichlorobenzene	3	µg/L	0%	-	-	-	-
2,2-Dichloropropane	3	µg/L	0%	-	-	-	-
2-butanone	3	µg/L	0%	-	-	-	-
2-Chloroethylvinylether	3	µg/L	0%	-	-	-	-
2-Chlorotoluene	3	µg/L	0%	-	-	-	-
2-Hexanone	3	µg/L	0%	-	-	-	-
4-Chlorotoluene	3	µg/L	0%	-	-	-	-
4-Isopropyltoluene	3	µg/L	0%	-	-	-	-
4-Methyl-2-pentanone (MIBK)	3	µg/L	0%	-	-	-	-
Acetone	3	µg/L	0%	-	-	-	-
Acrolein	3	µg/L	0%	-	-	-	-
Acrylonitrile	3	µg/L	0%	-	-	-	-
Alkalinity (as CaCO3)	3	mg/L	100%	198.00	191.67	6.51	3%
Arsenic, Dissolved	3	µg/L	100%	9.00	8.67	0.58	7%
Benzene	3	µg/L	0%	-	-	-	-
Bicarbonate As CaCO3	3	mg/L	100%	198.00	191.67	6.51	3%
Bromobenzene	3	µg/L	0%	-	-	-	-
Bromochloromethane	3	µg/L	0%	-	-	-	-
Bromodichloromethane	3	µg/L	0%	-	-	-	-
Bromoethane	3	µg/L	0%	-	-	-	-
Bromoform	3	µg/L	0%	-	-	-	-
Bromomethane	3	µg/L	0%	-	-	-	-
Calcium, Total	3	mg/L	100%	50.50	48.90	1.47	3%
Carbon dioxide	1	mg/L	100%	6.20	6.20	-	-
Carbon Disulfide	3	µg/L	0%	-	-	-	-
Carbon Tetrachloride	3	µg/L	0%	-	-	-	-
Carbonate as CaCO3	3	mg/L	0%	-	-	-	-
Chloride	3	mg/L	100%	16.70	16.37	0.35	2%
Chlorobenzene	3	µg/L	0%	-	-	-	-
Chloroethane	3	µg/L	0%	-	-	-	-

Table C-5. Northerly Plume - Saturated Alluvium Groundwater Data Statistics

Constituent	N	Units	% FOD	Max	Mean	STDEV	COV
Chloroform	3	µg/L	0%	-	-	-	-
Chloromethane	3	µg/L	0%	-	-	-	-
cis-1,2-Dichloroethene	3	µg/L	67%	0.05	0.04	0.02	58%
cis-1,3-Dichloropropene	3	µg/L	0%	-	-	-	-
Depth to Water	3	feet	100%	11.70	11.23	0.44	4%
Dibromochloromethane	3	µg/L	0%	-	-	-	-
Dibromomethane	3	µg/L	0%	-	-	-	-
Dissolved Oxygen	2	mg/L	100%	6.00	5.00	1.41	28%
Ethane	2	µg/L	0%	-	-	-	-
Ethylbenzene	3	µg/L	0%	-	-	-	-
Ethylene Dibromide (EDB)	3	µg/L	0%	-	-	-	-
Hexachlorobutadiene	3	µg/L	0%	-	-	-	-
Hydroxide (as CaCO3)	3	mg/L	0%	-	-	-	-
Iron, Dissolved	3	µg/L	0%	-	-	-	-
Iron, Total	1	µg/L	100%	150.00	150.00	-	-
Isopropylbenzene (Cumene)	3	µg/L	0%	-	-	-	-
Magnesium, Total	3	mg/L	100%	15.10	14.73	0.40	3%
Manganese, Dissolved	3	µg/L	67%	8.00	7.50	0.71	9%
Manganese, Total	1	µg/L	100%	2.00	2.00	-	-
Methane	1	µg/L	0%	-	-	-	-
Methyl iodide	3	µg/L	0%	-	-	-	-
Methylene Chloride	3	µg/L	0%	-	-	-	-
Naphthalene	3	µg/L	0%	-	-	-	-
n-Butylbenzene	3	µg/L	0%	-	-	-	-
Nitrate as Nitrogen	3	mg/L as N	100%	3.38	3.28	0.12	4%
Nitrate+Nitrite as Nitrogen	3	mg/L as N	100%	3.38	3.28	0.12	4%
Nitrite as Nitrogen	3	mg/L as N	0%	-	-	-	-
n-Propylbenzene	3	µg/L	0%	-	-	-	-
Oxidation Reduction Potential	2	mV	100%	164.00	129.00	49.50	38%
o-Xylene	3	µg/L	0%	-	-	-	-
pH	3	std. units	100%	7.22	7.14	0.08	1%
Potassium, Total	3	mg/L	100%	3.10	2.89	0.23	8%
sec-Butylbenzene	3	µg/L	0%	-	-	-	-
Sodium, Total	3	mg/L	100%	49.10	47.27	1.96	4%
Specific Conductance @ 25C	3	umhos/cm	100%	638.00	558.67	75.79	14%
Styrene	3	µg/L	0%	-	-	-	-
Sulfate	3	mg/L	100%	68.50	62.40	8.81	14%
Temperature, 0 F	3	0 F	100%	55.20	53.65	1.72	3%
tert-Butylbenzene	3	µg/L	0%	-	-	-	-
Tetrachloroethene (PCE)	3	µg/L	33%	0.15	0.15	-	-
Toluene	3	µg/L	0%	-	-	-	-
Total Dissolved Solids	3	mg/L	100%	395.00	368.67	22.94	6%
Total Kjeldahl Nitrogen	1	mg/L as N	0%	-	-	-	-
Total Organic Carbon	2	mg/L	100%	7.23	4.77	3.48	73%
trans-1,2-Dichloroethene	3	µg/L	0%	-	-	-	-
trans-1,3-Dichloropropene	3	µg/L	0%	-	-	-	-
trans-1,4-Dichloro-2-butene	3	µg/L	0%	-	-	-	-
Trichloroethene (TCE)	3	µg/L	33%	0.08	0.08	-	-
Trichlorofluoromethane	3	µg/L	0%	-	-	-	-

Table C-5. Northerly Plume - Saturated Alluvium Groundwater Data Statistics

Constituent	N	Units	% FOD	Max	Mean	STDEV	COV
Vinyl Acetate	3	µg/L	0%	-	-	-	-
Vinyl Chloride	3	µg/L	0%	-	-	-	-
Xylene Isomers, M+P	3	µg/L	0%	-	-	-	-

N = Sample size

%FOD = Percent Frequency of Detection

Max = Maximum value detected

Mean = Mean value detected

STDEV = Standard deviation of detected values

COV = Coefficient of Variation of detected values

Table C-6. Landfill Plume - Frenchman Springs Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STD	COV
1,1,1,2-Tetrachloroethane	3	µg/L	0%	-	-	-	-
1,1,1-Trichloroethane	3	µg/L	0%	-	-	-	-
1,1,2,2-Tetrachloroethane	3	µg/L	0%	-	-	-	-
1,1,2-Trichloroethane	3	µg/L	0%	-	-	-	-
1,1,2-Trichlorotrifluoroethane	3	µg/L	0%	-	-	-	-
1,1-Dichloroethane	3	µg/L	100%	0.4	0.33	0.06	17%
1,1-Dichloroethene	3	µg/L	0%	-	-	-	-
1,1-Dichloropropene	3	µg/L	0%	-	-	-	-
1,2,3-Trichlorobenzene	3	µg/L	0%	-	-	-	-
1,2,3-Trichloropropane	3	µg/L	0%	-	-	-	-
1,2,4-Trichlorobenzene	3	µg/L	0%	-	-	-	-
1,2,4-Trimethylbenzene	3	µg/L	0%	-	-	-	-
1,2-Dibromo-3-chloropropane	3	µg/L	0%	-	-	-	-
1,2-Dichlorobenzene	3	µg/L	0%	-	-	-	-
1,2-Dichloroethane (EDC)	3	µg/L	0%	-	-	-	-
1,2-Dichloropropane	3	µg/L	100%	0.4	0.37	0.06	16%
1,3,5-Trimethylbenzene	3	µg/L	0%	-	-	-	-
1,3-Dichlorobenzene	3	µg/L	0%	-	-	-	-
1,3-Dichloropropane	3	µg/L	0%	-	-	-	-
1,4-Dichlorobenzene	3	µg/L	0%	-	-	-	-
2,2-Dichloropropane	3	µg/L	0%	-	-	-	-
2-butanone	3	µg/L	0%	-	-	-	-
2-Chloroethylvinylether	3	µg/L	0%	-	-	-	-
2-Chlorotoluene	3	µg/L	0%	-	-	-	-
2-Hexanone	3	µg/L	0%	-	-	-	-
4-Chlorotoluene	3	µg/L	0%	-	-	-	-
4-Isopropyltoluene	3	µg/L	0%	-	-	-	-
4-Methyl-2-pentanone (MIBK)	3	µg/L	0%	-	-	-	-
Acetone	3	µg/L	0%	-	-	-	-
Acrolein	3	µg/L	0%	-	-	-	-
Acrylonitrile	3	µg/L	0%	-	-	-	-
Alkalinity (as CaCO3)	3	mg/L	100%	129	127.67	1.15	1%
Ammonia as Nitrogen, Total	1	mg/L as N	100%	0.015	0.02	-	-
Antimony, Dissolved	1	µg/L	0%	-	-	-	-
Arsenic, Dissolved	2	µg/L	50%	0.6	0.60	-	-
Barium, Dissolved	1	µg/L	100%	57	57.00	-	-
Benzene	3	µg/L	0%	-	-	-	-
Beryllium, Dissolved	1	µg/L	0%	-	-	-	-
Bicarbonate As CaCO3	3	mg/L	100%	129	127.67	1.15	1%
Bromobenzene	3	µg/L	0%	-	-	-	-
Bromochloromethane	3	µg/L	0%	-	-	-	-
Bromodichloromethane	3	µg/L	0%	-	-	-	-
Bromoethane	3	µg/L	0%	-	-	-	-
Bromoform	3	µg/L	0%	-	-	-	-
Bromomethane	3	µg/L	0%	-	-	-	-
Cadmium, Dissolved	1	µg/L	0%	-	-	-	-
Calcium, Total	3	mg/L	100%	63.3	57.10	6.20	11%
Carbon dioxide	1	mg/L	100%	2.6	2.60	-	-
Carbon Disulfide	3	µg/L	0%	-	-	-	-

Table C-6. Landfill Plume - Frenchman Springs Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STD	COV
Carbon Tetrachloride	3	µg/L	0%	-	-	-	-
Carbonate as CO3	3	mg/L	0%	-	-	-	0%
Chloride	3	mg/L	100%	103	98.67	5.13	5%
Chlorobenzene	3	µg/L	0%	-	-	-	-
Chloroethane	3	µg/L	0%	-	-	-	-
Chloroform	3	µg/L	0%	-	-	-	-
Chloromethane	3	µg/L	0%	-	-	-	-
Chromium, Dissolved	1	µg/L	0%	-	-	-	-
cis-1,2-Dichloroethene	3	µg/L	100%	2.1	1.77	0.31	17%
cis-1,3-Dichloropropene	3	µg/L	0%	-	-	-	-
Cobalt, Dissolved	1	µg/L	0%	-	-	-	-
Copper, Dissolved	1	µg/L	0%	-	-	-	-
Dibromochloromethane	3	µg/L	0%	-	-	-	-
Dibromomethane	3	µg/L	0%	-	-	-	-
Ethene	2	µg/L	0%	-	-	-	-
Ethylbenzene	3	µg/L	0%	-	-	-	-
Ethylene Dibromide (EDB)	3	µg/L	0%	-	-	-	-
Hexachlorobutadiene	3	µg/L	0%	-	-	-	-
Hexane	2	µg/L	0%	-	-	-	-
Hydrogen Sulfide	1	mg/L	100%	0	0.00	-	-
Hydroxide (as CaCO3)	3	mg/L	0%	-	-	-	-
Iron, Dissolved	1	µg/L	0%	-	-	-	-
Iron, Total	3	µg/L	100%	650	270.00	329.24	122%
Isopropylbenzene (Cumene)	3	µg/L	0%	-	-	-	-
Lead, Dissolved	1	µg/L	0%	-	-	-	-
Magnesium, Total	3	mg/L	100%	35.4	31.70	3.60	11%
Manganese, Dissolved	1	µg/L	100%	15	15.00	-	-
Manganese, Total	3	µg/L	100%	28	22.00	6.00	27%
Methane	1	µg/L	100%	9.1	9.10	-	-
Methyl iodide	3	µg/L	0%	-	-	-	-
Methyl tert-Butyl Ether	2	µg/L	0%	-	-	-	-
Methylene Chloride	3	µg/L	0%	-	-	-	-
Naphthalene	3	µg/L	0%	-	-	-	-
n-Butylbenzene	3	µg/L	0%	-	-	-	-
Nickel, Dissolved	1	µg/L	0%	-	-	-	-
Nitrate as Nitrogen	3	mg/L as N	100%	1.86	1.24	0.64	52%
Nitrate+Nitrite as Nitrogen	3	mg/L as N	100%	2.1	1.48	0.63	43%
Nitrite as Nitrogen	3	mg/L as N	100%	0.252	0.24	0.01	4%
n-Propylbenzene	3	µg/L	0%	-	-	-	-
o-Xylene	3	µg/L	0%	-	-	-	-
pH	3	std. units	100%	7.6	6.87	0.86	13%
Potassium, Total	3	mg/L	100%	8.1	7.80	0.26	3%
sec-Butylbenzene	3	µg/L	0%	-	-	-	-
Selenium, Dissolved	1	µg/L	0%	-	-	-	-
Silver, Dissolved	1	µg/L	0%	-	-	-	-
Sodium, Total	3	mg/L	100%	20.3	20.10	0.35	2%
Specific Conductance @ 25C	3	umhos/cm	100%	744	717.67	23.25	3%
Styrene	3	µg/L	0%	-	-	-	-
Sulfate	3	mg/L	100%	56	50.30	5.51	11%

Table C-6. Landfill Plume - Frenchman Springs Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STD	COV
Temperature, 0 F	3	0 F	100%	66.92	66.53	0.34	1%
tert-Butylbenzene	3	µg/L	0%	-	-	-	-
Tetrachloroethene (PCE)	3	µg/L	100%	2.4	1.80	0.60	33%
Thallium, Dissolved	1	µg/L	0%	-	-	-	-
Toluene	3	µg/L	33%	0.4	0.40	-	-
Total Dissolved Solids	3	mg/L	100%	429	395.67	32.53	8%
Total Kjeldahl Nitrogen	1	mg/L as N	0%	-	-	-	-
Total Organic Carbon	2	mg/L	100%	2.14	1.93	0.30	16%
trans-1,2-Dichloroethene	3	µg/L	0%	-	-	-	-
trans-1,3-Dichloropropene	3	µg/L	0%	-	-	-	-
trans-1,4-Dichloro-2-butene	3	µg/L	0%	-	-	-	-
Trichloroethene (TCE)	3	µg/L	100%	0.4	0.34	0.05	16%
Trichlorofluoromethane	3	µg/L	0%	-	-	-	-
Vanadium, Dissolved	1	µg/L	100%	6	6.00	-	-
Vinyl Acetate	3	µg/L	0%	-	-	-	-
Vinyl Chloride	3	µg/L	33%	0.028	0.03	-	-
Xylene Isomers, M+P	3	µg/L	0%	-	-	-	-
Zinc, Dissolved	1	µg/L	0%	-	-	-	-

N = Sample size

%FOD = Percent Frequency of Detection

Max = Maximum value detected

Mean = Mean value detected

STDEV = Standard deviation of detected values

COV = Coefficient of Variation of detected values

Table C-7. Landfill Plume - Outwash Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
1,1,1,2-Tetrachloroethane	20	µg/L	0%	-	-	-	-	*
1,1,1-Trichloroethane	20	µg/L	0%	-	-	-	-	*
1,1,2,2-Tetrachloroethane	22	µg/L	0%	-	-	-	-	*
1,1,2-Trichloroethane	20	µg/L	0%	-	-	-	-	*
1,1,2-Trichlorotrifluoroethane	20	µg/L	0%	-	-	-	-	*
1,1-Dichloroethane	20	µg/L	0%	-	-	-	-	*
1,1-Dichloroethene	22	µg/L	14%	0.07	0.06	0.01	13%	0.066
1,1-Dichloropropene	20	µg/L	0%	-	-	-	-	*
1,2,3-Trichlorobenzene	20	µg/L	0%	-	-	-	-	*
1,2,3-Trichloropropane	20	µg/L	0%	-	-	-	-	*
1,2,4-Trichlorobenzene	22	µg/L	0%	-	-	-	-	*
1,2,4-Trimethylbenzene	20	µg/L	0%	-	-	-	-	*
1,2-Dibromo-3-chloropropane	20	µg/L	0%	-	-	-	-	*
1,2-Dichlorobenzene	22	µg/L	0%	-	-	-	-	*
1,2-Dichloroethane (EDC)	20	µg/L	0%	-	-	-	-	*
1,2-Dichloropropane	20	µg/L	0%	-	-	-	-	*
1,3,5-Trimethylbenzene	20	µg/L	0%	-	-	-	-	*
1,3-Dichlorobenzene	24	µg/L	0%	-	-	-	-	*
1,3-Dichloropropane	20	µg/L	0%	-	-	-	-	*
1,4-Dichlorobenzene	22	µg/L	0%	-	-	-	-	*
1-Methylnaphthalene	2	µg/L	0%	-	-	-	-	*
2,2-Dichloropropane	20	µg/L	0%	-	-	-	-	*
2,2-Oxybis(1-Chloropropane)	2	µg/L	0%	-	-	-	-	*
2,4,5-Trichlorophenol	4	µg/L	0%	-	-	-	-	*
2,4-Dichlorophenol	2	µg/L	0%	-	-	-	-	*
2,4-Dimethylphenol	2	µg/L	0%	-	-	-	-	*
2,4-Dinitrophenol	2	µg/L	0%	-	-	-	-	*
2,6-Dinitrotoluene	3	µg/L	0%	-	-	-	-	*
2-butanone	20	µg/L	0%	-	-	-	-	*
2-Chloroethylvinylether	20	µg/L	0%	-	-	-	-	*
2-Chloronaphthalene	2	µg/L	0%	-	-	-	-	*
2-Chlorophenol	2	µg/L	0%	-	-	-	-	*
2-Chlorotoluene	20	µg/L	0%	-	-	-	-	*
2-Hexanone	20	µg/L	0%	-	-	-	-	*
2-Methyl-4,6-dinitrophenol	2	µg/L	0%	-	-	-	-	*
2-Methylnaphthalene	2	µg/L	0%	-	-	-	-	*
2-Methylphenol	2	µg/L	0%	-	-	-	-	*
2-Nitroaniline	2	µg/L	0%	-	-	-	-	*
2-Nitrophenol	2	µg/L	0%	-	-	-	-	*
3,3'-Dichlorobenzidine	2	µg/L	0%	-	-	-	-	*
3-Nitroaniline	2	µg/L	0%	-	-	-	-	*
4-Bromophenyl Phenyl Ether	2	µg/L	0%	-	-	-	-	*
4-Chloro-3-methylphenol	6	µg/L	0%	-	-	-	-	*
4-Chloroaniline	2	µg/L	0%	-	-	-	-	*
4-Chlorophenyl Phenyl Ether	2	µg/L	0%	-	-	-	-	*
4-Chlorotoluene	20	µg/L	0%	-	-	-	-	*
4-Isopropyltoluene	20	µg/L	0%	-	-	-	-	*
4-Methyl-2-pentanone (MIBK)	20	µg/L	0%	-	-	-	-	*

Table C-7. Landfill Plume - Outwash Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
4-Methylphenol	2	µg/L	0%	-	-	-	-	*
4-Nitroaniline	2	µg/L	0%	-	-	-	-	*
4-Nitrophenol	2	µg/L	0%	-	-	-	-	*
Acenaphthene	2	µg/L	0%	-	-	-	-	*
Acenaphthylene	2	µg/L	0%	-	-	-	-	*
Acetone	20	µg/L	10%	6.2	4.45	2.47	56%	6.2
Acrolein	20	µg/L	0%	-	-	-	-	*
Acrylonitrile	20	µg/L	0%	-	-	-	-	*
Alkalinity (as CaCO3)	20	mg/L	100%	304	200.10	33.49	17%	*
Ammonia as Nitrogen, Total	20	mg/L as N	55%	0.067	0.03	0.02	62%	*
Anthracene	2	µg/L	0%	-	-	-	-	*
Antimony, Dissolved	20	µg/L	0%	-	-	-	-	*
Arsenic, Dissolved	20	µg/L	95%	5.2	3.93	0.59	15%	4.158
Barium, Dissolved	20	µg/L	100%	73	31.90	18.46	58%	*
Benz(a)anthracene	2	µg/L	0%	-	-	-	-	*
Benzene	20	µg/L	0%	-	-	-	-	*
Benzo(a)pyrene	2	µg/L	0%	-	-	-	-	*
Benzo(b)fluoranthene	2	µg/L	0%	-	-	-	-	*
Benzo(g,h,i)perylene	2	µg/L	0%	-	-	-	-	*
Benzo(k)fluoranthene	2	µg/L	0%	-	-	-	-	*
Benzoic Acid	2	µg/L	0%	-	-	-	-	*
Benzyl Alcohol	2	µg/L	0%	-	-	-	-	*
Beryllium, Dissolved	20	µg/L	0%	-	-	-	-	*
Bicarbonate As CaCO3	20	mg/L	100%	304	200.10	33.49	17%	*
Bis(2-chloroethoxy)methane	2	µg/L	0%	-	-	-	-	*
Bis(2-chloroethyl) Ether	2	µg/L	0%	-	-	-	-	*
Bis(2-ethylhexyl) Phthalate	6	µg/L	17%	3.6	3.60	-	-	*
Bromobenzene	20	µg/L	0%	-	-	-	-	*
Bromochloromethane	20	µg/L	0%	-	-	-	-	*
Bromodichloromethane	20	µg/L	0%	-	-	-	-	*
Bromoethane	20	µg/L	0%	-	-	-	-	*
Bromoform	20	µg/L	0%	-	-	-	-	*
Bromomethane	20	µg/L	0%	-	-	-	-	*
Butylbenzyl Phthalate	6	µg/L	0%	-	-	-	-	*
Cadmium, Dissolved	20	µg/L	0%	-	-	-	-	*
Calcium, Total	20	mg/L	100%	86.8	52.80	10.61	20%	*
Carbazole	2	µg/L	0%	-	-	-	-	*
Carbon dioxide	2	mg/L	100%	38	21.75	22.98	106%	*
Carbon Disulfide	20	µg/L	0%	-	-	-	-	*
Carbon Tetrachloride	20	µg/L	0%	-	-	-	-	*
Carbonate as CaCO3	20	mg/L	0%	-	-	-	-	*
Chloride	20	mg/L	100%	22.1	16.00	2.36	15%	*
Chlorobenzene	20	µg/L	0%	-	-	-	-	*
Chloroethane	20	µg/L	0%	-	-	-	-	*
Chloroform	20	µg/L	0%	-	-	-	-	*
Chloromethane	20	µg/L	0%	-	-	-	-	*
Chromium, Dissolved	20	µg/L	0%	-	-	-	-	*
Chrysene	2	µg/L	0%	-	-	-	-	*

Table C-7. Landfill Plume - Outwash Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
cis-1,2-Dichloroethene	20	µg/L	0%	-	-	-	-	*
cis-1,3-Dichloropropene	20	µg/L	0%	-	-	-	-	*
Cobalt, Dissolved	20	µg/L	0%	-	-	-	-	*
Copper, Dissolved	20	µg/L	35%	3	2.43	0.53	22%	*
Dibenz(a,h)anthracene	2	µg/L	0%	-	-	-	-	*
Dibenzofuran	2	µg/L	0%	-	-	-	-	*
Dibromochloromethane	20	µg/L	0%	-	-	-	-	*
Dibromomethane	20	µg/L	0%	-	-	-	-	*
Diethyl Phthalate	6	µg/L	0%	-	-	-	-	*
Dimethyl Phthalate	2	µg/L	0%	-	-	-	-	*
Di-n-butyl Phthalate	6	µg/L	0%	-	-	-	-	*
Di-n-octyl Phthalate	2	µg/L	0%	-	-	-	-	*
Dissolved Oxygen	4	mg/L	100%	11.61	8.21	2.44	30%	*
Ethane	4	µg/L	0%	-	-	-	-	*
Ethylbenzene	20	µg/L	0%	-	-	-	-	*
Ethylene Dibromide (EDB)	20	µg/L	0%	-	-	-	-	*
Fluoranthene	2	µg/L	0%	-	-	-	-	*
Fluorene	2	µg/L	0%	-	-	-	-	*
Hexachlorobenzene	2	µg/L	0%	-	-	-	-	*
Hexachlorobutadiene	22	µg/L	0%	-	-	-	-	*
Hexachlorocyclopentadiene	2	µg/L	0%	-	-	-	-	*
Hexachloroethane	2	µg/L	0%	-	-	-	-	*
Hydrogen Sulfide	2	mg/L	100%	0	0.00	-	-	*
Hydroxide (as CaCO3)	20	mg/L	0%	-	-	-	-	*
Indeno(1,2,3-cd)pyrene	2	µg/L	0%	-	-	-	-	*
Iron, Dissolved	12	µg/L	0%	-	-	-	-	*
Iron, Total	20	µg/L	25%	1030	436.00	432.76	99%	*
Isophorone	2	µg/L	0%	-	-	-	-	*
Isopropylbenzene (Cumene)	20	µg/L	0%	-	-	-	-	*
Lead, Dissolved	20	µg/L	0%	-	-	-	-	*
Magnesium, Total	20	mg/L	100%	30.2	19.81	3.73	19%	9.5
Manganese, Dissolved	12	µg/L	17%	1	1.00	0.00	0%	*
Manganese, Total	20	µg/L	30%	41	12.67	16.13	127%	*
Methane	2	µg/L	50%	1.9	1.90	-	-	*
Methyl iodide	20	µg/L	0%	-	-	-	-	*
Methylene Chloride	20	µg/L	5%	0.5	0.50	-	-	*
Naphthalene	24	µg/L	0%	-	-	-	-	*
n-Butylbenzene	20	µg/L	0%	-	-	-	-	*
Nickel, Dissolved	20	µg/L	0%	-	-	-	-	*
Nitrate as Nitrogen	22	mg/L as N	100%	5.54	4.35	0.87	20%	*
Nitrate+Nitrite as Nitrogen	22	mg/L as N	100%	5.57	4.37	0.87	20%	*
Nitrite as Nitrogen	22	mg/L as N	64%	0.039	0.03	0.01	19%	*
Nitrobenzene	2	µg/L	0%	-	-	-	-	*
N-Nitrosodi-n-propylamine	2	µg/L	0%	-	-	-	-	*
N-Nitrosodiphenylamine	2	µg/L	0%	-	-	-	-	*
n-Propylbenzene	20	µg/L	0%	-	-	-	-	*
o-Xylene	20	µg/L	0%	-	-	-	-	*
Pentachlorophenol	2	µg/L	0%	-	-	-	-	*

Table C-7. Landfill Plume - Outwash Aquifer Component Groundwater Data Statistics

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
pH	21	std. units	100%	7.81	7.13	0.51	7%	*
Phenanthrene	2	µg/L	0%	-	-	-	-	*
Phenol	2	µg/L	0%	-	-	-	-	*
Potassium, Total	20	mg/L	100%	9.7	5.74	3.28	57%	*
Pyrene	2	µg/L	0%	-	-	-	-	*
sec-Butylbenzene	20	µg/L	0%	-	-	-	-	*
Selenium, Dissolved	20	µg/L	60%	1	0.83	0.12	15%	*
Silver, Dissolved	20	µg/L	0%	-	-	-	-	*
Sodium, Total	20	mg/L	100%	36.3	27.25	4.06	15%	*
Specific Conductance @ 25C	20	umhos/cm	100%	767	534.15	133.47	25%	*
Styrene	20	µg/L	0%	-	-	-	-	*
Sulfate	20	mg/L	100%	61.5	49.22	8.77	18%	*
Temperature, 0 F	20	0 F	100%	65.3	59.96	2.58	4%	*
tert-Butylbenzene	20	µg/L	0%	-	-	-	-	*
Tetrachloroethene (PCE)	22	µg/L	36%	0.2	0.15	0.05	30%	0.152
Thallium, Dissolved	20	µg/L	0%	-	-	-	-	*
Toluene	20	µg/L	0%	-	-	-	-	*
Total Dissolved Solids	20	mg/L	100%	397	347.25	37.70	11%	*
Total Kjeldahl Nitrogen	4	mg/L as N	50%	1.04	0.99	0.08	8%	*
Total Organic Carbon	20	mg/L	45%	3.62	2.44	0.50	20%	*
trans-1,2-Dichloroethene	20	µg/L	0%	-	-	-	-	*
trans-1,3-Dichloropropene	20	µg/L	0%	-	-	-	-	*
trans-1,4-Dichloro-2-butene	20	µg/L	0%	-	-	-	-	*
Trichloroethene (TCE)	22	µg/L	14%	0.15	0.12	0.03	21%	0.127
Trichlorofluoromethane	20	µg/L	45%	0.9	0.63	0.15	24%	0.642
Vanadium, Dissolved	20	µg/L	100%	63	34.70	21.61	62%	*
Vinyl Acetate	20	µg/L	0%	-	-	-	-	*
Vinyl Chloride	22	µg/L	0%	-	-	-	-	*
Xylene Isomers, M+P	20	µg/L	0%	-	-	-	-	*
Zinc, Dissolved	20	µg/L	0%	-	-	-	-	*

* Insufficient data to calculate a 95th Upper Confidence Level (UCL) (i.e., N ≤ 5), or constituent was not a COC

N = Sample size

%FOD = Percent Frequency of Detection

Max = Maximum value detected

Mean = Mean value detected

STDEV = Standard deviation of detected values

COV = Coefficient of Variation of detected values

Table C-8.Statistics for the Groundwater Data Used to Determine Vapor Intrusion Concentrations at the New Scale and Maintenance Shop

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
1,1,1,2-Tetrachloroethane	15	ug/L	0%	-	-	-	-	*
1,1,1-Trichloroethane	15	ug/l	0%	-	-	-	-	*
1,1,2,2-Tetrachloroethane	16	ug/L	0%	-	-	-	-	*
1,1,2-Trichloroethane	15	ug/L	0%	-	-	-	-	*
1,1,2-Trichlorotrifluoroethane	15	ug/L	0%	-	-	-	-	*
1,1-Dichloroethane	15	ug/L	0%	-	-	-	-	*
1,1-Dichloroethene	16	ug/L	0%	-	-	-	-	*
1,1-Dichloropropene	15	ug/L	0%	-	-	-	-	*
1,2,3-Trichlorobenzene	15	ug/L	0%	-	-	-	-	*
1,2,3-Trichloropropane	15	ug/L	0%	-	-	-	-	*
1,2,4-Trichlorobenzene	17	ug/L	0%	-	-	-	-	*
1,2,4-Trimethylbenzene	15	ug/L	0%	-	-	-	-	*
1,2-Dibromo-3-chloropropane	15	ug/L	0%	-	-	-	-	*
1,2-Dichlorobenzene	17	ug/L	0%	-	-	-	-	*
1,2-Dichloroethane (EDC)	15	ug/L	0%	-	-	-	-	*
1,2-Dichloropropane	15	ug/L	0%	-	-	-	-	*
1,3,5-Trimethylbenzene	15	ug/L	0%	-	-	-	-	*
1,3-Dichlorobenzene	18	ug/L	0%	-	-	-	-	*
1,3-Dichloropropane	15	ug/L	0%	-	-	-	-	*
1,4-Dichlorobenzene	17	ug/L	0%	-	-	-	-	*
1-Methylnaphthalene	2	ug/L	0%	-	-	-	-	*
2,2-Dichloropropane	15	ug/L	0%	-	-	-	-	*
2,2-Oxybis(1-Chloropropane)	2	ug/L	0%	-	-	-	-	*
2,4,5-Trichlorophenol	2	ug/L	0%	-	-	-	-	*
2,4,6-Trichlorophenol	2	ug/L	0%	-	-	-	-	*
2,4-Dichlorophenol	2	ug/L	0%	-	-	-	-	*
2,4-Dimethylphenol	2	ug/L	0%	-	-	-	-	*
2,4-Dinitrophenol	2	ug/L	0%	-	-	-	-	*
2,4-Dinitrotoluene	2	ug/L	0%	-	-	-	-	*
2,6-Dinitrotoluene	2	ug/L	0%	-	-	-	-	*
2-butanone	15	ug/L	0%	-	-	-	-	*
2-Chloroethylvinylether	15	ug/L	0%	-	-	-	-	*
2-Chloronaphthalene	2	ug/L	0%	-	-	-	-	*
2-Chlorophenol	2	ug/L	0%	-	-	-	-	*
2-Chlorotoluene	15	ug/L	0%	-	-	-	-	*
2-Hexanone	15	ug/L	0%	-	-	-	-	*
2-Methyl-4,6-dinitrophenol	2	ug/L	0%	-	-	-	-	*
2-Methylnaphthalene	2	ug/L	0%	-	-	-	-	*
2-Methylphenol	2	ug/L	0%	-	-	-	-	*
2-Nitroaniline	2	ug/L	0%	-	-	-	-	*
2-Nitrophenol	2	ug/L	0%	-	-	-	-	*
3,3'-Dichlorobenzidine	2	ug/L	0%	-	-	-	-	*
3-Nitroaniline	2	ug/L	0%	-	-	-	-	*
4-Bromophenyl Phenyl Ether	2	ug/L	0%	-	-	-	-	*
4-Chloro-3-methylphenol	4	ug/L	0%	-	-	-	-	*
4-Chloroaniline	2	ug/L	0%	-	-	-	-	*
4-Chlorophenyl Phenyl Ether	2	ug/l	0%	-	-	-	-	*
4-Chlorotoluene	15	ug/L	0%	-	-	-	-	*
4-Isopropyltoluene	15	ug/L	0%	-	-	-	-	*
4-Methyl-2-pentanone (MIBK)	15	ug/L	0%	-	-	-	-	*
4-Methylphenol	2	ug/L	0%	-	-	-	-	*
4-Nitroaniline	2	ug/L	0%	-	-	-	-	*
4-Nitrophenol	2	ug/L	0%	-	-	-	-	*

Table C-8.Statistics for the Groundwater Data Used to Determine Vapor Intrusion Concentrations at the New Scale and Maintenance Shop

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
Acenaphthene	2	ug/L	0%	-	-	-	-	*
Acenaphthylene	2	ug/L	0%	-	-	-	-	*
Acetone	15	ug/L	7%	5.3	5.3	-	-	**
Acrolein	15	ug/L	0%	-	-	-	-	*
Acrylonitrile	15	ug/L	0%	-	-	-	-	*
Alkalinity (as CaCO3)	15	mg/L	100%	244	220.9	16.9	8%	*
Ammonia as Nitrogen, Total	12	mg/L as N	42%	0.048	0.021	0.015	74%	*
Anthracene	2	ug/L	0%	-	-	-	-	*
Antimony, Dissolved	12	ug/L	0%	-	-	-	-	*
Arsenic, Dissolved	14	ug/L	100%	5.8	3.3	1.0	31%	N/A
Barium, Dissolved	12	ug/L	100%	26	15.6	4.3	27%	*
Benz(a)anthracene	2	ug/L	0%	-	-	-	-	*
Benzene	15	ug/L	0%	-	-	-	-	*
Benzo(a)pyrene	2	ug/L	0%	-	-	-	-	*
Benzo(b)fluoranthene	2	ug/L	0%	-	-	-	-	*
Benzo(g,h,i)perylene	2	ug/L	0%	-	-	-	-	*
Benzo(k)fluoranthene	2	ug/L	0%	-	-	-	-	*
Benzoic Acid	2	ug/L	0%	-	-	-	-	*
Benzyl Alcohol	2	ug/L	0%	-	-	-	-	*
Beryllium, Dissolved	12	ug/L	0%	-	-	-	-	*
Bicarbonate As CaCO3	15	mg/L	100%	244	220.9	16.9	8%	*
Bis(2-chloroethoxy)methane	1	mg/L	0%	-	-	-	-	*
Bis(2-chloroethoxy)methane	2	ug/L	0%	-	-	-	-	*
Bis(2-chloroethyl) Ether	2	ug/L	0%	-	-	-	-	*
Bis(2-ethylhexyl) Phthalate	4	ug/L	25%	5.3	5.3	-	-	**
Bromobenzene	15	ug/L	0%	-	-	-	-	*
Bromochloromethane	15	ug/L	0%	-	-	-	-	*
Bromodichloromethane	15	ug/L	0%	-	-	-	-	*
Bromoethane	15	ug/L	0%	-	-	-	-	*
Bromoform	15	ug/L	7%	0.5	0.5	-	-	*
Bromomethane	15	ug/L	0%	-	-	-	-	*
Butylbenzyl Phthalate	4	ug/L	0%	-	-	-	-	*
Cadmium, Dissolved	15	ug/L	20%	55.5	50.6	6.7	13%	*
Calcium, Total	15	mg/L	100%	63.6	53	5.3	10%	*
Carbazole	2	ug/L	0%	-	-	-	-	*
Carbon dioxide	2	mg/L	100%	18	18	0	0%	*
Carbon Disulfide	15	ug/L	0%	-	-	-	-	*
Carbon Tetrachloride	15	ug/L	0%	-	-	-	-	*
Carbonate as CaCO3	15	mg/L	0%	-	-	-	-	*
Chloride	15	mg/L	100%	26.7	14.6	4.4	30%	N/A
Chlorobenzene	15	ug/L	0%	-	-	-	-	*
Chloroethane	15	ug/L	0%	-	-	-	-	*
Chloroform	15	ug/L	0%	-	-	-	-	*
Chloromethane	15	ug/L	0%	-	-	-	-	*
Chromium, Dissolved	12	ug/L	8%	5	5	-	-	*
Chrysene	2	ug/L	0%	-	-	-	-	*
cis-1,2-Dichloroethene	15	ug/L	0%	-	-	-	-	*
cis-1,3-Dichloropropene	15	ug/L	0%	-	-	-	-	*
Cobalt, Dissolved	12	ug/L	0%	-	-	-	-	*
Copper, Dissolved	12	ug/L	50%	3	2.5	0.5	22%	*
Depth to Water	17	feet	100%	38.5	31.0	7.3	24%	*
Dibenz(a,h)anthracene	2	ug/L	0%	-	-	-	-	*
Dibenzofuran	2	ug/L	0%	-	-	-	-	*

Table C-8.Statistics for the Groundwater Data Used to Determine Vapor Intrusion Concentrations at the New Scale and Maintenance Shop

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
Dibromochloromethane	15	ug/L	0%	-	-	-	-	*
Dibromomethane	15	ug/L	0%	-	-	-	-	*
Diethyl Phthalate	4	ug/L	0%	-	-	-	-	*
Dimethyl Phthalate	2	ug/L	0%	-	-	-	-	*
Di-n-butyl Phthalate	4	ug/L	0%	-	-	-	-	*
Di-n-octyl Phthalate	2	ug/L	0%	-	-	-	-	*
Dissolved Oxygen	4	mg/L	100%	8.6	7.8	0.9	12%	*
Ethylbenzene	15	ug/L	0%	-	-	-	-	*
Ethylene Dibromide (EDB)	15	ug/L	0%	-	-	-	-	*
Fluoranthene	2	ug/L	0%	-	-	-	-	*
Fluorene	2	ug/L	0%	-	-	-	-	*
Hexachlorobenzene	2	ug/L	0%	-	-	-	-	*
Hexachlorobutadiene	17	ug/L	0%	-	-	-	-	*
Hexachlorocyclopentadiene	2	ug/L	0%	-	-	-	-	*
Hexachloroethane	2	ug/L	0%	-	-	-	-	*
Hexane	2	ug/L	0%	-	-	-	-	*
Hydrogen Sulfide	2	mg/L	100%	0	0	0	-	*
Hydroxide (as CaCO3)	15	mg/L	0%	-	-	-	-	*
Indeno(1,2,3-cd)pyrene	2	ug/L	0%	-	-	-	-	*
Iron, Dissolved	8	ug/L	0%	-	-	-	-	*
Iron, Total	14	ug/L	29%	270	140	95.9	69%	*
Isophorone	2	ug/L	0%	-	-	-	-	*
Isopropylbenzene (Cumene)	15	ug/L	0%	-	-	-	-	*
Lead, Dissolved	15	ug/L	20%	21.3	20.2	1.8	9%	*
Magnesium, Total	15	mg/L	100%	25	21.0	1.9	9%	*
Manganese, Dissolved	8	ug/L	13%	2	2	-	-	*
Manganese, Total	14	ug/L	36%	6	3.4	2.1	61%	*
Methane	2	ug/L	0%	-	-	-	-	*
Methyl iodide	15	ug/L	0%	-	-	-	-	*
Methyl tert-Butyl Ether	2	ug/L	0%	-	-	-	-	*
Methylene Chloride	15	ug/l	0%	-	-	-	-	*
Naphthalene	18	ug/L	0%	-	-	-	-	*
n-Butylbenzene	15	ug/L	0%	-	-	-	-	*
Nickel, Dissolved	12	ug/L	0%	-	-	-	-	*
Nitrate as Nitrogen	16	mg/L as N	100%	5.07	3.9	1.0	24%	N/A
Nitrate+Nitrite as Nitrogen	16	mg/L as N	100%	5.07	4.0	1.0	24%	*
Nitrite as Nitrogen	16	mg/L as N	63%	0.034	0.03	0.01	24%	*
Nitrobenzene	2	ug/L	0%	-	-	-	-	*
N-Nitrosodi-n-propylamine	2	ug/L	0%	-	-	-	-	*
N-Nitrosodiphenylamine	2	ug/L	0%	-	-	-	-	*
n-Propylbenzene	15	ug/L	0%	-	-	-	-	*
Oxidation Reduction Potential	8	mV	100%	314	74.4	142.7	192%	*
o-Xylene	15	ug/L	0%	-	-	-	-	*
Pentachlorophenol	2	ug/L	0%	-	-	-	-	*
pH	15	std. units	100%	7.43	7.02	0.6	9%	*
Phenanthrene	2	ug/L	0%	-	-	-	-	*
Phenol	2	ug/L	0%	-	-	-	-	*
Potassium, Total	15	mg/L	100%	8.5	7.9	0.4	6%	*
Pyrene	2	ug/L	0%	-	-	-	-	*
sec-Butylbenzene	15	ug/L	0%	-	-	-	-	*
Selenium, Dissolved	12	ug/L	67%	1	0.8	0.2	19%	*
Silver, Dissolved	12	ug/L	0%	-	-	-	-	*
Sodium, Total	15	mg/L	100%	34	31.0	1.6	5%	*

Table C-8.Statistics for the Groundwater Data Used to Determine Vapor Intrusion Concentrations at the New Scale and Maintenance Shop

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
Specific Conductance @ 25C	15	umhos/cm	100%	748	597.5	87.6	15%	*
Styrene	15	ug/L	0%	-	-	-	-	*
Sulfate	15	mg/L	100%	53.3	42.7	5.5	13%	*
Temperature, 0 F	15	0 F	100%	60.1	57.6	1.7	3%	*
tert-Butylbenzene	15	ug/L	0%	-	-	-	-	*
Tetrachloroethene (PCE)	16	ug/L	50%	0.12	0.10	0.01	15%	0.114
Thallium, Dissolved	12	ug/L	0%	-	-	-	-	*
Toluene	15	ug/L	7%	1.2	1.2	-	-	**
Total Dissolved Solids	15	mg/L	100%	534	372.7	54.5	15%	*
Total Kjeldahl Nitrogen	4	mg/L as N	0%	-	-	-	-	*
Total Organic Carbon	15	mg/L	80%	18.1	4.7	5.9	124%	*
trans-1,2-Dichloroethene	15	ug/L	0%	-	-	-	-	*
trans-1,3-Dichloropropene	15	ug/L	0%	-	-	-	-	*
trans-1,4-Dichloro-2-butene	15	ug/L	0%	-	-	-	-	*
Trichloroethene (TCE)	16	ug/L	0%	-	-	-	-	*
Trichlorofluoromethane	15	ug/l	0%	-	-	-	-	*
Vanadium, Dissolved	12	ug/L	100%	25	22.4	1.2	6%	*
Vinyl Acetate	15	ug/L	0%	-	-	-	-	*
Vinyl Chloride	16	ug/L	0%	-	-	-	-	*
Xylene Isomers, M+P	15	ug/L	0%	-	-	-	-	*
Zinc, Dissolved	12	ug/L	8%	10	10	-	-	*

* Insufficient data to calculate a 95th Upper Confidence Level (UCL) (i.e., N ≤ 5), or constituent was not a COC

** Maximum concentration was used to identify IHS when the 95th UCL could not be calculated by ProUCL (zero variance)

N/A = COC is not a volatile or semi-volatile organic compound and therefore would not volatilize
N = Sample size
%FOD = Percent Frequency of Detection
Max = Maximum value detected
Mean = Mean value detected
STDEV = Standard deviation of detected values
COV = Coefficient of Variation of detected values

Table C-9.Statistics for Source Area Groundwater Data

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
1,1,1-Trichloroethane	182	ug/L	10%	4200	461.8	1116	242%	228.5
1,1,2-Trichloroethane	182	ug/L	2%	35	12.93	16.16	125%	35
1,1-Dichloroethane	182	ug/L	65%	4500	124.4	565.2	454%	293.2
1,1-Dichloroethene	194	ug/L	47%	710	20.63	98.13	476%	40.19
1,2,4-Trimethylbenzene	182	ug/L	9%	300	78.45	77.36	99%	17.55
1,2-Dichlorobenzene	182	ug/L	27%	17	3.81	4.354	114%	2.134
1,2-Dichloroethane (EDC)	182	ug/L	37%	440	20.52	79.26	386%	30.7
1,2-Dichloropropane	182	ug/L	48%	1200	61.88	223.5	361%	102.7
1,3,5-Trimethylbenzene	182	ug/L	8%	160	36.57	42.21	115%	10.34
1,3-Dichlorobenzene	182	ug/L	5%	4.7	0.811	1.461	180%	0.403
1,4-Dichlorobenzene	182	ug/L	31%	32	3.302	5.759	174%	2.87
2-Butanone	182	ug/L	2%	9000	2910	4238	146%	338.2
2-Hexanone	182	ug/L	1%	340	206.5	188.8	91%	340
2-Methylphenol**	22	ug/L	9%	510	330	254.6	77%	205.3
4-Isopropyltoluene	182	ug/L	4%	3.6	1.188	1.202	101%	0.542
4-Methyl-2-pentanone (MIBK)	182	ug/L	3%	3700	913.2	1433	157%	136.6
4-Methylphenol**	22	ug/L	9%	430	300	183.8	61%	209.9
Acetone	182	ug/L	22%	26000	966.1	4480	464%	1205
Arsenic, Dissolved	171	ug/L	91%	16.4	3.903	3.604	92%	4.767
Benzene	182	ug/L	34%	150	17.35	36.58	211%	16.46
Bis(2-ethylhexyl) Phthalate	35	ug/L	14%	11	6.32	4.011	63%	2.88
Bromobenzene	182	ug/L	12%	3.2	0.668	0.723	108%	0.406
Chloroethane	182	ug/L	34%	1600	125.1	272.7	218%	121.5
Chloroform	182	ug/L	17%	280	23.31	66.43	285%	17.48
Chloromethane	182	ug/L	1%	0.3	0.3	0	0%	*
cis-1,2-Dichloroethene	182	ug/L	62%	1100	38.03	142.6	375%	76.39
Ethylbenzene	182	ug/L	12%	1300	265.7	366.9	138%	51.77
Iron, Dissolved	112	ug/L	38%	34000	4723	6733	143%	4660
Manganese, Dissolved	112	ug/L	70%	23100	4666	6978	150%	5808
Methylene Chloride	182	ug/L	30%	230	11.34	43.06	380%	15.09
Naphthalene	182	ug/L	5%	34	11.18	10.89	97%	6.09
n-Butylbenzene	182	ug/L	1%	0.2	0.2	N/A	N/A	*
Nitrate as Nitrogen	192	mg/L as N	77%	24.9	6.872	5.985	87%	7.15
o-Xylene	182	ug/L	17%	2000	234.3	456.3	195%	136.6
sec-Butylbenzene	182	ug/L	2%	0.4	0.275	0.0957	35%	0.205
Tetrachloroethene (PCE)	194	ug/L	73%	24	2.631	4.163	158%	3.655
Toluene	182	ug/L	18%	18000	1708	3989	234%	1155
trans-1,2-Dichloroethene	182	ug/L	25%	9.1	1.029	1.466	142%	0.712
Trichloroethene (TCE)	194	ug/L	69%	180	3.048	16.1	528%	8.163
Trichlorofluoromethane	182	ug/L	18%	5.5	2.224	1.937	87%	0.728
Vinyl Chloride	194	ug/L	48%	1300	56.97	197	346%	90.44
Xylene Isomers, M+P	182	ug/L	10%	4000	699.9	1064	152%	262.4

* Maximum concentration was used to identify IHS when the 95th UCL could not be calculated by ProUCL (zero variance)

** 2-Methylphenol and 4-methylphenol were detected in groundwater samples collected in September 2010 from two source area wells (MW-35p2 and MW-38p2).

N = Sample size

%FOD = Percent Frequency of Detection

Max = Maximum value detected

Mean = Mean value detected

STDEV = Standard deviation of detected values

COV = Coefficient of Variation of detected values

Table C-10.Statistics for North End Soils Data

Constituent	N	Units	%FOD	Max	Mean	STD	COV	95th UCL
Arsenic, Total	18	mg/kg	100%	14.8	5.31	4.01	75%	7.28
Iron, Total	18	mg/kg	100%	98700	49261	22174	45%	59215
Manganese, Total	18	mg/kg	100%	1880	538.39	346.94	64%	1352
Nitrate	18	mg-N/kg	67%	77.6	13.9	23.6	170%	25.0
Total Solids	18	Percent	100%	95.4	85.4	6.90	8%	88.2
Chloride	18	mg/kg	94%	410	132	111	84%	178
Nitrate+Nitrite	18	mg-N/kg	67%	78.1	14.0	23.8	170%	25.1
Nitrite	18	mg-N/kg	50%	0.52	0.169	0.100	59%	0.404
Sulfate	18	mg/kg	100%	19400	2926	5731	196%	16367
1,1-Dichloroethane	18	mg/kg	0%	-	-	-	-	-
1,1-Dichloroethene	18	mg/kg	0%	-	-	-	-	-
1,2-Dichlorobenzene	18	mg/kg	0%	-	-	-	-	-
1,2-Dichloroethane (EDC)	18	mg/kg	0%	-	-	-	-	-
1,2-Dichloropropane	18	mg/kg	6%	0.0038	0.0323	0.0411	-	*
1,4-Dichlorobenzene	18	mg/kg	17%	2.2	0.230	0.603	262%	0.539
Benzene	18	mg/kg	50%	0.23	0.0415	0.0572	138%	0.147
Chloroethane	18	mg/kg	0%	-	-	-	-	-
Chloromethane	18	mg/kg	0%	-	-	-	-	-
cis-1,2-Dichloroethene	18	mg/kg	33%	2.8	0.282	0.690	245%	1.36
Ethylbenzene	18	mg/kg	56%	1	0.129	0.256	198%	0.228
Methylene Chloride	18	mg/kg	0%	-	-	-	-	-
o-Xylene	18	mg/kg	33%	1.4	0.118	0.326	276%	0.930
Tetrachloroethene (PCE)	18	mg/kg	50%	4	0.270	0.935	346%	2.52
Toluene	18	mg/kg	72%	2.3	0.171	0.535	312%	0.724
trans-1,2-Dichloroethene	18	mg/kg	0%	-	-	-	-	-
Trichloroethene (TCE)	18	mg/kg	39%	1.1	0.205	0.358	175%	0.351
Trichlorofluoromethane (CFC 11)	18	mg/kg	0%	-	-	-	-	-
Vinyl Chloride	18	mg/kg	17%	0.28	0.0454	0.0692	152%	0.28
Xylene Isomers, M+P	18	mg/kg	50%	2.7	0.229	0.631	275%	1.75

* For 1,2-dichloropropane, the maximum detected concentration was used as the 95th UCL because a 95th UCL could not be calculated by ProUCL (zero variance of detected concentrations).

N = Sample size

%FOD = Percent Frequency of Detection

Max = Maximum value detected

Mean = Mean value detected

STDEV = Standard deviation of detected values

COV = Coefficient of Variation of detected values

Table C-11. Groundwater COCs with MTCA Method B SFVs Dropped from the CLARC Database and Risk-based Screening Values Calculated from Toxicity Values Found in Tier 3 Sources

Chemical	CAS RN	Exposure Pathway		Toxicity Value[1]	Groundwater Ingestion Screening Value from Tier 3 Sources (Calculated using MTCA Method B Equation 720-2) (μg/L)	Screening Values Derived for Groundwater Based on Indoor Air Inhalation	
						Air Screening Value from Tier 3 Sources (Calculated using MTCA Method B Equations 750-1 and 750-2) (μg/m^3)	Derived Groundwater Screening Value (μg/L)[2]
1,1-Dichloroethane	75-34-3	Noncarcinogenic	Inhalation	0.1	---[3]	160	1,150
		Carcinogenic	Inhalation	0.0057	---	1.5	11
1,2,4-Trimethylbenzene	95-63-6	Noncarcinogenic	Ingestion	N/A[4]	N/A	---	---
1,2-Dichloroethane (EDC)	107-06-2	Noncarcinogenic	Inhalation	N/A	---	N/A	N/A
1,2-Dichloropropane	78-87-5	Carcinogenic	Inhalation	0.036	---	0.24	3.7
		Carcinogenic	Ingestion	0.036	1.2	---	---
Chloroethane	75-00-3	Noncarcinogenic	Ingestion	N/A	N/A	---	---
		Carcinogenic	Ingestion	N/A	N/A	---	---
Chloroform	67-66-3	Carcinogenic	Ingestion	0.031	1.4	---	---
Chloromethane	74-87-3	Carcinogenic	Ingestion	0.013	3.4	---	---
cis-1,2-Dichloroethene	156-59-2	Noncarcinogenic	Inhalation	N/A	---	N/A	N/A
Methylene Chloride	75-09-2	Noncarcinogenic	Inhalation	N/A	---	N/A	N/A

[1] Units are mg/kg-day for noncarcinogenic toxicity values and (mg/kg-day)$^{-1}$ for carcinogenic toxicity values.

[2] MTCA Method B risk-based screening values for the inhalation pathway are groundwater values derived from MTCA Method B air SFVs using the equation and methods provided by Ecology (2009).

[3] Calculation of screening value was not appropriate for the specified exposure pathway.

[4] No value was available from any Tier 3 source (chemical not included, no toxicity value listed for the applicable exposure pathway, or toxicity value not applicable for use in MTCA risk calculations).

Table C-12. MTCA Method B Indoor Air Standard Formula Values and Associated Groundwater Screening Levels for Volatile COCs Detected in Plume Components with a Complete Indoor Air Exposure Pathway or in Shallow Groundwater under the New Scale and Maintenance Shop

COC	CAS #	Method B Indoor Air SFV, C (µg/m^3)[1]	Method B Indoor Air SFV, NC (µg/m^3)[1]	Adjusted Henry's Law Constant	Method B Groundwater SL, C (µg/L)[2]	Method B Groundwater SL, NC (µg/L)[2]	Method C Groundwater SL, C (µg/L)[3]	Method C Groundwater SL, NC (µg/L)[4]
1,1,1-Trichloroethane	71-55-6	NR	2,300	0.417	--	5,515	--	17,233
1,1-Dichloroethane	75-34-3	1.5	160	0.139	11	1,150	154	3,594
1,1-Dichloroethene	75-35-4	RND	91	0.700	--	130	--	406
1,2-Dichloroethane (EDC)	107-06-2	0.096	RND	0.0229	4.2	--	60	--
1,2-Dichloropropane	78-87-5	0.24	1.8	0.0643	3.7	28	53	88
Acetone	67-64-1	NR	NR	0.000965	--	--	--	--
bis(2-Ethylhexyl)phthalate	117-81-7	NR	NR	0.000000656	--	--	--	--
cis-1,2-Dichloroethene	156-59-2	NR	RND	0.100	--	--	--	--
Methylene chloride	75-09-2	5.3	RND	0.0564	94	--	1,343	--
Tetrachloroethene (PCE)[5]	127-18-4	9.6	18	0.420	23	43	327	134
Toluene	108-88-3	NR	2,300	0.147	--	15,682	--	49,006
Trichloroethene (TCE)[5]	79-01-6	0.37	0.90	0.238	1.6	3.8	22	12

Definitions:

C = Carcinogen.
NC = Noncarcinogen.
NR = Not Researched (CLARC Database).
RND = Researched - No Data (CLARC Database).
SFV = Standard formula value.
SL = Screening level.
-- = Not calculated (no SFV).

[1] Provided by Ecology (Ecology 2011). Based on MTCA Equation 750-1 for noncarcinogens and 750-2 for carcinogens.

[2] Calculated from the Indoor Air SFV using Equation 1 in Ecology's draft vapor intrusion guidance (Ecology 2009) adjusted for Henry's Law Constant at 13°C (the CLARC Database provides Henry's Law Constants at 25°C).

[3] Calculated from Method B SL, adjusted for a risk level of 1 in 100,000 and an exposure frequency of 0.7.

[4] Calculated from Method B SL using an average body weight of 70 kg, a breathing rate of 20 m^3/day, and an exposure frequency of 0.7.

[5] PCE and TCE Method B Air SFVs were calculated by based on new EPA toxicity values (Ecology 2012) .

APPENDIX D

Background Arsenic Concentrations in Groundwater for the Ephrata Landfill RI/FS

PACIFIC groundwater GROUP

Technical Memorandum

To: Charlie Wisdom and Linda Logan (Parametrix, Inc.)

From: Dawn Chapel and Charles Ellingson (Pacific Groundwater Group)

Re: Background Arsenic Concentrations in Groundwater for the Ephrata Landfill RI/FS

Date: January 25, 2011

This memorandum provides an improved assessment of background concentrations for dissolved arsenic in groundwater for the Ephrata Landfill RI/FS. An arsenic background concentration of 3.0 ug/L was presented in the Remedial Investigation Report (PGG, 2010b) [1]. The RI value was based on groundwater data collected from 18 wells completed in basalt aquifers with concentrations ranging from 0.10 to 4.30 ug/L (Table 1). The wells chosen for the RI assessment were those that did not have detections of volatile organic compounds (VOCs) and were therefore not likely impacted by the Landfill. However, it was noted in the RI that arsenic concentrations were generally higher in the Outwash aquifer with concentrations ranging from 2.5 to 10.0 ug/L. The higher concentration of arsenic in the Outwash aquifer is likely natural and related to differences in aquifer mineralogy; however; groundwater data from Outwash aquifer wells were not used in the RI assessment because of low level detections of VOCs.

The imroved assessment presented in this memo includes expanding the groundwater arsenic dataset to include data from the U.S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) for Grant County. Inclusion of the NAWQA dataset expands the arsenic dataset from 18 wells to 51 wells (Table 1). Using the same approach as presented in the RI to define background, a Shapiro-Wilkes W-test for normality was performed on the expanded dataset. The results indicate the expanded dataset is best approximated as a log-normal distribution and, in accordance with MTCA (WAC 173-340-709), the 90th percentile of the expanded dataset is therefore used to define background. Based on this analysis, the more appropriate background value for dissolved arsenic in groundwater for the RI/FS is 14.7 ug/L (Table 2).

The following paragraphs provide a more detailed summary of the updated assessment.

The background concentration of dissolved arsenic in groundwater was updated by expanding the RI background dataset to include additional groundwater data from the USGS NAWQA dataset for Grant County, Washington. The Grant County NAWQA dataset includes 33 sample stations with sample dates ranging from 2002 to 2010. NAWQA sample stations are located mainly south of the Ephrata Landfill (Figure 1). NAWQA stations were either sampled once in 2002 or five times during the eight year period. For stations sampled multiple times, the maximum con-

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[1] The RI background arsenic concentration is based on the 80th percentile of the dataset. A Shaprio-Wilkes test for non-normality indicated the dataset more closely matched a normal distribution compared to a log-normal distribution. Based on WAC 173-340-709, the 80th percentile is used to define background for normal distributions.

centration was used, which is similar to the approach used with the RI dataset (PGG, 2010b). Concentrations of dissolved arsenic in groundwater from the NAWQA dataset[2] range from 0.90 to 45.42 ug/L (Table 1 and Figure 1).

Although aquifer information is not provided in the NAWQA dataset, most NAWQA wells are fairly shallow (less than 50 feet deep), suggesting many are completed in the Outwash aquifer. The distributions of the RI and NAWQA datasets overlap (Figure 2).

Using the same approach as presented in the RI to define background, a Shapiro-Wilkes W-test for normality was performed on the expanded dataset. In accordance with WAC 173-340-709, background concentrations are defined as the upper 90th percentile for log-normally distributed data, the upper 80th percentile for normally distributed data, or four times the 50th percentile for either distribution if this value is lower. The results of the statistical test indicate the distribution of the expanded dataset is best approximated as log-normal and background is defined as the 90th percentile, 14.7 ug/L (Table 2).

State of Washington
Hydrogeologist
2651
Licensed Geologist
Dawn Chapel

Dawn Chapel

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[2] One NAWQA sample had a very high concentration of 116.39 ug/L (USGS Station ID 465748119340601). This sample was considered an outlier and omitted from the analysis.

Table 1. Data Used to Define Background Concentrations of Dissolved Arsenic in Groundwater

Station ID	Data Source[1 and 2]	Concentration (ug/L)
Bolyard Deep	Ephrata Landfill RI	0.10
MW-50c	Ephrata Landfill RI	0.60
MW-52p2	Ephrata Landfill RI	0.70
MW-49p2	Ephrata Landfill RI	0.70
MW-4c	Ephrata Landfill RI	1.00
Olivares	Ephrata Landfill RI	1.00
MW-48b	Ephrata Landfill RI	1.60
MW-47c	Ephrata Landfill RI	1.70
MW-51b	Ephrata Landfill RI	2.00
MW-16d	Ephrata Landfill RI	2.00
Country Boys	Ephrata Landfill RI	2.20
Gutierrez-ACE908	Ephrata Landfill RI	2.40
Bohr	Ephrata Landfill RI	2.50
MW-20c	Ephrata Landfill RI	3.00
Gutierrez-ABO220	Ephrata Landfill RI	3.10
Atkins New	Ephrata Landfill RI	3.40
Atkins Old	Ephrata Landfill RI	4.00
Moore	Ephrata Landfill RI	4.30
464535119430501	USGS NAWQA	0.89
470844119182501	USGS NAWQA	1.68
471449119522801	USGS NAWQA	1.83
473008119174901	USGS NAWQA	2.57
465325119405201	USGS NAWQA	3.04
465631119432901	USGS NAWQA	3.13
470904119190401	USGS NAWQA	3.32
465533119344601	USGS NAWQA	3.36
465755119254901	USGS NAWQA	3.47
465319119305701	USGS NAWQA	4.44
465531119315501	USGS NAWQA	4.48
465303119284201	USGS NAWQA	4.73
465852119210801	USGS NAWQA	4.86
470759119143101	USGS NAWQA	4.91
470805119140501	USGS NAWQA	4.98
471120119485901	USGS NAWQA	5.52
475205119050401	USGS NAWQA	5.79
465457119214701	USGS NAWQA	6.57
470801119293601	USGS NAWQA	7.49
464418119432901	USGS NAWQA	7.76
465330119243001	USGS NAWQA	8.34
470850119323501	USGS NAWQA	8.62
470145119131101	USGS NAWQA	10.21
470803119480001	USGS NAWQA	11.40
470430119334801	USGS NAWQA	11.41
471013119433401	USGS NAWQA	11.41
465509119371501	USGS NAWQA	13.50
465958119080301	USGS NAWQA	14.68
475119119074001	USGS NAWQA	15.54
470152119432301	USGS NAWQA	20.55
470056119063801	USGS NAWQA	41.19
465738119322001	USGS NAWQA	44.19
465821119365401	USGS NAWQA	45.42

Notes

1 . Data from RI/FS wells were the same as presented in the RI report (PGG, 2010b).
The RI wells included Site monitoring wells and sampled private wells that did not have detections of volatile organic compounds (VOCs).
RI well values are the maximum concentration observed in each well since 2001.

2. Except for a single outlier value of 116.4 ug/L at station #465748119340601, USGS values include all NAWQA groundwater samples collected in Grant County for analysis of dissolved arsenic.
USGS data were collected between 2002 and 2010. Stations were either sampled once in 2002 or five times over the 8 year period.
For stations sampled on five occassions, the maximum value was used.

Table 2. Statistics and Background Concentrations of Dissolved Arsenic in Groundwater

Statistics/Background	Value
No. Stations	51
p-value (normal-dist.)[1]	0.00
p-value (log normal dist.)[1]	0.29
minimum (ug/L)[2]	0.10
maximum (ug/L)	45.42
mean (ug/L)	7.40
50th Percentile (ug/L)	4.00
80th Percentile (ug/L)	10.21
90th Percentile (ug/L)	14.68
Background (ug/L)[3]	14.68

Notes

1. p-values are from Shapiro-Wilk W test for non-normality. A low p-value (<0.05) rejectes these data as being from a normal or log normal distribution

   For the purposes of defining background, a log normal distribution was assumed (test with the higher p-value)

2. Values are in micrograms-per-liter (ug/L)

3. Background defined as 90th percentile for log normal distribution in accordance with WAC 173-340-209

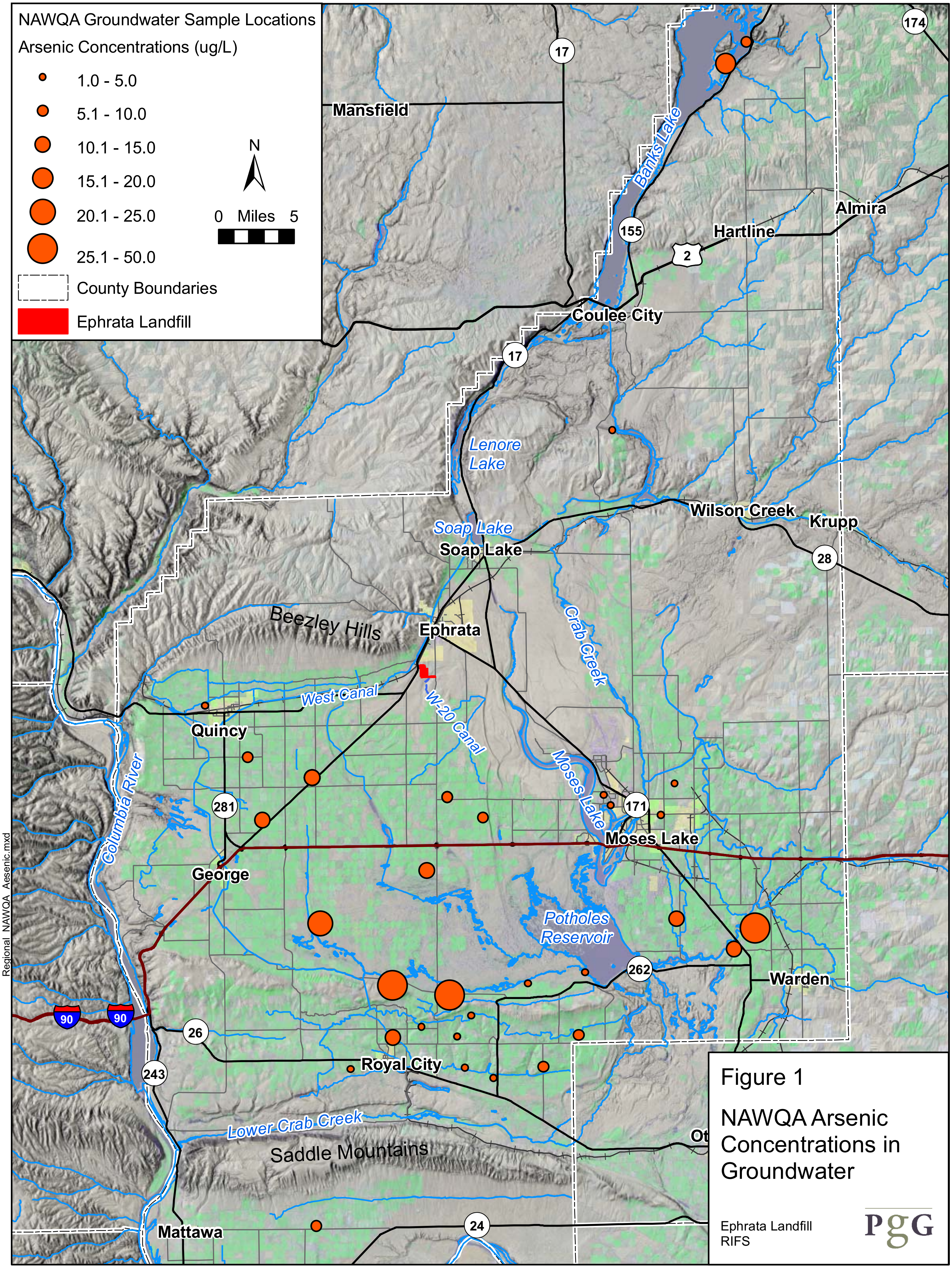
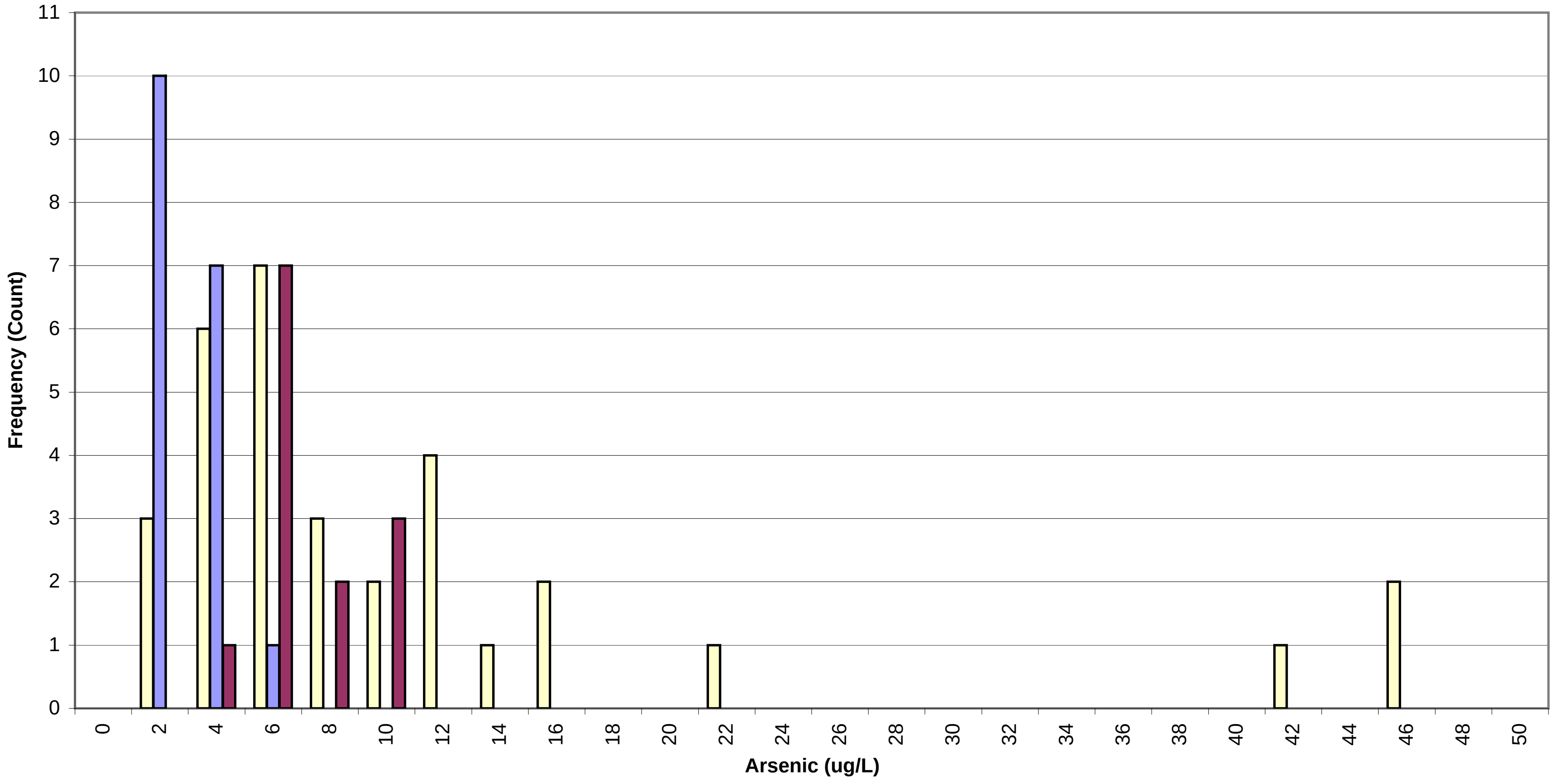


Figure 1

NAWQA Arsenic Concentrations in Groundwater

Ephrata Landfill
RIFS

PGG



Dataset:

- 🟨 NAWQA Dataset (Used in Assessment)
- 🟦 RI Basalt Aquifer Dataset (Used in Assessment)
- 🟥 RI Outwash Aquifer Dataset (Not Used in Assessment)

Figure 2. Distribtuion of Dissolved Arsenic Concentation in Groundwater

Ephrata RI/FS
JE0714

APPENDIX E

Results of Groundwater Extraction and LNAPL Recovery at the Ephrata Landfill for 2010 Season and Proposed Modifications for 2011 Season Technical Memorandum

PACIFIC groundwater GROUP

Technical Memorandum

To: Ephrata Landfill RI/FS PLPs

From: Dawn Chapel and Charles Ellingson (Pacific Groundwater Group)

Re: Results of Groundwater Extraction and LNAPL Removal at the Ephrata Landfill for 2010 Season and Proposed Modifications for 2011 Season.

Date: February 8, 2011

Groundwater extraction and removal of light non-aqueous phase liquids (LNAPL) are interim remedial actions being conducted at the Ephrata Landfill in Grant County (the Site[1]) during the Remedial Investigation and Feasibility Study (RI/FS). Interim remedial actions are being performed to remove sources of known contamination and reduce potential for future transport of contamination off site.

The purpose of this memo is to document groundwater extraction and LNAPL removal activities and observations conducted during the 2010 season. Based on the 2010 results, we propose plan modifications to incorporate during the 2011 extraction season.

The following section provides a summary of important observations during the 2010 season and proposed plans for the 2011 season. Subsequent sections provide more detail on the background of groundwater extraction activities performed at the site and results of the 2010 activities.

SUMMARY OF 2010 ACTIVITIES AND PROPOSED 2011 ACTIVITITES

Groundwater was extracted from well MW-34p1 between June 15th and November 16th 2010. Pumping rates were varied between 0.1 and 0.3 gpm in order to increase groundwater extraction and LNAPL removal while maintaining at least 2-ft of water above the pump intake to minimize the risk of pumping LNAPL to the evaporation pond.

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[1] The “Site” is defined in the original Agreed Order with Ecology as the extent of contamination caused by release of hazardous substances at the Ephrata Landfill. This terminology differs from the landfill’s solid-waste permitted property boundary, which is also sometimes referred to as the “site”; however, the word site is not capitalized when referring to the permitted property boundary.

Approximately 34,000 gallons of contaminated groundwater water were extracted from MW-34p1 and discharged to the evaporation pond at the southwest corner of the original landfill. The total mass of VOCs removed with the extracted groundwater is estimated to be 7.5 kg.

Approximately 4.3 gallons of LNAPL were removed from MW-34p1 and MW-36p1 during the 2010 extraction season. LNAPL was removed using hydrocarbon-absorbent socks placed inside the wells in accordance with the Work Plan. The total volume of LNAPL removed from both wells since LNAPL monitoring first began in June 2009 is 15.5 gallons. The total mass of VOCs removed with the 15.5 gallons of removed LNAPL is estimated to be 13.3 kg.

The concentration of total VOCs in the extracted groundwater decreased over the course of the 2010 extraction period from 132,000 ug/L (June 2010) to 55,000 ug/L (September 2010). The decrease may be related to the well's zone of contribution extending to less contaminated portions of the aquifer over time and/or to equilibrium concentrations being replaced by non-equilibrium concentrations due to the kinetics of groundwater movement towards the well. VOCs with the highest concentrations were toluene, xylenes, ethylbenzene, chlorinated ethanes, and cis-1,2-dichloroethene.

During the 2010 extraction season, measurable LNAPL was first observed in MW-34p1 on September 15th, once groundwater elevations had declined to an elevation of about 1251-ft. Similar (e.g. late-season LNAPL) observations were made in 2009. This observation is most likely due to changes in LNAPL permeability and mobility brought about by a fluctuating water table and not to a sudden appearance of LNAPL in the subsurface at this location. Also, the 1251-ft elevation appears to correlate with the top of the P1 zone at this location and may represent an upper limit for LNAPL mobility. Above 1251-ft, LNAPL may no longer float on an unconfined water table, but rather become trapped in the saturated soils of a confined aquifer. Additionally, LNAPL may no longer discharge to the wells when groundwater elevations (and associated floating LNAPL) have risen above the tops of the well screens. The tops of the well screens are set near an elevation of 1251-ft.

Absorbent socks were inspected and replaced weekly by PGG personnel starting on September 15, 2010 and then daily by County personnel starting October 26, 2010. During weekly site visits by PGG personnel, LNAPL was actively removed from MW-34p1 using a combination of a hand bailer and multiple absorbent socks. All removed LNAPL was contained with adsorbent socks and/or adsorbent pads and placed into heavy duty garbage bags for disposal into the designated on-site 55-gallon drum. Switching to a daily schedule of sock removal by County personnel appeared to accommodate LNAPL discharge rates into the well. Estimated LNAPL discharge rates varied from about 0.05 to 0.2 gpd (based on rate of LNAPL removal with absorbent socks).

A continuation of the current groundwater extraction and LNAPL removal plan is proposed for the 2011 season, with the following modifications designed to increase LNAPL removal:

- The 2011 groundwater season is planned to start in March, depending on temperatures and evaporation pond relocation (see below). The March start date should allow for about a ten month pumping season. This will be the longest continuous groundwater pumping period since the interim action began.
- Groundwater pumping rates will be adjusted between 0.1 and 0.3 gpm to increase drawdown and LNAPL removal from MW-34p1 compared to prior years. Higher pumping rates will be maintained during the high groundwater season (spring) and lower pumping rates will be maintained during the low groundwater season (fall).
- Daily or twice-daily inspection and replacement of absorbent socks by County personnel will begin once measurable LNAPL is observed in the well.
- Pumping rates will be reduced if water levels decline to within 2 feet of the pump intake or if LNAPL discharge rates into the well occur faster than can be accommodated with daily to twice-daily sock replacement.
- Groundwater elevations and LNAPL thicknesses will be measured approximately monthly in MW-34p1 and MW-36p1 by PGG personnel.

The County plans to decommission the old evaporation pond and construct a new pond at a different location on site to comply with permitting requirements for the landfill’s water supply well. The schedule for new pond construction is not set, but it could delay the start of the 2011 extraction season.

BACKGROUND

Groundwater extraction and LNAPL management plans developed for the removal of contaminants at the north end of the original landfill are summarized in the following work plans:

- Sampling Analysis and Quality Assurance Project Plan - Remedial Investigation (Task 6) - Pump Groundwater from the Hole - Ephrata Landfill Corrective Action (PGG, August 2007 Report).
- Sampling and Analysis and Quality Assurance Project Plan - Shallow Groundwater Extraction and Treatment near Former Buried Drums (Task 6b) - Ephrata Landfill Corrective Action (PGG, July 2009 Report).
- LNAPL Recovery as Interim Action at Ephrata Landfill (PGG, 2010 Letter to Ecology)

Groundwater extraction at the site first began in 2008 with groundwater extraction from the Hole (EW-1). The Hole is a 20-ft depression in the basalt surface beneath the original landfill where refuse mixed with sand-and-gravel is in contact with shallow groundwater (Figure 1). Approximately 85,000 gallons were extracted from EW-1 over a two month period during the spring of 2008. The extracted groundwater is discharged to an on-site double-lined evaporation pond at the southwest corner of the original landfill. The results of the 2008 extraction season were summarized in the Phase 1 RI Report (PGG, 2009).

Shallow groundwater extraction and LNAPL removal near the former drum cache first began in 2009 after the discovery of contaminated groundwater and LNAPL (monitoring wells MW-34p1 and MW-36p1). The former drum cache is located at the northern edge of the original landfill and MW-34p1 and MW-36p1 are located immediately south of the former drum cache (Figure 1). MW-34p1 and MW-36p1 are drilled to depths of about 35 feet and completed in the first saturated weathered-basalt zone, referred to as the P1 shallow groundwater zone. The occurrence of LNAPL appears to be isolated to the P1 zone in the immediately vicinity of the former drum cache (PGG, 2010).

In accordance with the current work plans, shallow groundwater is extracted from MW-34p1 and LNAPL is removed with hydrocarbon-absorbent socks in MW-34p1 and MW-36p1. The extracted groundwater is piped into the same discharge line that conveys groundwater from EW-1 to the evaporation pond. During the 2009 extraction season contaminated groundwater was extracted from both EW-1 and MW-34p1; however repeated pump failures in both wells limited the total volume extracted. A total of 58,000 gallons were extracted from EW-1 and less than 1,000 gallons were extracted from MW-34p1. LNAPL was also removed with absorbent socks during the 2009 period. Approximately 11 gallons of LNAPL were removed in 2009 (about 8 gallons from MW-36p1 and about 3 gallons from MW-34p1). The results of the 2009 extraction season were summarized in the RI Report (PGG, 2010).

The 2010 groundwater extraction season focused on extraction of shallow groundwater and LNAPL removal near the former drum cache (groundwater was not extracted from EW-1 during the 2010 season). The results of the 2010 extraction season are discussed in more detail below.

GROUNDWATER EXTRACTION AND LNAPL REMOVAL (2010 RESULTS)

Groundwater was extracted from MW-34p1 between June 15, 2010 and November 16, 2010 using a newly installed bladderless pneumatic pump system. Pumping rates were measured in the field during each site visit and periodically adjusted in order to maintain a minimum of 2 feet of water above the pump intake (the 2-ft minimum is maintained in order to prevent LNAPL from entering the pump intake). Pumping rates were varied from about 0.1 to 0.3 gallons-per-minute (gpm) during the extraction period. The pump operated continuously except for interruptions on three occasions (10/5, 10/27 and 11/16). The disruptions lasted from 1 to 5 days and were due to air leaks developing in the ¼-inch polyethylene air line that runs approximately 600 feet from the compressor to the well head. The leaks occurred at discrete tears/ruptures in the polyethylene line that may have been the result of animal activity or natural abrasion. The ¼-inch line will be replaced in 2011 and threaded through a larger diameter protective pipe to reduce the likelihood of ruptures in the future.

Groundwater elevations[2] and LNAPL thicknesses were measured in MW-34p1 and MW-36p1 during each site visit by PGG personnel. Absorbent socks in both wells were also inspected and replaced as needed during each PGG site visit. Measurable LNAPL was not observed in either well until September 15th. Prior to that date, PGG site visits occurred approximately bi-weekly to monthly. In response to measurable LNAPL in MW-34p1, weekly site visits by PGG personnel began on September 15th. Daily inspections by County personnel began on October 26th and continued until the end of the extraction season. Inspection activities by County personnel were limited to inspection/replacement of absorbent socks in MW-34p1. Groundwater elevations and LNAPL thicknesses were not measured during the County's daily inspections, nor were absorbent socks in MW-36p1 inspected[3].

The following sections summarize groundwater extraction, groundwater chemistry, and LNAPL observations and removal in more detail.

GROUNDWATER EXTRACTION

Pumping rates were varied between 0.1 and 0.3 gpm during the extraction season. Rates were varied to increase groundwater extraction and LNAPL removal while maintaining at least 2-ft of water above the pump intake to minimize the risk of pumping LNAPL. Pumping rates were initially set low, then gradually increased, and then lowered over the course of the extraction period. Pumping rates were generally as follows:

- Less than 0.1 gpm (June 15th to August 3rd)
- 0.2 gpm (August 3rd to September 22nd)
- 0.3 gpm (September 22nd to October 21st)
- 0.2 gpm (October 21st to October 25th)
- 0.1 gpm (October 25th to November 15th)

Approximately 34,000 gallons of contaminated groundwater was extracted from MW-34p1 and discharged to the on-site evaporation pond during the 2010 season with pond levels remaining below 1-ft during the entire season. The pond could likely accommodate year-round pumping at these discharge rates; however, freezing temperatures prevent operation during the winter months.

The pump failed sometime between November 15th and November 16th due to an airline leak, and the system was subsequently shutdown on November 16th in preparation for winter conditions.

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[2] Groundwater elevations are corrected for LNAPL thicknesses in the well.

[3] Very little LNAPL migrated into MW-36p1 during the 2010 season; therefore, daily inspections were not warranted.

GROUNDWATER ELEVATIONS

Hydrographs[4] for MW-34p1 and MW-36p1 from June 2009 to November 2010 show seasonal variations in groundwater elevations with high elevations generally occurring in spring to early summer and low elevations generally occurring in fall to early winter (Figure 2).

At the start of the extraction season (June 15, 2010), groundwater elevations in MW-34p1 and MW-36p1 were at a seasonal high with elevations in MW-34p1 about 1 ft higher than MW-36p1. Groundwater elevations in both wells gradually declined throughout the pumping season with the rate of decline occurring faster in MW-34p1 due to pumping; although some of the reduction in both wells is likely from natural seasonal declines. By late September 2010 the groundwater elevation in MW-34p1 was lower than MW-36p1. The maximum decline in groundwater elevations observed in MW-34p1 and MW-36p1 during the extraction period was 4.01 feet and 2.57 feet respectively.

As discussed below, LNAPL mobility to MW-34p1 and MW-36p1 appears to correlate inversely to groundwater elevations, with LNAPL movement into the wells occurring during times of low groundwater elevations (see LNAPL section below).

GROUNDWATER CHEMISTRY

Five groundwater samples were collected for laboratory analysis from MW-34p1 during the 2010 extraction period (Table 1). Samples were collected on June 15th, June 18th, June 23rd, September 21st, and September 15th in order to monitor groundwater quality and air emissions compliance levels for the evaporation pond. Samples were analyzed for volatile organic compounds (VOCs), metals, and select inorganic parameters. A single sample for pesticides, herbicides and aldehydes was also collected on June 23rd, and a single sample for semi-volatile organic compounds (SVOCs) was collected on September 15th.

VOCs with the highest concentrations during all five sampling events were toluene, xylenes, ethylbenzene, chlorinated ethanes, and cis-1,2-dichloroethene. With the exception of elevated concentrations of acetone on September 15th, the concentration of VOCs decreased noticeably between each successive sampling event. Total VOCs over the course of the five sampling events decreased from about 132,000 ug/L to 55,000 ug/L (Figure 3). The decrease in VOC concentrations may be related to the well's zone of contribution extending to less contaminated portions of the aquifer over time and/or to equilibrium concentrations being replaced by non-equilibrium concentrations due to the kinetics of groundwater movement towards the well. Most of the decrease in total VOCs occurred relatively early, after extraction of about 1,500 gallons of groundwater (Figure 3).

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[4] Groundwater elevation measurements in MW-34p1 and MW-36p1 were collected as early as November 2008; however these earlier data are not plotted in the hydrograph because LNAPL thicknesses were not measured and therefore the data could not be corrected for LNAPL thicknesses in the well.

Herbicides were not detected in MW-34p1. A single pesticide (aldrin) was detected at 0.29 ug/L and two aldehydes (acetaldehyde and formaldehyde) were detected at 59 ug/L and 198 ug/L respectively. Several SVOCs were detected with concentrations of individual parameters ranging from 10 ug/L to 500 ug/L (Table 1). SVOCs with the highest concentrations were benzoic acid and methylphenols (both of which are breakdown products of toluene). Naphthalene and phthalates were also detected (Table 1).

Concentrations of dissolved iron and manganese were noticeably high with concentrations of iron ranging from about 55,000 to 79,000 ug/L and concentrations of dissolved manganese ranging from about 6,000 to 8,000 ug/L (Table 1). Dissolved arsenic concentrations were also elevated ranging from 13 to 17 ug/L. Chloride (300 to 500 ug/L), sodium (200 to 300 ug/L), alkalinity (1200 to 1400 ug/L) and total dissolved solids (1,700 to 2,200 ug/L) were also elevated (Table 1).

LNAPL OBSERVATIONS AND REMOVAL

The thickness of LNAPL measured in MW-34p1 and MW-36p1 has been highly variable since LNAPL measurements first began (June 2009). LNAPL thicknesses in these wells have varied from non-measurable (less than 0.01 ft) to a maximum of about 1 ft, with thicknesses increasing as water levels in the well decrease (Figure 2). Declining water levels allow mobile LNAPL to drain from the adjacent formation and migrate into the monitoring well. This increase therefore represents an exaggerated apparent LNAPL thickness in the well rather than an actual increase in LNAPL thickness in the adjacent formation (Newell et al, 1995).

There was a critical water level elevation of about 1251 ft required in both wells before measurable LNAPL was observed in either well (Figure 4). The same observation was made in 2009. Above 1251 ft, LNAPL thicknesses in both wells generally remained non-measurable (less than 0.01 ft). This observation is most likely due to changes in LNAPL permeability and mobility brought about by a fluctuating water table and not to a sudden appearance of LNAPL in the subsurface at this location. Also, the 1251 ft elevation appears to correlate with the top of the P1 zone[5] at this location and may represent an upper limit for LNAPL mobility. Above 1251 ft, LNAPL may no longer float on an unconfined water table, but rather become trapped in the saturated soils of a confined aquifer. Additionally, LNAPL may no longer discharge to the wells when groundwater elevations (and associated floating LNAPL) have risen above the tops of the well screens. The tops of the well screens are set near an elevation of 1251 ft

During the 2010 extraction season, measurable LNAPL was not observed in either well until September 15th when groundwater elevations had declined to an elevation of about 1251 ft. Measurable LNAPL occurred primarily in MW-34p1 (the pumped well), with LNAPL reaching a maximum thickness of 0.91 feet. In contrast, the maximum LNAPL thickness observed in MW-36p1 during the 2010 extraction season was 0.02 feet (Figure

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[5] The P1 zone is a thin saturated zone characterized as relatively permeable weathered basalt (PGG, 2010). The P1 zone is about 2 feet thick at MW-36p1 and 5 feet thick at MW-34p1. Approximately 5 to 7 feet of hard dry basalt occurs above the P1 at MW-34p1 and MW-36p1 respectively.

2). This differs from 2009 when the maximum LNAPL thickness was observed in MW-36p1 (1.0 foot) and not in MW-34p1 (0.2 feet) (Figure 2). The change in 2010 suggests long-term pumping at MW-34p1 impacted local hydraulic gradients and captured or otherwise affected mobile LNAPL as far as MW-36p1 (about 90 feet). As mentioned above, the groundwater elevation in MW-34p1 was drawn down below the groundwater elevation in MW-36p1 during the extraction period, indicating a reversal of hydraulic gradient between these two wells. Also, when the pump failed at the end of the season, recovery of groundwater levels was observed in both wells, again indicating pumping impacts extended to MW-36p1 (Figure 2).

The maximum LNAPL thicknesses observed during the 2010 extraction season occurred on October 21st, after the pump had been operating at its peak rate of 0.3 gpm and groundwater elevations were at their lowest (Figure 2). However, during discrete instances when the pump failed, LNAPL thicknesses in MW-34p1 decreased relatively quickly despite groundwater elevations being lower than 1251 ft. This observation may be explained by mobile LNAPL temporarily becoming trapped in the adjacent formation as the water table increased (Fetter, 1993). When pumping was resumed, LNAPL began to migrate into the well again.

On October 26th, the pumping rate in MW-34p1 was adjusted downward to about 0.1 gpm because the water level in MW-34p1 had declined to within 1.5 ft of the pump intake. On this date, County personnel began daily inspections and replacement of absorbent socks in MW-34p1 until the end of the season (November 16th). The effects on groundwater elevations and LNAPL thicknesses caused by decreasing the pumping rate to 0.1 gpm were not measured directly by County personnel. However, daily inspections by County personnel noted socks consistently 10 to 50% oil-saturated; indicating LNAPL continued to migrate into the well. County personnel initially inspected socks twice-per-day, but switched to daily inspections after observing a reduction in percent oil saturation when using two socks per day. These observations suggest LNAPL removal with daily replacement of absorbent socks kept pace with LNAPL discharge rates into the well. The pump failed sometime between November 15th and November 16th. On November 16th, after the pump had failed, the LNAPL thickness in MW-34p1 was non-measureable (less than 0.01 ft) and groundwater elevations had recovered approximately 0.7 feet in MW-34p1 and 0.2 feet in MW-36p1 (Figure 2).

LNAPL and Mass Removal

Between September 15th and November 16th 2010, a total of 4.0 gallons of LNAPL were removed from MW-34p1 and a total of 0.3 gallons were removed from MW-36p1[6]. Since LNAPL management with absorbent socks first began in 2009 a total of 8.7 gallons have been removed from MW-36p1 and a total of 6.8 gallons have been removed from MW-34p1 (Figure 5). Using LNAPL chemical data (PGG, 2010), the total mass of VOCs removed with the LNAPL can be estimated as follows:

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[6] Most LNAPL was removed with regular sorbent sock replacement; however, on four occasions LNAPL was actively extracted from the well using hand bailers and sorbent socks until LNAPL thicknesses were decreased to non-measurable (Sept. 30th, Oct. 13th, Oct. 21st, and Oct. 25th)

- Total Detected VOCs in LNAPL[7] = 262,300 mg/kg
- LNAPL density[8] = 0.87 g/mL or kg/L
- Total VOC mass removed from MW-36p1 = (262,300 mg/kg)*(0.87 kg/L)*(3.78 L/gallon)*(8.7 gallons)*(1x10^{-6} kg/mg) = 7.5 kg
- Total VOC mass removed from MW-34p1 = (262,300 ug/kg)*(0.87 kg/L)*(3.78 L/gallon)*(6.8 gallons)*(1x10^{-6} kg/mg) = 5.8 kg

A similar analysis can be performed for total mass of VOCs removed with extracted groundwater:

- Total VOCs in extracted groundwater[9] = 58,000 ug/L
- Total groundwater extracted = 34,000 gallons
- Total VOC mass removed from MW-34p1 = (58,000 ug/L)*(1x10^{-9} kg/ug)*(3.78 L/gallon)*(34,000 gallons) = 7.5 kg

The total mass of VOCs in the 2010 extracted groundwater is below prior year estimates made for pond emission calculations (Parametrix, 2009), which were well below SQERs[10]. Parametrix is preparing an emissions update based on 2010 observations.

The analysis above shows that while the volume of LNAPL removed is orders of magnitude less than the volume of extracted groundwater, the total VOC mass removed with the LNAPL is similar.

LNAPL Discharge Rates and Sustainable Pumping Rates

LNAPL discharge rates into the well were not measured directly during the 2010 season; however discharge rates can be estimated from the volume of LNAPL removed between site visits. As mentioned above daily site visits appeared to keep pace with LNAPL discharge rates into the well. Based on this method, estimated discharge rates varied from about 0.05 gallons-per-day (gpd) to about 0.2 gpd based on observations of the absorbent socks. A rate of 0.4 gpd was estimated for a single site visit on October 26th when the largest LNAPL thickness of 2010 was measured.

The sock manufacturer's specification indicates each 3-ft long, 2-inch diameter absorbent sock is capable of absorbing a total of 0.25 gallons at a rate of 0.1 gallons-per-second. Based on those specifications, LNAPL removal using absorbent socks is not expected to be a limiting factor in 2011.

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[7] LNAPL VOC laboratory reporting limits were high (2,500 to 12,000 mg/kg) and the detectable VOCs only accounted for 26% of the LNAPL mass (PGG, 2010). The total VOC mass removed is therefore likely higher than the estimate presented.

[8] An average density based on the densities and relative amounts of individual VOCs detected in LNAPL.

[9] Total VOCs in groundwater is a weighted average of total detected VOCs from the five 2010 sampling events of MW-34p1 (Figure 3). The total VOCs for each sampling event are weighted by the total gallons pumped at the time of sample collection.

[10] Small Quantity Emission Rates (SQERs).

PROPOSED MODIFICATIONS FOR 2011 SEASON

Interim remedial activities will continue into 2011 during development of the Feasibility Study for the original landfill.

The data collected during the 2010 extraction season indicate pumping rates of about 0.1 to 0.3 gpm can maintain 2-ft of water above the pump intake in MW-34p1; however, lower pumping rates may be required during drier years. The results of 2010 also indicate that daily removal of LNAPL with absorbent socks should accommodate LNAPL discharge rates into the well.

Higher LNAPL removal rates might be possible with additional drawdown in the well; however, the available additional drawdown of about 2-ft might not significantly increase LNAPL discharge rates into the well. Accomplishing the additional drawdown would also requiring switching to a total fluids recovery system with an oil/water separator. Also, additional treatment equipment and a dangerous waste accumulation area would be required near the well. We therefore propose a continuation of the current groundwater extraction and LNAPL removal plan in 2011 with the following modifications to increase LNAPL removal compared to previous years:

- Given the large capacity of the evaporation pond, the 2011 groundwater extraction season could be extended up to a ten month period (March to November)[11]. The longer season would allow a larger volume of contaminated groundwater to be extracted and the earlier start date may induce LNAPL movement into the well earlier than was observed in 2010. However, the 2011 start date may be delayed depending on the County's schedule for constructing a new evaporation pond. The County plans to decommission the old evaporation pond and construct a new pond at a different on-site location to comply with permitting requirements for the landfill's water supply well.
- Groundwater pumping rates will be adjusted between 0.1 to 0.3 gpm in order to increase drawdown and induce LNAPL movement into MW-34p1, while maintaining at least 2 ft of water above the pump intake. During times of high groundwater elevations (spring), higher pumping rates will be maintained. During times of low groundwater elevations (fall), lower pumping rates will be maintained.
- Daily or twice-daily inspection and replacement of absorbent socks by County personnel will commence once measureable LNAPL is observed in the well. Prior to that, weekly inspections will be performed. Pumping rates may be adjusted downward if LNAPL cannot be managed with daily to twice-daily replacement of absorbent socks.
- Groundwater elevations and LNAPL thicknesses will be measured approximately monthly by PGG personnel.

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[11] Exact start and end dates will depend on weather and daily temperatures.

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Table 1. Groundwater Chemistry Data (MW-34p1 2010 Extraction Season)

		Date of Sample				
Volatile Organic Compounds (VOCs)	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
1,1,1,2-Tetrachloroethane	ug/L	400U	400U	400U	200U	3U
1,1,1-Trichloroethane	ug/l	**4,600**	**2,600**	**2,100**	**1,100**	**220**
1,1,2,2-Tetrachloroethane	ug/L	400U	400U	400U	200U	3U
1,1,2-Trichloroethane	ug/L	400U	400U	400U	200U	**8M**
1,1,2-Trichlorotrifluoroethane	ug/L	400U	400U	400U	200U	3U
1,1-Dichloroethane	ug/L	**2,900**	**1,700**	**1,300**	**1,100**	**600**
1,1-Dichloroethene	ug/L	400U	400U	400U	200U	**9**
1,1-Dichloropropene	ug/L	400U	400U	400U	200U	3U
1,2,3-Trichlorobenzene	ug/L	1000U	1000U	1000U	500U	7.5U
1,2,3-Trichloropropane	ug/L	1000U	1000U	1000U	500U	7.5U
1,2,4-Trichlorobenzene	ug/L	1000U	1000U	1000U	500U	
1,2,4-Trimethylbenzene	ug/L	**720**	**860**	**740**	**670**	**500**
1,2-Dibromo-3-chloropropane	ug/L	1000U	1000U	1000U	500U	7.5U
1,2-Dichlorobenzene	ug/L	400U	400U	400U	200U	**83**
1,2-Dichloroethane (EDC)	ug/L	**700**	**440**	400U	**280**	**210**
1,2-Dichloropropane	ug/L	**740**	**460**	400U	**240**	**160**
1,3,5-Trimethylbenzene	ug/L	400U	400U	400U	**300**	**240**
1,3-Dichlorobenzene	ug/L	400U	400U	400U	200U	**6**
1,3-Dichloropropane	ug/L	400U	400U	400U	200U	3U
1,4-Dichlorobenzene	ug/L	400U	400U	400U	200U	**34**
2,2-Dichloropropane	ug/L	400U	400U	400U	200U	3U
2-butanone	ug/L	10000U	10000U	10000U	5000U	**3,100**
2-Chloroethylvinylether	ug/L	2000U	2000U	2000U	1000U	15U
2-Chlorotoluene	ug/L	400U	400U	400U	200U	3U
2-Hexanone	ug/L	10000U	10000U	10000U	5000U	**170**
4-Chlorotoluene	ug/L	400U	400U	400U	200U	3U

Bold results = detection

Blank Result = Not Measured

#U = Undetected; associated number is lab reporting limit (e.g. 0.2U)

#Y = Undetected but with elevated reporting limit; associated number is lab reporting limit (e.g. 0.13Y)

#M = Estimated value by lab due to low spectral match parameters, associated number is estimated value (e.g. 8M)

Table 1. Groundwater Chemistry Data (MW-34p1 2010 Extraction Season)

		Date of Sample				
VOCs cont.	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
4-Isopropyltoluene	ug/L	400U	400U	400U	200U	3U
4-Methyl-2-pentanone (MIBK)	ug/L	10000U	10000U	10000U	5000U	**2,500**
Acetone	ug/L	10000U	10000U	10000U	5000U	**18,000**
Acrolein	ug/L	10000U	10000U	10000U	5000U	75U
Acrylonitrile	ug/L	2000U	2000U	2000U	1000U	15U
Benzene	ug/L	400U	400U	400U	200U	**32**
Bromobenzene	ug/L	400U	400U	400U	200U	3U
Bromochloromethane	ug/L	400U	400U	400U	200U	3U
Bromodichloromethane	ug/L	400U	400U	400U	200U	3U
Bromoethane	ug/L	400U	400U	400U	200U	3U
Bromoform	ug/L	400U	400U	400U	200U	3U
Bromomethane	ug/L	2000U	2000U	2000U	1000U	15U
Carbon Disulfide	ug/L	400U	400U	400U	200U	3U
Carbon Tetrachloride	ug/L	400U	400U	400U	200U	3U
Chlorobenzene	ug/L	400U	400U	400U	200U	3U
Chloroethane	ug/L	400U	400U	400U	200U	**26**
Chloroform	ug/L	400U	400U	400U	200U	**10**
Chloromethane	ug/L	1000U	1000U	1000U	500U	7.5U
cis-1,2-Dichloroethene	ug/L	**4,300**	**2,100**	**1,600**	**1,400**	**690**
cis-1,3-Dichloropropene	ug/L	400U	400U	400U	200U	3U
Dibromochloromethane	ug/L	400U	400U	400U	200U	3U
Dibromomethane	ug/L	400U	400U	400U	200U	3U
Ethylbenzene	ug/L	**5,700**	**5,600**	**5,200**	**4,100**	**2,300**
Ethylene Dibromide (EDB)	ug/L	400U	400U	400U	200U	3U
Hexachlorobutadiene	ug/L	1000U	1000U	1000U	500U	7.5U
Isopropylbenzene (Cumene)	ug/L	400U	400U	400U	200U	**63**
Methyl iodide	ug/L	2000U	2000U	2000U	1000U	15U
Methylene Chloride	ug/l	1000U	1000U	1000U	500U	**16**
Naphthalene	ug/L	1000U	1000U	1000U	500U	**370**

Bold results = detection

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#M = Estimated value by lab due to low spectral match parameters, associated number is estimated value (e.g. 8M)

Table 1. Groundwater Chemistry Data (MW-34p1 2010 Extraction Season)

		Date of Sample				
VOCs cont.	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
n-Butylbenzene	ug/L	400U	400U	400U	200U	3U
n-Propylbenzene	ug/L	400U	400U	400U	200U	**120**
o-Xylene	ug/L	**4,600**	**4,700**	**4,300**	**3,200**	**2,400**
sec-Butylbenzene	ug/L	400U	400U	400U	200U	**7**
Styrene	ug/L	400U	400U	400U	200U	**17**
tert-Butylbenzene	ug/L	400U	400U	400U	200U	3U
Tetrachloroethene (PCE)	ug/L	400U	400U	400U	200U	**6**
Toluene	ug/L	**95,000**	**74,000**	**63,000**	**39,000**	**17,000**
trans-1,2-Dichloroethene	ug/L	400U	400U	400U	200U	3U
trans-1,3-Dichloropropene	ug/L	400U	400U	400U	200U	3U
trans-1,4-Dichloro-2-butene	ug/L	2000U	2000U	2000U	1000U	15U
Trichloroethene (TCE)	ug/L	400U	400U	400U	200U	**2**
Trichlorofluoromethane	ug/l	400U	400U	400U	200U	3U
Vinyl Acetate	ug/L	2000U	2000U	2000U	1000U	15U
Vinyl Chloride	ug/L	400U	400U	400U	**260**	**54**
Xylene Isomers, M+P	ug/L	**13,000**	**13,000**	**12,000**	**8,900**	**5,600**
TOTAL VOCS	ug/L	**132,260**	**105,460**	**90,240**	**60,550**	**54,544**

Semi Volatile Organic Compounds (SVOCS)	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
1,2,4-Trichlorobenzene	ug/L					1U
1,2-Dichlorobenzene	ug/L					**53**
1-Methylnaphthalene	ug/L					**16**
2,2-Oxybis(1-Chloropropane)	ug/L					1U
2,4,5-Trichlorophenol	ug/L					5U
2,4,6-Trichlorophenol	ug/L					5U
2,4-Dichlorophenol	ug/L					5U
2,4-Dimethylphenol	ug/L					1U

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#M = Estimated value by lab due to low spectral match parameters, associated number is estimated value (e.g. 8M)

Table 1. Groundwater Chemistry Data (MW-34p1 2010 Extraction Season)

		Date of Sample				
SVOCs cont.	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
2,4-Dinitrophenol	ug/L					10U
2,4-Dinitrotoluene	ug/L					5U
2,6-Dinitrotoluene	ug/L					5U
2-Chloronaphthalene	ug/L					1U
2-Chlorophenol	ug/L					1U
2-Methyl-4,6-dinitrophenol	ug/L					10U
2-Methylnaphthalene	ug/L					**27**
2-Methylphenol	ug/L					**160**
2-Nitroaniline	ug/L					5U
2-Nitrophenol	ug/L					5U
3,3'-Dichlorobenzidine	ug/L					5U
3-Nitroaniline	ug/L					5U
4-Bromophenyl Phenyl Ether	ug/L					1U
4-Chloro-3-methylphenol	ug/L					5U
4-Chloroaniline	ug/L					5U
4-Chlorophenyl Phenyl Ether	ug/l					1U
4-Methylphenol	ug/L					**340**
4-Nitroaniline	ug/L					5U
4-Nitrophenol	ug/L					5U
Acenaphthene	ug/L					1U
Acenaphthylene	ug/L					1U
Anthracene	ug/L					1U
Benz(a)anthracene	ug/L					1U
Benzo(a)pyrene	ug/L					1U
Benzo(b)fluoranthene	ug/L					1U
Benzo(g,h,i)perylene	ug/L					1U
Benzo(k)fluoranthene	ug/L					1U
Benzoic Acid	ug/L					**500**
Benzyl Alcohol	ug/L					**20**

Bold results = detection

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Table 1. Groundwater Chemistry Data (MW-34p1 2010 Extraction Season)

		Date of Sample				
SVOCs cont.	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
Bis(2-chloroethoxy)methane	ug/L					1U
Bis(2-chloroethyl) Ether	ug/L					1U
Bis(2-ethylhexyl) Phthalate	ug/L					**22**
Butylbenzyl Phthalate	ug/L					**10**
Carbazole	ug/L					1U
Chrysene	ug/L					1U
Dibenz(a,h)anthracene	ug/L					1U
Dibenzofuran	ug/L					1U
Diethyl Phthalate	ug/L					**19**
Dimethyl Phthalate	ug/L					1U
Di-n-butyl Phthalate	ug/L					1U
Di-n-octyl Phthalate	ug/L					1U
Fluoranthene	ug/L					1U
Fluorene	ug/L					1U
Hexachlorobenzene	ug/L					1U
Hexachlorobutadiene	ug/L					1U
Hexachlorocyclopentadiene	ug/L					5U
Hexachloroethane	ug/L					1U
Indeno(1,2,3-cd)pyrene	ug/L					1U
Isophorone	ug/L					1U
Naphthalene	ug/L					**190**
Nitrobenzene	ug/L					1U
N-Nitrosodi-n-propylamine	ug/L					1U
N-Nitrosodiphenylamine	ug/L					5U
Pentachlorophenol	ug/L					5U
Phenanthrene	ug/L					1U
Phenol	ug/L					**76**
Pyrene	ug/L					1U
TOTAL SVOCS	ug/L					**1,433**

Bold results = detection

Blank Result = Not Measured

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#Y = Undetected but with elevated reporting limit; associated number is lab reporting limit (e.g. 0.13Y)

#M = Estimated value by lab due to low spectral match parameters, associated number is estimated value (e.g. 8M)

Table 1. Groundwater Chemistry Data (MW-34p1 2010 Extraction Season)

		Date of Sample				
HERBICIDES	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
2,4,5-T	ug/L			0.25U		
2,4,5-TP (Silvex)	ug/L			1Y		
2,4-D	ug/L			1U		
2,4-DB	ug/L			5U		
Dalapon	ug/L			1U		
Dicamba	ug/L			0.5U		
Dichloroprop	ug/L			1U		
Dinoseb	ug/L			0.5U		
MCPA	ug/L			250U		

PESTICIDES	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
4,4-DDD	ug/L			0.1U		
4,4-DDE	ug/L			0.1U		
4,4-DDT	ug/L			0.1U		
Aldrin	ug/L			**0.29**		
alpha Chlordane	ug/L			0.05U		
Alpha-BHC	ug/L			0.05U		
Beta-BHC	ug/L			0.13Y		
Delta-BHC	ug/L			0.28Y		
Dieldrin	ug/L			0.1U		
Endosulfan I	ug/L			0.05U		
Endosulfan II	ug/L			0.1U		
Endosulfan Sulfate	ug/L			0.1U		
Endrin	ug/L			0.1U		
Endrin Aldehyde	ug/L			0.1U		
Endrin Ketone	ug/L			0.1U		
gamma Chlordane	ug/L			0.05U		
Gamma-BHC (Lindane)	ug/L			0.05U		
Heptachlor	ug/L			0.05U		

Bold results = detection

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Table 1. Groundwater Chemistry Data (MW-34p1 2010 Extraction Season)

		Date of Sample				
PESTICIDES cont.	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
Heptachlor Epoxide	ug/L			0.071Y		
Methoxychlor	ug/L			0.5U		
Toxaphene	ug/L			5U		

METALS	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
Antimony, Dissolved	ug/L			50U		
Arsenic, Dissolved	ug/L	**16**	**17**	**16**	**13**	**15**
Barium, Dissolved	ug/L			**363**		
Beryllium, Dissolved	ug/L			1U		
Cadmium, Dissolved	ug/L			2U		
Calcium, Total	mg/L	**243**	**213**	**208**	**165**	**265**
Chromium, Dissolved	ug/L			5U		
Cobalt, Dissolved	ug/L			**18**		
Copper, Dissolved	ug/L			**4**		
Iron, Dissolved	ug/L	**65,000**	**62,600**	**54,900**	**55,300**	**53,100**
Iron, Total	ug/L	**67,400**	**59,800**	**55,300**		**78,700**
Lead, Dissolved	ug/L			20U		
Magnesium, Total	mg/L	**143**	**122**	**121**	**103**	**155**
Manganese, Dissolved	ug/L	**7,630**	**6,940**	**6,060**	**5,890**	**7,010**
Manganese, Total	ug/L	**7,930**	**6,340**	**5,980**		**7,700**
Mercury	mg/L			0.0001U		
Nickel, Dissolved	ug/L			**30**		
Potassium, Total	mg/L	**59**	**57**	**56**	**48**	**68**
Selenium, Dissolved	ug/L			**2**		
Silver, Dissolved	ug/L			3U		
Sodium, Total	mg/L	**301**	**264**	**256**	**216**	**285**
Thallium, Dissolved	ug/L			0.2U		
Vanadium, Dissolved	ug/L			**8**		
Zinc, Dissolved	ug/L			10U		

Bold results = detection

Blank Result = Not Measured

#U = Undetected; associated number is lab reporting limit (e.g. 0.2U)

#Y = Undetected but with elevated reporting limit; associated number is lab reporting limit (e.g. 0.13Y)

#M = Estimated value by lab due to low spectral match parameters, associated number is estimated value (e.g. 8M)

Table 1. Groundwater Chemistry Data (MW-34p1 2010 Extraction Season)

		Date of Sample				
ALDEHYDES	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
Acetaldehyde	ug/L			**59**		
Butyraldehyde	ug/L			10U		
Formaldehyde	ug/L			**198**		
Propionaldehyde	ug/L			10U		

INORGANIC PARAMETERS	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
Alkalinity (as CaCO3)	mg/L	1,360	1,250	1,270	1,210	1,190
Bicarbonate As CaCO3	mg/L	1,360	1,250	1,270	1,210	1,190
Biochemical Oxygen Demand (BOD)	mg/L			150U		
Carbonate as CaCO3	mg/L	1U	1U	1U	1U	1U
Chloride	mg/L	442	380	343	289	520
Hydroxide (as CaCO3)	mg/L	1U	1U	1U	1U	1U
Nitrate as Nitrogen	mg/L	0.05U	0.01U	0.05U	0.1U	0.01U
Nitrate+Nitrite as Nitrogen	mg/L	0.05U	0	0.05U	0.169	0.01U
Nitrite as Nitrogen	mg/L	0.125	0.073	0.093	0.141	0.01U
Sulfate	mg/L	67	17	130	67	20
Total Dissolved Solids	mg/L	2,120	1,910	1,950	1,690	2,200
Total Organic Carbon	mg/L	213	150	145	169	194
Total Phosphorus	mg/L			1		

FIELD PARAMETERS	Units	6/15/2010	6/18/2010	6/23/2010	7/21/2010	9/15/2010
Depth To Product	feet	32.15	32.46	32.35		34.68
Depth to Water	feet	32.16	32.46	32.35		34.69
Dissolved Oxygen	mg/L	2	1	2		
Oxidation Reduction Potential	mV	-127	-136			
pH	std. units	7	6	6		
Specific Conductance @ 25C	umhos/cm	4,030	3,720	3,450		
Temperature, 0 F	0 F	71	70	86		

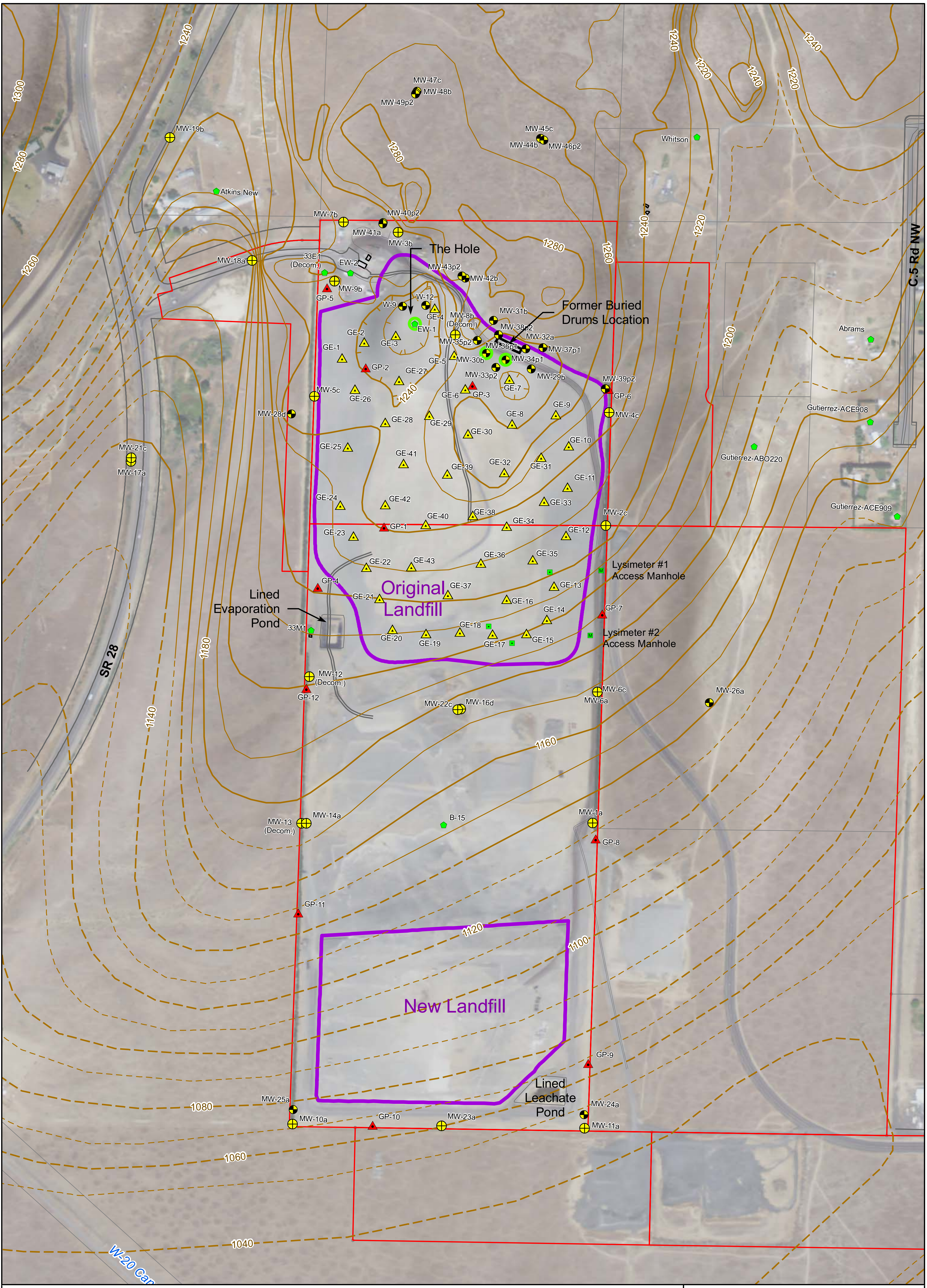
Bold results = detection

Blank Result = Not Measured

#U = Undetected; associated number is lab reporting limit (e.g. 0.2U)

#Y = Undetected but with elevated reporting limit; associated number is lab reporting limit (e.g. 0.13Y)

#M = Estimated value by lab due to low spectral match parameters, associated number is estimated value (e.g. 8M)



○ Interim Action Wells

Well Type

⊕ Quarterly Monitoring Well (MW)

◐ Remedial Investigation Monitoring Well (MW)

△ Gas Extraction (GE)

▲ Gas Probe (GP)

⬟ Other Well

▪ Lysimeter Access Manhole

Top of Basalt Elevation Contours
(dashed where inferred)

20-ft Contour

10-ft Contour

Depression

County Owned Parcels

Landfill Extents

0 Feet 400

2009 NAIP Orthophoto

N

Figure 1
Ephrata Landfill Site Map

Ephrata Landfill
RIFS

PgG

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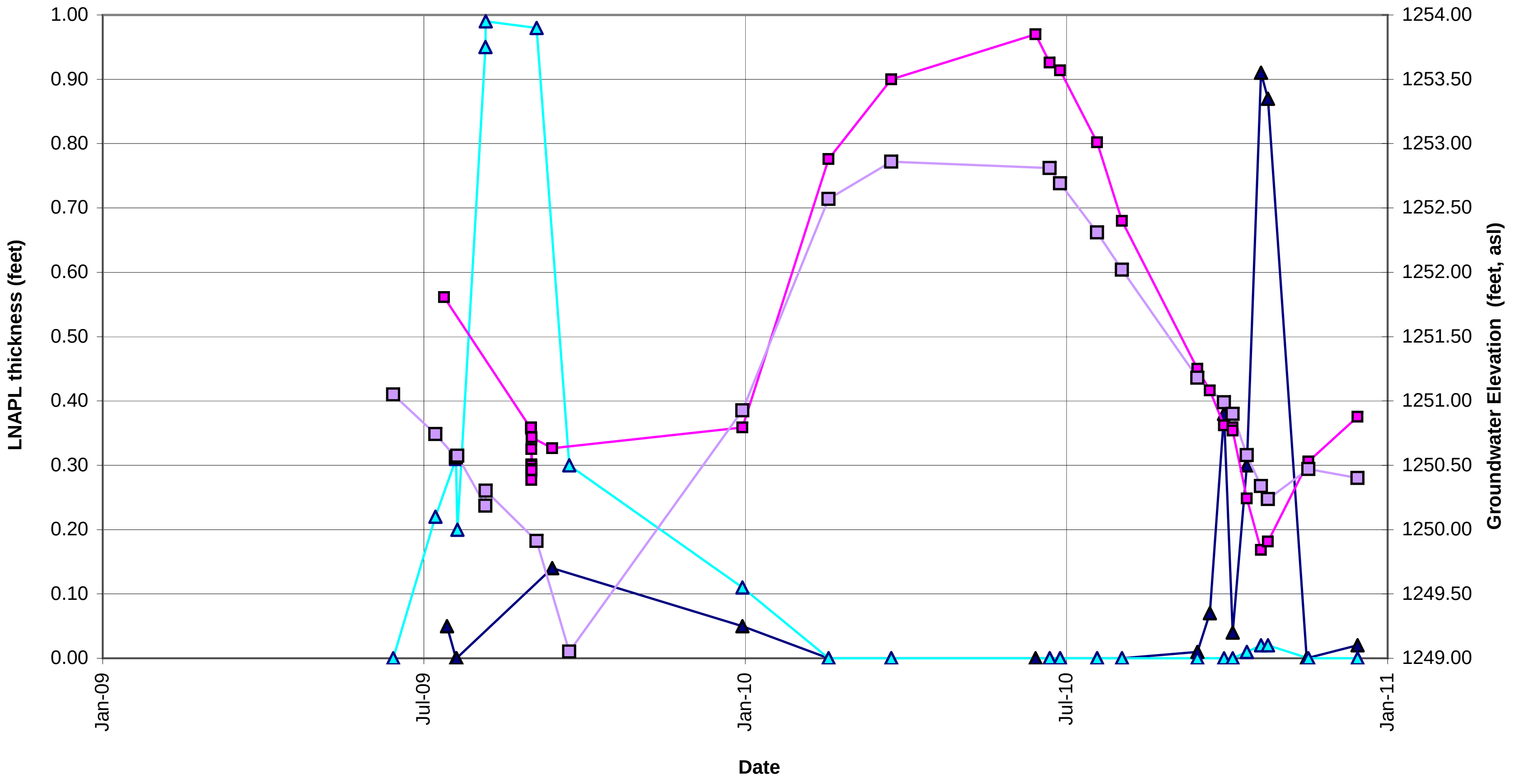
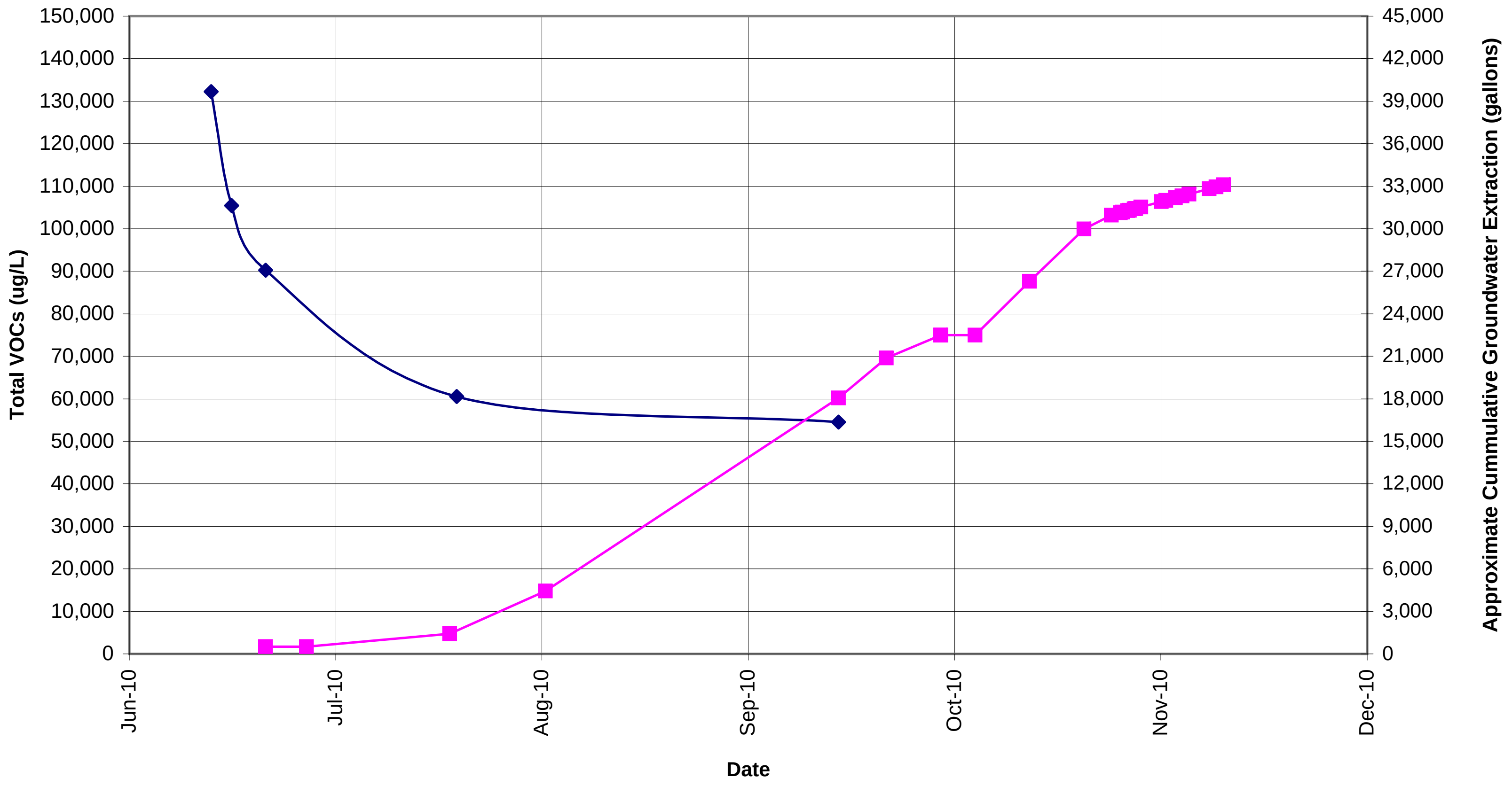


LENGEND

▲ LNAPL thickness MW-34p1
△ LNAPL thickness MW-36p1
■ Groundwater Elevation MW-34p1
□ Groundwater Elevation MW-36p1

Figure 2. Hydrographs and LNAPL Thickness (MW-34p1 and MW-36p1)

Ephrata RI/FS
JE0714



LENGEND

◆ Total VOCs

■ Approximate Cummulative Extraction (gallons)

Cummulative extraction volume is approximated from field measured pumping rates.

Figure 3. Total VOCs and Cummulative Groundwater Extraction (MW-34p1 2010 Extraction Season)

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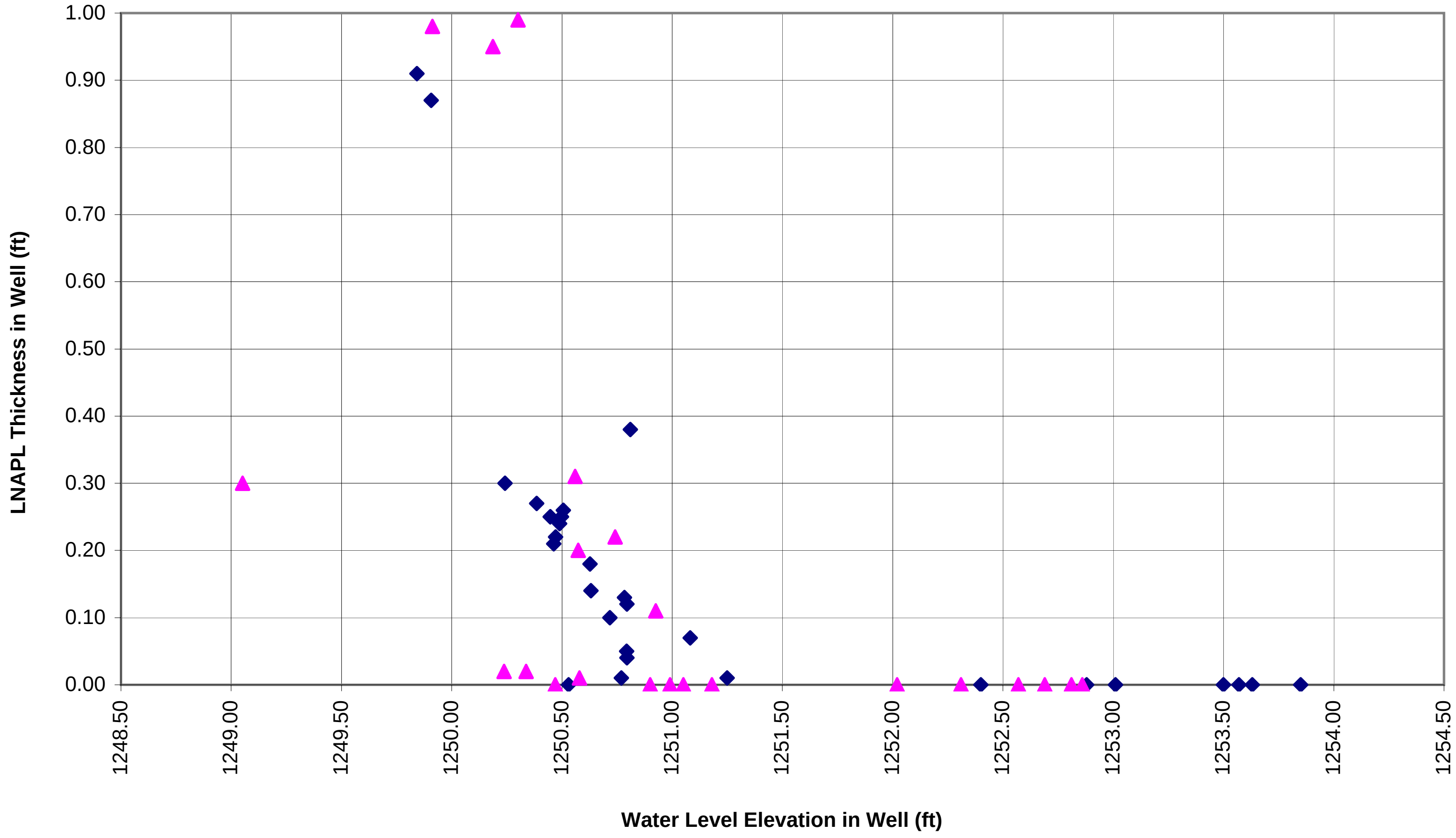

LENGEND

◆ MW-34p1

▲ MW-36p1

Figure 4. Groundwater Elevation vs LNAPL Thickness (MW-34p1 and MW-36p1)

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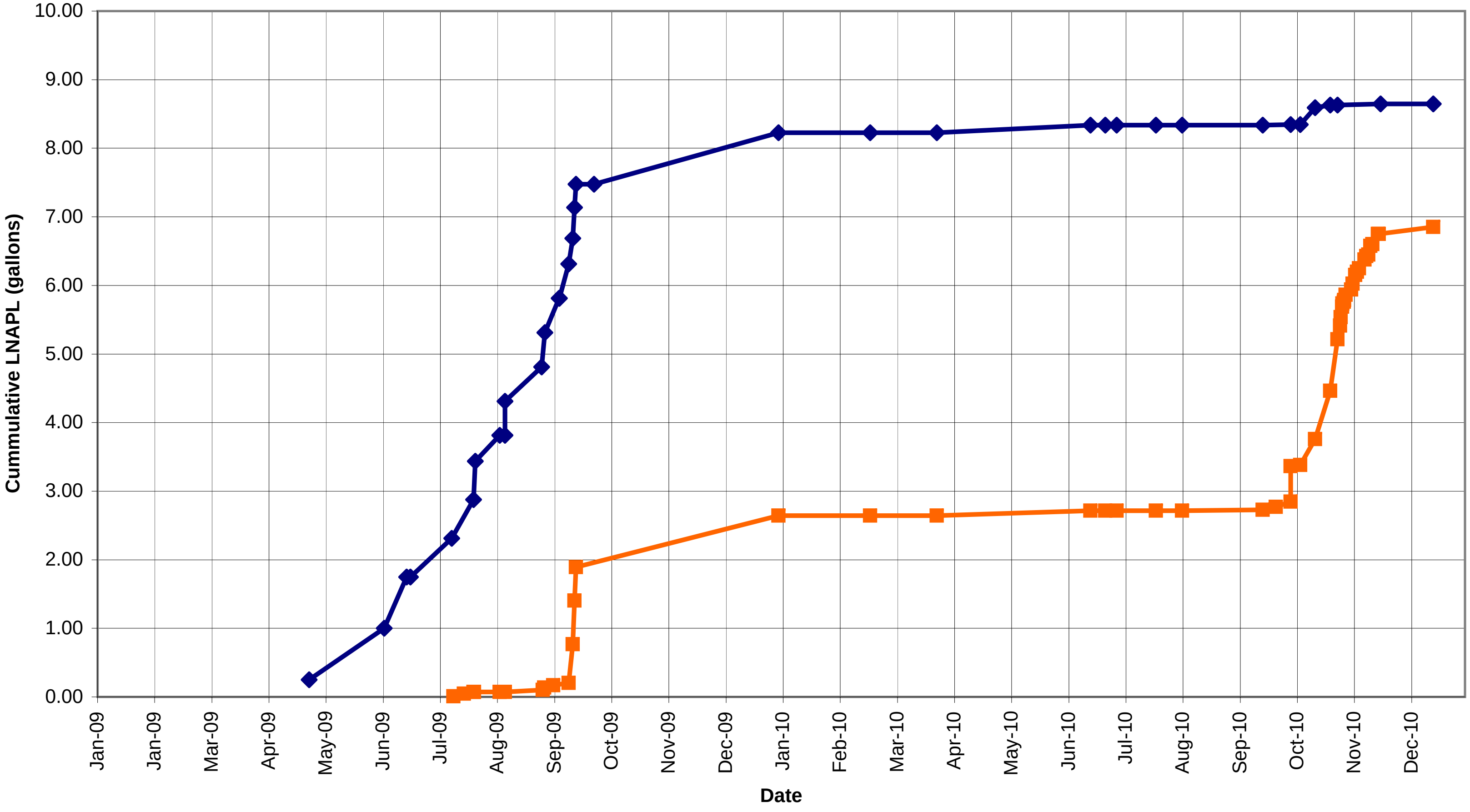

LEGEND

🟧 MW-34p1 (LNAPL removed)

◆ MW-36p1 (LNAPL removed)

Figure 5. Cumulative LNAPL Removed (MW-34p1 and MW-36p1)

Ephrata RI/FS
JE0714

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APPENDIX F

Wastewater Disposal or Circulation to Ground
Internal Technical Memorandum

CELEBRATING 25 years
PACIFIC groundwater GROUP

Internal Technical Memorandum

To: Brian Pippin and Blaine Hardy (Parametrix, Inc.)
From: Pony Ellingson and Dawn Chapel (Pacific Groundwater Group)
Re: Wastewater Disposal or Circulation to Ground
Date: April 17, 2012

State of Washington Licensed Geologist
Hydrogeologist
631
Charles Ellingson

This memo responds to Parametrix' request for evaluation of ground-based water disposal options for potential remedial actions at Ephrata Landfill. Discharges up to 15 gpm are possible, which would be derived from remedial groundwater extraction from the Roza aquifer, Hole, and P1 source zone (in order of decreasing discharge rate).

1) DEFINITIONS
    a) *Percolate* means to dispose of water to the ground above the water table. Galleries, infiltration ponds, and dry wells all percolate.
    b) *Inject* means to force water into a well that is completed below the water table.
    c) *Disposal* means to percolate or inject water from the treatment system to the ground, without the intent of enhancing source removal or hydraulic control.
    d) *Circulation* means to percolate or inject water from the treatment system into the ground with intent to enhance remediation. Two circulation schemes are considered:
        i) *Gradient control* means to percolate or inject the water where it will create a groundwater mound or ridge that helps control contaminant migration.
        ii) *Flushing* means to percolate or inject the water where it will encounter contaminants and help flush them from a source zone towards extraction wells.

2) REGULATIONS
    a) WAC 173-200. Groundwater Quality Criteria. Regulation that requires discharges of waste to the ground to be treated to AKART. Includes "anti-degradation" policy. Based on background groundwater quality or in the absence of background, numeric criteria which are similar to Drinking Water MCLs, but more extensive. Check with Ecology Toxics Cleanup Program for possible exemptions to treatment standards within hydraulically controlled areas undergoing remediation.
    b) WAC 173-216 State Waste Discharge Permit program. Requires all discharges of wastewater to the ground to be permitted. Uses Groundwater Quality Criteria as performance standard.
    c) WAC 173-340 MTCA. Cleanup regulation. Regulation does not deal directly with disposal or circulation of treated wastewater but precedent exists in State. Contact Toxics Cleanup Program to improve understanding of disposal and circulation at remediation sites.
    d) WAC 173-218 Underground Injection Control (UIC). Classifies/prohibits/permits injection wells. Class V wells include "injection wells used for remediation wells receiving

fluids intended to clean up, treat or prevent subsurface contamination" (WAC 173-218(a)(x)). Ecology UIC coordinator referred PGG to Toxics Cleanup Program for details on Class V UIC wells used in remediation projects regulated by the State. PGG did not follow up with Toxics Cleanup Program.

3) QUALITATIVE INPUT

UIC Well

Any well used for percolation or injection would be a Class V UIC well. We found no written restriction on which formation a Class V well can discharge to[1] but discussion with Ecology TCP is warranted at some point.

Circulation

We do not recommend circulation in the P1 source zone unless application of surfactants or heat shows this to be better than other source reduction actions. It would be possible to circulate groundwater through the P1 source zone and enhance removal of source mass; however, the high source mass and comparatively low groundwater concentrations for PCE at the source indicates that without addition of surfactants or heat, this action is not likely to be competitive with non-groundwater source removal actions (eg: SVE). Circulation would conflict with SVE because it would raise the water level in P1 and reduce the vadose zone where SVE is effective. Therefore we do not recommend this action unless surfactants or heat are evaluated and found to be better than other actions.

Circulation in the Hole is not recommended because it would require increasing water levels within refuse. The Hole and high Transmissivity (T) Roza zone provide the only high T zones where capture of contaminants can occur with relatively few wells. The bounded nature of both of these high T zones promotes containment and capture, without circulation.

Circulation in the Roza aquifer high T zone is not recommended. The high T zone is where we want to focus drawdown to capture contaminants both locally and from considerable distance to the east with the goal of capturing the entire Roza plume at the property boundary. Although we might be able to finesse the areas where heads are lowered by pumping (property line), and raised by injection (possibly near MW-9b), the overall effect would be to *reduce drawdown*. We thus expect circulation in the high T zone to reduce our ability to capture contaminants from the Roza in areas remote from the pumping center (eg: low T zone) which would reduce our ability to capture the entire Roza plume at the property boundary.

Circulation by injection into the Roza low T zone (eg: near MW-44b and Whitson) might be used to reverse groundwater flow and enhance capture of the northerly plume from extraction wells placed at the property boundary in the high T zone. However, many wells would be required to dispose of 15 gpm in the low T zone. PGG will evaluate this option further if requested.

Disposal

Because of the small footprint of the local high-T Roza zone, it would not be possible to dispose of water there without influencing the Roza extraction system. Thus the effect of disposal is similar to circulation and is not recommended.

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[1] Class IV wells must discharge to the formation the water came from.

The outwash formation is preferred for water disposal. From a hydraulic standpoint the outwash aquifer is an easy formation in which to percolate or inject water. Its use would not interfere with any remedial action, and it is not used for water supply. Percolation is generally more favorable than injection because it should be cheaper and in some cases reduces regulatory hurdles and treatment requirements. Substantial thicknesses of unsaturated outwash occur west, east, and south of the landfill. Percolation through a small infiltration pond should be possible to the east or south, whereas a dry well (UIC) would likely be required to the west because silt occurs at land surface (above the outwash).

Permitting an infiltration pond likely requires a State Waste Discharge permit. It should be possible to obtain if treatment standards meet AKART and water quality meets numerical groundwater quality criteria of WAC 173-200. The permit conditions might focus on assuring that infiltration does not occur if the treatment system fails. Use of a dry well to the west might require a UIC permit in addition to a State Waste Discharge Permit.

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APPENDIX G

Detailed Cost Estimates

Opinion of Probable Cost for Institutional Controls

Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual[1]	O&M Cost Present Worth[2]	Source
Institutional Control Construction							
Fencing	4,800	LF	$29	$139,200	$1,250	$15,511	Similar project
Signage	1	LS	$1,000	$1,000			Similar project
Mobilization	10%	of Capital Cost		$14,020			Similar project
Construction Subtotal				**$154,220**			
Sales Tax			8.7%	$13,417			
O&M Subtotal						**$16,876**	
NET PRESENT WORTH						**$185,000**	

Definitions:

LF – linear feet.

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Opinion of Probable Cost for Seasonal Pumping from the Hole and P1 Zone

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Seasonal Pumping from EW-1, MW-34p1, and MW-36p1							
Electrical Supply	1	LS	$32,250	$32,250	$900	$11,168	Engineer's estimate; $0.0754/kWh
Extraction Pumps	3	each	$8,000	$24,000	$2,619	$78,561	Vendor quote
Installation	20%	of Capital Cost		$4,800			
Wellhead Completions	3	each	$2,800	$8,400			Engineer's estimate
Discharge Pipeline to Evaporation Pond	1,400	LF	$20.00	$28,000			Similar project
Instrumentation and Controls	1	LS	$5,000	$5,000			Engineer's estimate
Performance Monitoring	1	each	$1,030			$12,781	Engineer's estimate
Equipment Decommissioning	1	LS	$5,000			$1,706	Engineer's estimate
Mobilization	10%	of Capital Cost		$10,245			Engineer's estimate
Contingency	25%	of Capital Cost		$25,613		$26,054	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$41,492		$39,081	Engineer's estimate
Construction Subtotal				**$179,800**			
Sales Tax			8.7%	$15,643			
O&M Subtotal						**$169,351**	
NET PRESENT WORTH						**$365,000**	
The Hole						**$260,000**	290,000 gal/yr of 405,000 gal/yr total
P1 Zone						**$105,000**	115,000 gal/yr of 405,000 gal/yr total

Definitions:

gal/yr – gallons per year.
kWh – kilowatt hour.
LF – linear feet.
LS – lump sum.
O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Opinion of Probable Cost for Continuous Pumping from the Hole and P1 Zone

Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual[1]	O&M Cost Present Worth[2]	Source
Continuous Pumping from the Hole and P1 Zone							
Electrical Supply	1	LS	$49,500	$49,500	$2,700	$33,504	Engineer's estimate; $0.0754/kWh
Extraction Pumps	9	each	$8,000	$72,000	$6,086	$182,592	Vendor quote
Installation	20%	of Capital Cost		$14,400			
Wellhead Completions	9	each	$2,800	$25,200			Engineer's estimate
Discharge Pipeline to Evaporation Pond	2,000	LF	$20.00	$40,000			Similar project
Instrumentation and Controls	1	LS	$15,000	$15,000			Engineer's estimate
Equipment Decommissioning	1	LS	$10,000			$3,412	Engineer's estimate
Mobilization	10%	of Capital Cost		$21,610		$21,951	Engineer's estimate
Contingency	25%	of Capital Cost		$54,025		$54,877	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$87,521		$88,901	Engineer's estimate
Construction Subtotal				**$379,256**			
Sales Tax			8.7%	$32,995			
O&M Subtotal						**$415,838**	
NET PRESENT WORTH						**$828,000**	
The Hole						**$613,000**	7 new wells, 61% of water volume
P1 Zone						**$215,000**	2 new wells, 39% of water volume

Definitions:

kWh – kilowatt hour.

LF – linear feet.

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Opinion of Probable Cost for Soil Vapor Extraction

Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual[1]	O&M Cost Present Worth[2]	Source
SVE System							
SVE Pilot Test	1	LS	$25,000	$25,000			Engineer's estimate
SVE Wells	6	each	$18,000	$108,000			Engineer's estimate
Well Vaults	6	each	$2,000	$12,000			Vendor quote
Knockout Tank	1	each	$8,000	$8,000			Vendor quote
Vacuum Pump	1	each	$10,000	$10,000	$2,624	$13,121	Vendor quote
Piping, Valving	500	LF	$10	$5,000			Engineer's estimate
System Housing including Site Preparation	1	LS	$20,000	$20,000			Engineer's estimate
Equipment Installation	20%	of Capital Cost		$8,600			Similar project
Electrical, Instrumentation and Controls	1	LS	$42,250	$42,250	$4,925	$20,194	Similar project
System Startup	1	LS	$15,000	$15,000			Similar project
Performance Monitoring	1	each	$7,500			$30,751	
O&M Labor	1	LS	$25,000			$102,505	Similar project
System Decommissioning	1	LS	$17,200			$14,217	Similar project
Mobilization	8%	of Capital Cost		$18,308			Similar project
Contingency	25%	of Capital Cost		$68,040		$45,197	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$102,059		$67,796	Engineer's estimate
Construction Subtotal				**$442,257**			
Sales Tax			8.7%	$38,476			
O&M Subtotal						**$308,000**	
NET PRESENT WORTH						**$789,000**	

Definitions:

LF – linear feet.
LS – lump sum.
O&M – operation and maintenance.
SVE – soil vapor extraction.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Opinion of Probable Cost for
Northerly Plume Capture (with Continuous or Seasonal Pumping from the Hole and P1 Zone)

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual**[1]	**Present Worth**[2]	**Source**
Pumping from the Hole, P1 Zone, and Roza Aquifer							
Electrical Supply	1	LS	$71,750	$71,750	$3,300	$40,950	Engineer's estimate; $0.0754/kWh
Extraction Pumps	11	each	$8,000	$88,000	$7,685	$230,542	Vendor quote
Installation	20%	of Capital Cost		$18,000			
Wellhead Completions	11	each	$2,800	$30,800			Engineer's estimate
Discharge Pipeline to Evaporation Pond	2,350	LF	$20.00	$47,000			Similar project
Instrumentation and Controls	1	LS	$20,000	$20,000			Engineer's estimate
Equipment Decommissioning	1	LS	$15,000			$5,118	Engineer's estimate
Mobilization	10%	of Capital Cost		$27,555		$27,661	Engineer's estimate
Contingency	25%	of Capital Cost		$68,888		$69,152	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$111,598		$112,027	Engineer's estimate
Construction Subtotal				**$483,590**			
Sales Tax			8.7%	$42,072			
O&M Subtotal						**$524,121**	
NET PRESENT WORTH						**$1,050,000**	
Continuous Pumping from the Hole (page G-3)						($613,000)	
Continuous Pumping from the P1 Zone (page G-3)						($215,000)	
Roza Aquifer Only (Net Present Worth - Costs for the Hole and P1 Zone)						**$222,000**	

Definitions:

kWh – kilowatt hour.

LF – linear feet.

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Opinion of Probable Cost for
Northerly Plume Capture (with No Pumping from the Hole or P1 Zone)

Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost		Source
					Annual[1]	Present Worth[2]	
Continuous Pumping from the Roza Aquifer							
Electrical Supply	1	LS	$32,250	$32,250	$600	$7,445	Engineer's estimate; $0.0754/kWh
Extraction Pumps	2	each	$8,000	$16,000	$2,619	$78,561	Vendor quote
Installation	20%	of Capital Cost		$3,000			
Wellhead Completions	2	each	$2,800	$5,600			Engineer's estimate
Discharge Pipeline to Evaporation Pond	1,500	LF	$20.00	$30,000			Similar project
Instrumentation and Controls	1	LS	$5,000	$5,000			Engineer's estimate
Equipment Decommissioning	1	LS	$5,000			$1,706	Engineer's estimate
Mobilization	10%	of Capital Cost		$9,185		$8,771	Engineer's estimate
Contingency	25%	of Capital Cost		$22,963		$21,928	Engineer's estimate
Project Management/Engineering/Permitting	30%	of Capital Cost		$37,199		$35,523	Engineer's estimate
Construction Subtotal				**$161,197**			
Sales Tax			8.7%	$14,024			
O&M Subtotal						**$166,679**	
NET PRESENT WORTH						**$342,000**	

Definitions:

kWh – kilowatt hour.

LF – linear feet.

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Opinion of Probable Cost for
Manual LNAPL Removal and LNAPL Separation and Disposal

Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual[1]	O&M Cost Present Worth[2]	Source
Manual LNAPL Removal							
Grant County Labor	48	hour	$75	$3,600	$2,681	$80,432	Engineer's estimate
Consultant Labor	8	hour	$120	$960			Engineer's estimate
Materials (absorbent socks, personal protective equipment, etc.)	1	LS	$500	$500			Engineer's estimate
Materials Disposal	1	Drum	$1,000	$1,000			Engineer's estimate
Contingency	25%	of Capital Cost		$1,515		$20,108	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$2,273		$30,162	Engineer's estimate
Construction Subtotal				**$9,848**			
Sales Tax			8.7%	$857			
O&M Subtotal						**$131,000**	
NET PRESENT WORTH						**$142,000**	

Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual	O&M Cost Present Worth[2]	Source
LNAPL Separation and Disposal							
LNAPL Characterization	1	each	$2,140	$2,140		$26,555	
LNAPL/Solids Disposal	5	Drum	$1,000	$5,000		$62,045	Actual costs
Construction Subtotal				**$7,140**			
Sales Tax			8.7%	$621			
O&M Subtotal						**$88,601**	
NET PRESENT WORTH						**$96,000**	

Definitions:

LNAPL – light non-aqueous phase liquid.

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Opinion of Probable Cost for
Evaporation Sized for Treating Continuous Pumping from the Hole and P1 Zone and Northerly Plume Capture without Treatment

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Evaporation Pond (4.65 acres)							
Pond Excavation and Grading							
Soil Excavation, Haul, and Disposal[3]	9,300	CY	$8.13	$75,609			WSDOT Unit Bid Analysis - April 2011 to April 2012
Common Borrow (Berms)[4]	4,300	CY	$7.10	$30,530			WSDOT Unit Bid Analysis - April 2011 to April 2012
Soil Compaction (Berms)[4]	4,300	CY	$1.63	$7,009			WSDOT Unit Bid Analysis - April 2011 to April 2012
Bedding Layer from Stockpile	3,750	CY	$20.00	$75,000			Similar projects
Mobilization	8%	of Capital Cost		$15,052			Similar project
Pond Liner and Balasting[5]							
Geomembrane Liner	45,000	SY	$8.00	$360,000	$10,000	$124,090	Similar project
Geonet (Leak Detection)	22,500	SY	$6.00	$135,000			
Geotextile Cushion Layer	22,500	SY	$3.00	$67,500			
Monitoring/Leak Detection Layer Collection	1	LS	$10,000	$10,000			
Balast	9,000	LF	$4.00	$36,000			10% of liner cost, based on similar projects
Mobilization	8%	of Capital Cost		$48,680			Similar project
Access							
Crushed Surfacing Base Course[6]	1,100	TN	$17.00	$18,700			
Mobilization	8%	of Capital Cost		$1,496			
Pond Decommissioning							
Embankment	24,000	CY	$5.00			$40,942	Similar project;average of equivelent materials
Geomembrane Liner[7]	23,000	SY	$10.00			$78,472	Similar projects
Geosynthetic Clay Liner	23,000	SY	$6.00			$47,083	Similar projects
Geotextile Cushion	23,000	SY	$3.00			$23,542	Similar projects
Cover Layer (2' Thick)	16,000	CY	$5.00			$27,295	20% of liner cost, based on similar projects
Mobilization	8%	of Capital Cost				$17,387	Similar project
Contingency	25%	of Capital Cost		$220,144		$89,703	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$330,216		$134,554	Engineer's estimate
Construction Subtotal				**$1,430,936**			
Sales Tax			8.7%	$124,491			
O&M Subtotal						**$622,998**	
NET PRESENT WORTH						**$2,178,000**	

Definitions:

CY– cubic yard.
LF – linear foot.
LS – lump sum.
O&M – operation and maintenance.
SY – square yard.
TN – ton.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

[3] Soil excavation, haul, and disposal assumes soil excavated is stockpiled for daily cover.

[4] Common borrow and soil compaction assumes berms for the pond will be 15' wide at the top with 3:1 slopes on both sides.

[5] Liner system assumes double liner with leak detection layer and geotextile cushion.

[6] Includes road to pond (150' long) and access around pond at top of berm (750' long, 15'6" wide).

[7] Annual costs for geomembrane include yearly cleaning and regular testing.

Opinion of Probable Cost for
Evaporation Sized for Treating Northerly Plume Capture and Seasonal Pumping from the Hole and P1 Zone without Treatment

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Evaporation Pond (4.15 acres)							
Pond Excavation and Grading							
Soil Excavation, Haul, and Disposal[3]	6,848	CY	$8.13	$55,670			WSDOT Unit Bid Analysis - April 2011 to April 2012
Common Borrow (Berms)[4]	4,150	CY	$7.10	$29,465			WSDOT Unit Bid Analysis - April 2011 to April 2012
Soil Compaction (Berms)[4]	4,150	CY	$1.63	$6,765			WSDOT Unit Bid Analysis - April 2011 to April 2012
Bedding Layer from Stockpile	3,424	CY	$20.00	$68,475			Similar projects
Mobilization	8%	of Capital Cost		$12,830			Similar project
Pond Liner and Balasting[5]							
Geomembrane Liner	40,172	SY	$8.00	$321,376	$10,000	$124,090	Similar project
Geonet (Leak Detection)	20,086	SY	$6.00	$120,516			
Geotextile Cushion Layer	20,086	SY	$3.00	$60,258			
Monitoring/Leak Detection Layer Collection	1	LS	$10,000	$10,000			
Balast	8,300	LF	$4.00	$33,200			10% of liner cost, based on similar projects
Mobilization	8%	of Capital Cost		$43,628			Similar project
Access							
Crushed Surfacing Base Course[6]	1,000	TN	$17.00	$17,000			
Mobilization	8%	of Capital Cost		$1,360			
Pond Decommissioning							
Embankment	30,433	CY	$5.00			$51,917	Similar project, average of equivelent materials
Geomembrane Liner[7]	21,128	SY	$10.00			$72,085	Similar projects
Geosynthetic Clay Liner	21,027	SY	$6.00			$43,044	Similar projects
Geotextile Cushion	21,027	SY	$3.00			$21,522	Similar projects
Cover Layer (2' Thick)	14,387	CY	$5.00			$24,542	20% of liner cost, based on similar projects
Mobilization	8%	of Capital Cost				$17,049	Similar project
Contingency	25%	of Capital Cost		$195,136		$88,562	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$292,703		$132,843	Engineer's estimate
Construction Subtotal				**$1,268,382**			
Sales Tax			8.7%	$110,349			
O&M Subtotal						**$614,940**	
NET PRESENT WORTH						**$1,994,000**	

Definitions:

CY– cubic yard.
LF – linear foot.
LS – lump sum.
O&M – operation and maintenance.
SY – square yard.
TN – ton.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount 7%

[3] Soil excavation, haul, and disposal assumes soil excavated is stockpiled for daily cover.

[4] Common borrow and soil compaction assumes berms for the pond will be 15' wide at the top with 3:1 slopes on both sides.

[5] Liner system assumes double liner with leak detection layer and geotextile cushion.

[6] Includes road to pond (150' long) and access around pond at top of berm (750' long, 15'6" wide).

[7] Annual costs for geomembrane include yearly cleaning and regular testing.

Opinion of Probable Cost for
Evaporation Sized for Treating Northerly Plume Capture without Treatment

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Evaporation Pond (3.9 acres)							
Pond Excavation and Grading							
Soil Excavation, Haul, and Disposal[3]	6,435	CY	$8.13	$52,317			WSDOT Unit Bid Analysis - April 2011 to April 2012
Common Borrow (Berms)[4]	3,900	CY	$7.10	$27,690			WSDOT Unit Bid Analysis - April 2011 to April 2012
Soil Compaction (Berms)[4]	3,900	CY	$1.63	$6,357			WSDOT Unit Bid Analysis - April 2011 to April 2012
Bedding Layer from Stockpile	3,218	CY	$20.00	$64,350			Similar projects
Mobilization	8%	of Capital Cost		$12,057			Similar project
Pond Liner and Balasting[5]							
Geomembrane Liner	37,752	SY	$8.00	$302,016	$10,000	$124,090	Similar project
Geonet (Leak Detection)	18,876	SY	$6.00	$113,256			
Geotextile Cushion Layer	18,876	SY	$3.00	$56,628			
Monitoring/Leak Detection Layer Collection	1	LS	$10,000	$10,000			
Balast	7,800	LF	$4.00	$31,200			10% of liner cost, based on similar projects
Mobilization	8%	of Capital Cost		$41,048			Similar project
Access							
Crushed Surfacing Base Course[6]	1,000	TN	$17.00	$17,000			
Mobilization	8%	of Capital Cost		$1,360			
Pond Decommissioning							
Embankment	28,600	CY	$5.00			$48,789	Similar project, average of equivelent materials
Geomembrane Liner[7]	19,760	SY	$10.00			$67,418	Similar projects
Geosynthetic Clay Liner	19,760	SY	$6.00			$40,451	Similar projects
Geotextile Cushion	19,760	SY	$3.00			$20,225	Similar projects
Cover Layer (2' Thick)	13,520	CY	$5.00			$23,064	20% of liner cost, based on similar projects
Mobilization	8%	of Capital Cost				$15,996	Similar project
Contingency	25%	of Capital Cost		$183,820		$85,008	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$275,729		$127,512	Engineer's estimate
Construction Subtotal				**$1,194,828**			
Sales Tax			8.7%	$103,950			
O&M Subtotal						**$589,830**	
NET PRESENT WORTH						**$1,889,000**	

Definitions:

CY– cubic yard.
LF – linear foot.
LS – lump sum.
O&M – operation and maintenance.
SY – square yard.
TN – ton.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

[3] Soil excavation, haul, and disposal assumes soil excavated is stockpiled for daily cover.

[4] Common borrow and soil compaction assumes berms for the pond will be 15' wide at the top with 3:1 slopes on both sides.

[5] Liner system assumes double liner with leak detection layer and geotextile cushion.

[6] Includes road to pond (150' long) and access around pond at top of berm (750' long, 15'6" wide).

[7] Annual costs for geomembrane include yearly cleaning and regular testing.

Opinion of Probable Cost for
Evaporation Sized for Evaporation of Effluent Streams from Treatment Train

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Evaporation Pond (2.6 acres)							
Pond Excavation and Grading							
Soil Excavation, Haul, and Disposal[3]	4,290	CY	$8.13	$34,878			WSDOT Unit Bid Analysis - April 2011 to April 2012
Common Borrow (Berms)[4]	2,600	CY	$7.10	$18,460			WSDOT Unit Bid Analysis - April 2011 to April 2012
Soil Compaction (Berms)[4]	2,600	CY	$1.63	$4,238			WSDOT Unit Bid Analysis - April 2011 to April 2012
Bedding Layer from Stockpile	2,145	CY	$20.00	$42,900			Similar projects
Mobilization	8%	of Capital Cost		$8,038			Similar project
Pond Liner and Balasting[5]							
Geomembrane Liner	25,168	SY	$8.00	$201,344	$10,000	$124,090	Similar project
Geonet (Leak Detection)	12,584	SY	$6.00	$75,504			
Geotextile Cushion Layer	12,584	SY	$3.00	$37,752			
Monitoring/Leak Detection Layer Collection	1	LS	$26,000	$26,000			
Balast	5,200	LF	$4.00	$20,800			10% of liner cost, based on similar projects
Mobilization	8%	of Capital Cost		$28,912			Similar project
Access							
Crushed Surfacing Base Course[6]	500	TN	$17.00	$8,500			
Mobilization	8%	of Capital Cost		$680			
Pond Decommissioning							
Embankment	19,067	CY	$5.00			$32,526	Similar project, average of equivelent materials
Geomembrane Liner[7]	13,173	SY	$10.00			$44,945	Similar projects
Geosynthetic Clay Liner	13,173	SY	$6.00			$26,967	Similar projects
Geotextile Cushion	13,173	SY	$3.00			$13,484	Similar projects
Cover Layer (2' Thick)	9,013	CY	$5.00			$15,376	20% of liner cost, based on similar projects
Mobilization	8%	of Capital Cost				$10,664	Similar project
Contingency	25%	of Capital Cost		$127,001		$67,013	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$190,502		$100,520	Engineer's estimate
Construction Subtotal				**$825,509**			
Sales Tax			8.7%	$71,819			
O&M Subtotal						**$462,685**	
NET PRESENT WORTH						**$1,360,000**	

Definitions:

CY– cubic yard.
LF – linear foot.
LS – lump sum.
O&M – operation and maintenance.
SY – square yard.
TN – ton.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

[3] Soil excavation, haul, and disposal assumes soil excavated is stockpiled for daily cover.

[4] Common borrow and soil compaction assumes berms for the pond will be 15' wide at the top with 3:1 slopes on both sides.

[5] Liner system assumes double liner with leak detection layer and geotextile cushion.

[6] Includes road to pond (150' long) and access around pond at top of berm (750' long, 15'6" wide).

[7] Annual costs for geomembrane include yearly cleaning and regular testing.

Opinion of Probable Cost for
Evaporation Sized for Disposal of Continuous Pumping from the Hole and P1 Zone Only without Treatment

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Evaporation Pond (0.75 acre)							
Pond Excavation and Grading							
Soil Excavation, Haul, and Disposal[3]	1,238	CY	$8.13	$10,061			
Common Borrow (Berms)[4]	1,425	CY	$7.10	$10,118			
Soil Compaction (Berms)[4]	1,425	CY	$1.63	$2,323			
Bedding Layer from Stockpile	619	CY	$20	$12,375			
Mobilization	10%	of Capital Cost		$3,488			
Pond Liner and Balasting[5]							
Geomembrane Liner	7,260	SY	$10	$72,600	$10,000	$124,090	
Geonet (Leak Detection)	3,630	SY	$6.00	$21,780			
Geotextile Cushion Layer	3,630	SY	$3.00	$10,890			
Monitoring/Leak Detection Layer Collection	1	LS	$7,500	$7,500			
Balast	1,500	LF	$9.50	$14,250			
Mobilization	12%	of Capital Cost		$15,242			
Access							
Crushed Surfacing Base Course[6]	500	TN	$17.00	$8,500			
Mobilization	8%	of Capital Cost		$680			
Pond Decommissioning							
Embankment	5,500	CY	$5.00			$9,383	Similar project, average of equivelent materials
Geomembrane Liner[7]	3,800	SY	$10.00			$12,965	Similar projects
Geosynthetic Clay Liner	3,800	SY	$6.00			$7,779	Similar projects
Geotextile Cushion	3,800	SY	$3.00			$3,889	Similar projects
Cover Layer (2' Thick)	2,600	CY	$5.00			$4,435	20% of liner cost, based on similar projects
Mobilization	10%	of Capital Cost				$3,845	Similar project
Contingency	25%	of Capital Cost		$47,452		$41,597	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$71,177		$45,548	Engineer's estimate (22% PM/Eng for O&M)
Construction Subtotal				**$308,435**			
Sales Tax			8.7%	$26,834			
O&M Subtotal						**$264,793**	
NET PRESENT WORTH						**$600,000**	

Definitions:

CY– cubic yard.
LF – linear foot.
LS – lump sum.
O&M – operation and maintenance.
SY – square yard.
TN – ton.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

[3] Soil excavation, haul, and disposal assumes soil excavated is stockpiled for daily cover.

[4] Common borrow and soil compaction assumes berms for the pond will be 15' wide at the top with 3:1 slopes on both sides.

[5] Liner system assumes double liner with leak detection layer and geotextile cushion.

[6] Includes road to pond (150' long) and access around pond at top of berm (750' long, 15'6" wide).

[7] Annual costs for geomembrane include yearly cleaning and regular testing.

Opinion of Probable Cost for Evaporation Sized for Disposal of Seasonal Pumping from the Hole and P1 Zone

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Evaporation Pond (0.5 acre)							
Pond Excavation and Grading							
Soil Excavation, Haul, and Disposal[3]	825	CY	$8.13	$6,707			
Common Borrow (Berms)[4]	950	CY	$7.10	$6,745			
Soil Compaction (Berms)[4]	950	CY	$1.63	$1,549			
Bedding Layer from Stockpile	413	CY	$20	$8,250			
Mobilization	10%	of Capital Cost		$2,325			
Pond Liner and Balasting[5]							
Geomembrane Liner	4,840	SY	$10.00	$48,400	$5,000	$62,045	
Geonet (Leak Detection)	2,420	SY	$6.00	$14,520			
Geotextile Cushion Layer	2,420	SY	$3.00	$7,260			
Monitoring/Leak Detection Layer Collection	1	LS	$5,000	$5,000			
Balast	1,000	LF	$9.50	$9,500			
Mobilization	12%	of Capital Cost		$10,162			
Access							
Crushed Surfacing Base Course[6]	500	TN	$17.00	$8,500			
Mobilization	8%	of Capital Cost		$680			
Pond Decommissioning							
Embankment	3,500	CY	$5.00			$5,971	Similar project, average of equivelent materials
Geomembrane Liner (7)	2,533	SY	$10.00			$8,643	Similar projects
Geosynthetic Clay Liner	2,533	SY	$6.00			$5,186	Similar projects
Geotextile Cushion	2,533	SY	$3.00			$2,593	Similar projects
Cover Layer (2' Thick)	1,733	LS	$5.00			$2,957	20% of liner cost, based on similar projects
Mobilization	10%	of Capital Cost				$2,535	Similar project
Contingency	25%	of Capital Cost		$32,399		$6,971	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$48,599		$8,365	Engineer's estimate
O&M Contingency	20%	of Capital Cost				$12,409	
O&M Project Management, Engineering, Permitting	30%	of Capital Cost				$18,614	
Construction Subtotal				**$210,596**			
Sales Tax			8.7%	$18,322			
O&M Subtotal						**$136,289**	
NET PRESENT WORTH						**$365,000**	

Definitions:

CY– cubic yard.
LF – linear foot.
LS – lump sum.
O&M – operation and maintenance.
SY – square yard.
TN – ton.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

[3] Soil excavation, haul, and disposal assumes soil excavated is stockpiled for daily cover.

[4] Common borrow and soil compaction assumes berms for the pond will be 15' wide at the top with 3:1 slopes on both sides.

[5] Liner system assumes double liner with leak detection layer and geotextile cushion.

[6] Includes road to pond (150' long) and access around pond at top of berm (750' long, 15'6" wide).

[7] Annual costs for geomembrane include yearly cleaning and regular testing.

Opinion of Probable Cost for
Treatment Train for Continuous Pumping from the Hole and P1 Zone and Northerly Plume Capture

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Building and Utilities							
4,000 SF Steel Pre-engineered, one 20'-tall story, insulated	1	LS	$300,000	$300,000	$500	$6,205	
Building Foundation	1	LS	$16,500	$16,500			Excavate, form, cast
Slab on Grade (4,000 SF)	1	LS	$22,700	$22,700			Vapor barrier, capillary break, cast in place
Site Development (Parking, Access, Foundations)	1	AC	$60,000	$60,000			1' crushed surfacing base course, clearing, preloading
Electrical Supply - 3-Phase, from Flare Station, on Poles	3,500	LF	$100	$350,000			
Building Electrical	1	LS	$150,000	$150,000	$2,400	$29,782	
Potable Water - 2" PVC	3,000	LF	$20.00	$60,000			Similar Projects
Sewer - 4" PVC, Pump, and Grinder	3,000	LF	$25.00	$75,000			Similar Projects
Discharge Pipeline to Infiltration Pond	1,000	LF	$20.00	$20,000			Similar project
Discharge Pipeline to Evaporation Pond	600	LF	$20.00	$12,000			Similar project
Mobilization	8%	of Capital Cost		$82,736			Similar project
Contingency	25%	of Capital Cost		$287,234		$8,997	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$430,851		$13,495	Engineer's estimate
***Ex-situ* Treatment System**							
Bench-scale Treatability Testing	1	LS	$100,000	$100,000			Engineer's estimate
Equalization Tanks (20,000 gallons)	1	each	$50,000	$50,000			Vendor quote
Oil/Water Separator	1	each	$9,000	$9,000			Vendor quote
Air Compressor	1	each	$9,000	$9,000			Vendor quote
Transfer Pumps	6	each	$1,000	$6,000			Vendor quote
Sludge Pumps	5	each	$3,500	$17,500			Vendor quote
Oil Pump	1	each	$3,250	$3,250	$18,353	$550,585	Vendor quote
Surge Tanks (1,000 gallons)	4	each	$2,000	$8,000			Vendor quote
Lime Feed System	1	each	$74,972	$74,972			Vendor quote
Clarifier System with Chemical Storage Tank	1	each	$57,160	$57,160			Vendor quote
Air Stripper System	1	each	$19,220	$19,220			Vendor quote
Reverse Osmosis System with Greensand Prefilter	1	each	$92,000	$92,000	$41,400	$513,734	Vendor quote
Granular Activated Carbon System (Liquid Phase)	1	each	$23,000	$23,000	$5,475	$67,940	Vendor quote
General Piping	7%	of Capital Cost		$25,837			Similar project
Equipment Installation	20%	of Capital Cost		$78,988			Similar project
Electrical, Instrumentation, and Controls	1	LS	$350,000	$350,000			Similar project
System Startup	1	LS	$40,000	$40,000			Similar project
Performance Monitoring	4	each	$2,140			$106,221	
O&M Labor	1	LS	$75,000			$930,678	Similar project
System Decommissioning	1	LS	$50,000			$17,059	Similar project
Mobilization	8%	of Capital Cost		$69,114			Similar project
Contingency	25%	of Capital Cost		$233,260		$546,554	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$349,890		$819,831	Engineer's estimate
Construction Subtotal				**$3,483,213**			
Sales Tax			8.7%	$303,040			
O&M Subtotal						**$3,793,839**	
NET PRESENT WORTH						**$7,580,000**	

Definitions:

AC– acre.
LF – linear foot.
LS – lump sum.
O&M – operation and maintenance.
PVC – polyvinyl chloride.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Opinion of Probable Cost for Infiltration of Clean Discharge from Treatment of Continuous Pumping from the Hole and P1 Zone and Northerly Plume Capture

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Infiltration Pond for Treated Water Disposal							
Pond Excavation and Grading							
Soil Excavation, Haul, and Disposal[3]	400	CY	$15.00	$6,000			
Common Borrow (Berms)[4]	100	CY	$11.00	$1,100			
Soil Compaction (Berms)[4]	100	CY	$3.00	$300			
Bedding Layer from Stockpile	150	CY	$20.00	$3,000			
Mobilization	12%	of Capital Cost		$1,248			
Access							
Crushed Surfacing Base Course[5]	100	TN	$17.00	$1,700			
Mobilization	8%	of Capital Cost		$136			
Pond Decommissioning							
Embankment	400	CY	$5.00			$682	Similar project, average of equivelent materials
Mobilization	12%	of Capital Cost				$82	Similar project
Contingency	25%	of Capital Cost		$3,371		$191	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$5,057		$287	Engineer's estimate
Construction Subtotal				**$21,912**			
Sales Tax			8.7%	$1,906			
O&M Subtotal						**$1,350**	
NET PRESENT WORTH						**$25,000**	

Definitions:

CY– cubic yard.

LS – lump sum.

O&M – operation and maintenance.

TN – ton.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

[3] Soil excavation, haul, and disposal assumes soil excavated is stockpiled for daily cover.

[4] Common borrow and soil compaction assumes berms for the pond will be 15' wide at the top with 3:1 slopes on both sides.

[5] Includes road to pond (150' long) and access around pond at top of berm (750' long, 15'6" wide).

Opinion of Probable Cost for
Whitson Well (Property Purchase and Well Decommissioning)

Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost Annual[1]	O&M Cost Present Worth[2]	Source
Whitson Property Purchase							
Property Purchase	1	LS	$98,094	$98,094			Actual costs
Whitson Well Decommissioning							
Mobilization	1	LS	$1,500	$1,500			Driller's estimate
Notice to Decommission	1	each	$50	$50			Driller's estimate
Grout Well	2.1	CY	$450	$962			Driller's estimate
Rig and Crew Decommissioning	8	hour	$450	$3,600			Driller's estimate
Contingency	25%	of Capital Cost		$1,528			
Project Management, Engineering, Permitting	1	LS	$2,660	$2,660			Engineer's estimate
Construction Subtotal				**$108,394**			
Sales Tax			8.7%	$896			
O&M Subtotal						**$0**	
NET PRESENT WORTH						**$109,000**	

Definitions:

CY– cubic yard.

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Opinion of Probable Cost for Alternative 1 Compliance Monitoring

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual**[1]	**Present Worth**[2]	**Source**
Monitoring Well Installation/Decommissioning							
Well Installation	6	each	$15,000	$90,000			Engineer's estimate
Well Decommissioning	54	each	$1,200			$22,109	Driller's quote
Contingency	25%	of Capital Cost		$22,500		$5,527	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$27,000		$2,829	Engineer's estimate
Construction Subtotal				**$139,500**			
Sales Tax			8.7%	$12,137			
Environmental Oversight							
General Reporting							
Draft Groundwater Monitoring and Well Maintenance Plan	1	each	$14,000	$14,000			Engineer's estimate
Final Groundwater Monitoring and Well Maintenance Plan	1	each	$6,500	$6,500			Engineer's estimate
Annual Groundwater Monitoring Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Periodic Review Report (Every 5 Years)	6	each	$27,700		$10,654	$63,923	Engineer's estimate
Project Management	1	LS	$2,050	$2,050	$686.46	$20,594	Engineer's estimate
Institutional Controls							
Environmental Covenant	1	LS	$6,000	$6,000	$500	$7,143	Engineer's estimate
Draft Implementation Plan	1	LS	$5,000	$5,000			Engineer's estimate
Final Implementation Plan	1	LS	$2,200	$2,200	$500	$7,143	Engineer's estimate
Notice of Conveyance or Other Transfer of an Interest in the Property	1	LS	$2,000			$1,921	Engineer's estimate
Institutional Control Maintenance	1	LS	$1,000		$1,000	$14,286	Engineer's estimate
Quarterly Groundwater Monitoring (Years 1-5)							
Groundwater Monitoring	5	year	$108,798		$95,461	$477,304	Engineer's estimate
Semi-annual Groundwater Monitoring (Years 6-30)							
Groundwater Monitoring	25	year	$56,949		$21,851	$546,268	Engineer's estimate
Environmental Oversight Subtotal				**$35,750**			
O&M Subtotal						**$1,311,063**	
O&M Project Management and Support	10%	of O&M Present Worth				$128,060	
O&M Contingency	25%	of O&M Present Worth				$320,150	
NET PRESENT WORTH						**$1,947,000**	

Definitions:

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Alternative 1 Groundwater Monitoring Net Present Worth Value for FS Study Comparison: $1,950,000

Opinion of Probable Cost for Alternative 2 Compliance Monitoring

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Monitoring/Extraction Well Installation/Decommissioning							
Well Installation	6	each	$15,000	$90,000			Engineer's estimate
Well Decommissioning	54	each	$1,200			$22,109	Driller's quote
Contingency	25%	of Capital Cost		$22,500		$5,527	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$27,000		$2,829	Engineer's estimate
Construction Subtotal				**$139,500**			
Sales Tax			8.7%	$12,137			
Environmental Oversight							
General Reporting							
Draft Groundwater Monitoring and Well Maintenance Plan	1	each	$14,000	$14,000			Engineer's estimate
Final Groundwater Monitoring and Well Maintenance Plan	1	each	$6,500	$6,500			Engineer's estimate
Annual Groundwater Monitoring Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Cleanup Action Activity Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Dangerous Waste Reports	30	each	$14,300		$5,915	$177,449	Engineer's estimate
Periodic Review Report (Every 5 Years)	6	each	$27,700		$10,654	$63,923	Engineer's estimate
Project Management	1	LS	$2,050	$2,050	$1,751	$52,540	Engineer's estimate
Institutional Controls							
Environmental Covenant	1	LS	$6,000	$6,000	$500	$7,143	Engineer's estimate
Draft Implementation Plan	1	LS	$5,000	$5,000			Engineer's estimate
Final Implementation Plan	1	LS	$2,200	$2,200	$500	$7,143	Engineer's estimate
Notice of Conveyance or Other Transfer of an Interest in the Property	1	LS	$2,000			$1,921	Engineer's estimate
Institutional Control Maintenance	1	LS	$1,000		$1,000	$14,286	Engineer's estimate
Quarterly Groundwater Monitoring (Years 1-5)							
Groundwater Monitoring	5	year	$108,798		$95,461	$477,304	Engineer's estimate
Semi-annual Groundwater Monitoring (Years 6-30)							
Groundwater Monitoring	25	year	$56,949		$21,851	$546,268	Engineer's estimate
Environmental Oversight Subtotal				**$35,750**			
O&M Subtotal						**$1,662,475**	
O&M Project Management and Support	10%	of O&M Present Worth				$163,201	
O&M Contingency	25%	of O&M Present Worth				$408,003	
O&M Total						**$2,233,678**	
NET PRESENT WORTH						**$2,421,000**	

Definitions:

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Alternative 2 Groundwater Monitoring Net Present Worth Value for FS Study Comparison: $2,430,000

Opinion of Probable Cost for
Alternative 3 Compliance Monitoring

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Monitoring/Extraction Well Installation/Decommissioning							
Well Installation	12	each	$16,500	$198,000			Engineer's estimate
Well Decommissioning	60	each	$1,200			$24,565	Driller's quote
Contingency	25%	of Capital Cost		$49,500		$6,141	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$59,400		$3,143	Engineer's estimate
Construction Subtotal				**$306,900**			
Sales Tax			8.7%	$26,700			
Environmental Oversight							
General Reporting							
Draft Groundwater Monitoring and Well Maintenance Plan	1	each	$14,000	$14,000			Engineer's estimate
Final Groundwater Monitoring and Well Maintenance Plan	1	each	$6,500	$6,500			Engineer's estimate
Annual Groundwater Monitoring Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Cleanup Action Activity Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Dangerous Waste Reports	30	each	$14,300		$5,915	$177,449	Engineer's estimate
Periodic Review Report (Every 5 Years)	6	each	$27,700		$10,654	$63,923	Engineer's estimate
Project Management	1	LS	$2,050	$2,050	$1,751	$52,540	Engineer's estimate
Institutional Controls							
Environmental Covenant	1	LS	$6,000	$6,000	$500	$7,143	Engineer's estimate
Draft Implementation Plan	1	LS	$5,000	$5,000			Engineer's estimate
Final Implementation Plan	1	LS	$2,200	$2,200	$500	$7,143	Engineer's estimate
Notice of Conveyance or Other Transfer of an Interest in the Property	1	LS	$2,000			$1,921	Engineer's estimate
Institutional Control Maintenance	1	LS	$1,000		$1,000	$14,286	Engineer's estimate
Quarterly Groundwater Monitoring (Years 1-5)							
Groundwater Monitoring	5	year	$124,098		$108,885	$544,427	Engineer's estimate
Semi-annual Groundwater Monitoring (Years 6-30)							
Groundwater Monitoring	25	year	$72,249		$26,936	$673,394	Engineer's estimate
Environmental Oversight Subtotal				**$35,750**			
O&M Subtotal						**$1,860,107**	
O&M Project Management and Support	10%	of O&M Present Worth				$182,626	
O&M Contingency	25%	of O&M Present Worth				$456,564	
O&M Total						**$2,499,297**	
NET PRESENT WORTH						**$2,869,000**	

Definitions:
LS – lump sum.
O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Alternative 3 Groundwater Monitoring Net Present Worth Value for FS Study Comparison: $2,870,000

Opinion of Probable Cost for Alternative 4 Compliance Monitoring

Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost		Source
					Annual[1]	**Present Worth[2]**	
Monitoring/Extraction Well Installation/Decommissioning							
Well Installation	21	each	$17,143	$360,000			Engineer's estimate
Well Decommissioning	69	each	$1,200			$28,250	Driller's quote
Contingency	25%	of Capital Cost		$90,000		$7,062	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$108,000		$3,614	Engineer's estimate
Construction Subtotal				**$558,000**			
Sales Tax			8.7%	$48,546			
Environmental Oversight							
General Reporting							
Draft Groundwater Monitoring and Well Maintenance Plan	1	each	$14,000	$14,000			Engineer's estimate
Final Groundwater Monitoring and Well Maintenance Plan	1	each	$6,500	$6,500			Engineer's estimate
Annual Groundwater Monitoring Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Cleanup Action Activity Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Dangerous Waste Reports	30	each	$14,300		$5,915	$177,449	Engineer's estimate
Periodic Review Report (Every 5 Years)	6	each	$27,700		$10,654	$63,923	Engineer's estimate
Project Management	1	LS	$2,050	$2,050	$1,751	$52,540	Engineer's estimate
Institutional Controls							
Environmental Covenant	1	LS	$6,000	$6,000	$500	$7,143	Engineer's estimate
Draft Implementation Plan	1	LS	$5,000	$5,000			Engineer's estimate
Final Implementation Plan	1	LS	$2,200	$2,200	$500	$7,143	Engineer's estimate
Notice of Conveyance or Other Transfer of an Interest in the Property	1	LS	$2,000			$1,921	Engineer's estimate
Institutional Control Maintenance	1	LS	$1,000		$1,000	$14,286	Engineer's estimate
Quarterly Groundwater Monitoring (Years 1-5)							
Groundwater Monitoring	5	year	$155,792		$136,694	$683,470	Engineer's estimate
Semi-annual Groundwater Monitoring (Years 6-30)							
Groundwater Monitoring	25	year	$91,421		$33,308	$832,691	Engineer's Estimate
Environmental Oversight Subtotal				**$35,750**			
O&M Subtotal						**$2,163,525**	
O&M Project Management and Support	10%	of O&M Present Worth				$212,460	
O&M Contingency	25%	of O&M Present Worth				$531,150	
O&M Total						**$2,907,135**	
NET PRESENT WORTH						**$3,549,000**	

Definitions:

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Alternative 4 Groundwater Monitoring Net Present Worth Value for FS Study Comparison: $3,550,000

Opinion of Probable Cost for
Alternative 5 Compliance Monitoring

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Monitoring/Extraction Well Installation/Decommissioning							
Well Installation	16	each	$22,500	$360,000			Engineer's estimate
Well Decommissioning	64	each	$1,200			$26,203	Driller's quote
Contingency	25%	of Capital Cost		$90,000		$6,551	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$108,000		$3,352	Engineer's estimate
Construction Subtotal				**$558,000**			
Sales Tax			8.7%	$48,546			
Environmental Oversight							
General Reporting							
Draft Groundwater Monitoring and Well Maintenance Plan	1	each	$14,000	$14,000			Engineer's estimate
Final Groundwater Monitoring and Well Maintenance Plan	1	each	$6,500	$6,500			Engineer's estimate
Annual Groundwater Monitoring Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Cleanup Action Activity Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Dangerous Waste Reports	30	each	$14,300		$5,915	$177,449	Engineer's estimate
Periodic Review Report (Every 5 Years)	6	each	$27,700		$10,654	$63,923	Engineer's estimate
Project Management	1	LS	$2,050	$2,050	$1,751	$52,540	Engineer's estimate
Institutional Controls							
Environmental Covenant	1	LS	$6,000	$6,000	$500	$7,143	Engineer's estimate
Draft Implementation Plan	1	LS	$5,000	$5,000			Engineer's estimate
Final Implementation Plan	1	LS	$2,200	$2,200	$500	$7,143	Engineer's estimate
Notice of Conveyance or Other Transfer of an Interest in the Property	1	LS	$2,000			$1,921	Engineer's estimate
Institutional Control Maintenance	1	LS	$1,000		$1,000	$14,286	Engineer's estimate
Quarterly Groundwater Monitoring (Years 1-5)							
Groundwater Monitoring	5	year	$143,042		$125,507	$627,535	Engineer's estimate
Semi-annual Groundwater Monitoring (Years 6-30)							
Groundwater Monitoring	25	year	$78,671		$29,070	$726,753	Engineer's estimate
Environmental Oversight Subtotal				**$35,750**			
O&M Subtotal						**$1,998,832**	
O&M Project Management and Support	10%	of O&M Present Worth				$196,273	
O&M Contingency	25%	of O&M Present Worth				$490,681	
O&M Total						**$2,685,786**	
NET PRESENT WORTH						**$3,328,000**	

Definitions:

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Alternative 5 Groundwater Monitoring Net Present Worth Value for FS Study Comparison: **$3,330,000**

Opinion of Probable Cost for
Alternative 6 Compliance Monitoring

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Monitoring/Extraction Well Installation/Decommissioning							
Well Installation	22	each	$16,364	$360,000			Engineer's estimate
Well Decommissioning	70	each	$1,200			$28,659	Driller's quote
Contingency	25%	of Capital Cost		$90,000		$7,165	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$108,000		$3,667	Engineer's estimate
Construction Subtotal				**$558,000**			
Sales Tax			8.7%	$48,546			
Environmental Oversight							
General Reporting							
Draft Groundwater Monitoring and Well Maintenance Plan	1	each	$14,000	$14,000			Engineer's estimate
Final Groundwater Monitoring and Well Maintenance Plan	1	each	$6,500	$6,500			Engineer's estimate
Annual Groundwater Monitoring Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Cleanup Action Activity Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Dangerous Waste Reports	30	each	$14,300		$5,915	$177,449	Engineer's estimate
Periodic Review Report (Every 5 Years)	6	each	$27,700		$10,654	$63,923	Engineer's estimate
Project Management	1	LS	$2,050	$2,050	$1,751	$52,540	Engineer's estimate
Institutional Controls							
Environmental Covenant	1	LS	$6,000	$6,000	$500	$7,143	Engineer's estimate
Draft Implementation Plan	1	LS	$5,000	$5,000			Engineer's estimate
Final Implementation Plan	1	LS	$2,200	$2,200	$500	$7,143	Engineer's estimate
Notice of Conveyance or Other Transfer of an Interest in the Property	1	LS	$2,000			$1,921	Engineer's estimate
Institutional Control Maintenance	1	LS	$1,000		$1,000	$14,286	Engineer's estimate
Quarterly Groundwater Monitoring (Years 1-5)							
Groundwater Monitoring	5	year	$158,342		$138,931	$694,657	Engineer's estimate
Semi-annual Groundwater Monitoring (Years 6-30)							
Groundwater Monitoring	25	year	$93,971		$34,155	$853,878	Engineer's estimate
Environmental Oversight Subtotal				**$35,750**			
O&M Subtotal						**$2,196,464**	
O&M Project Management and Support	10%	of O&M Present Worth				$215,697	
O&M Contingency	25%	of O&M Present Worth				$539,243	
O&M Total						**$2,951,405**	
NET PRESENT WORTH						**$3,594,000**	

Definitions:
LS – lump sum.
O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Alternative 6 Groundwater Monitoring Net Present Worth Value for FS Study Comparison: $3,600,000

Opinion of Probable Cost for
Alternative 7 Compliance Monitoring

					O&M Cost		
Item	**Quantity**	**Units**	**Unit Cost**	**Capital Cost**	**Annual[1]**	**Present Worth[2]**	**Source**
Monitoring/Extraction Well Installation/Decommissioning							
Well Installation	22	each	$16,364	$360,000			Engineer's estimate
Well Decommissioning	70	each	$1,200			$28,659	Driller's quote
Contingency	25%	of Capital Cost		$90,000		$7,165	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$108,000		$3,667	Engineer's estimate
Construction Subtotal				**$558,000**			
Sales Tax			8.7%	$48,546			
Environmental Oversight							
General Reporting							
Draft Groundwater Monitoring and Well Maintenance Plan	1	each	$14,000	$14,000			Engineer's estimate
Final Groundwater Monitoring and Well Maintenance Plan	1	each	$6,500	$6,500			Engineer's estimate
Annual Groundwater Monitoring Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Cleanup Action Activity Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Dangerous Waste Reports	30	each	$14,300		$5,915	$177,449	Engineer's estimate
Periodic Review Report (Every 5 Years)	6	each	$27,700		$10,654	$63,923	Engineer's estimate
Project Management	1	LS	$2,050	$2,050	$1,751	$52,540	Engineer's estimate
Institutional Controls							
Environmental Covenant	1	LS	$6,000	$6,000	$500	$7,143	Engineer's estimate
Draft Implementation Plan	1	LS	$5,000	$5,000			Engineer's estimate
Final Implementation Plan	1	LS	$2,200	$2,200	$500	$7,143	Engineer's estimate
Notice of Conveyance or Other Transfer of an Interest in the Property	1	LS	$2,000			$1,921	Engineer's estimate
Institutional Control Maintenance	1	LS	$1,000		$1,000	$14,286	Engineer's estimate
Quarterly Groundwater Monitoring (Years 1-5)							
Groundwater Monitoring	5	year	$158,342		$138,931	$694,657	Engineer's estimate
Semi-annual Groundwater Monitoring (Years 6-30)							
Groundwater Monitoring	25	year	$93,971		$34,155	$853,878	Engineer's estimate
Environmental Oversight Subtotal				**$35,750**			
O&M Subtotal						**$2,196,464**	
O&M Project Management and Support	10%	of O&M Present Worth				$215,697	
O&M Contingency	25%	of O&M Present Worth				$539,243	
O&M Total						**$2,951,405**	
NET PRESENT WORTH						**$3,594,000**	

Definitions:
LS – lump sum.
O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per E 7%

Alternative 7 Groundwater Monitoring Net Present Worth Value for FS Study Comparison: $3,600,000

Opinion of Probable Cost for
Alternative 8 Compliance Monitoring

Item	Quantity	Units	Unit Cost	Capital Cost	O&M Cost		Source
					Annual[1]	**Present Worth[2]**	
Monitoring/Extraction Well Installation/Decommissioning							
Well Installation	24	each	$15,000	$360,000			Engineer's estimate
Well Decommissioning	72	each	$1,200			$29,478	Driller's quote
Contingency	25%	of Capital Cost		$90,000		$7,370	Engineer's estimate
Project Management, Engineering, Permitting	30%	of Capital Cost		$108,000		$3,772	Engineer's estimate
Construction Subtotal				**$558,000**			
Sales Tax			8.7%	$48,546			
Environmental Oversight							
General Reporting							
Draft Groundwater Monitoring and Well Maintenance Plan	1	each	$14,000	$14,000			Engineer's estimate
Final Groundwater Monitoring and Well Maintenance Plan	1	each	$6,500	$6,500			Engineer's estimate
Annual Groundwater Monitoring Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Cleanup Action Activity Reports	30	each	$10,700		$4,734	$142,016	Engineer's estimate
Annual Dangerous Waste Reports	30	each	$14,300		$5,915	$177,449	Engineer's estimate
Periodic Review Report (Every 5 Years)	6	each	$27,700		$10,654	$63,923	Engineer's estimate
Project Management	1	LS	$2,050	$2,050	$1,751	$52,540	Engineer's estimate
Institutional Controls							
Environmental Covenant	1	LS	$6,000	$6,000	$500	$7,143	Engineer's estimate
Draft Implementation Plan	1	LS	$5,000	$5,000			Engineer's estimate
Final Implementation Plan	1	LS	$2,200	$2,200	$500	$7,143	Engineer's estimate
Notice of Conveyance or Other Transfer of an Interest in the Property	1	LS	$2,000			$1,921	Engineer's estimate
Implementation Control Maintenance	1	LS	$1,000		$1,000	$14,286	Engineer's estimate
Quarterly Groundwater Monitoring (Years 1-5)							
Groundwater Monitoring	5	year	$163,442		$143,406	$717,031	Engineer's estimate
Semi-annual Groundwater Monitoring (Years 6-30)							
Groundwater Monitoring	25	year	$99,071		$35,850	$896,253	Engineer's estimate
Environmental Oversight Subtotal				**$35,750**			
O&M Subtotal						**$2,262,342**	
O&M Project Management and Support	10%	of O&M Present Worth				$222,172	
O&M Contingency	25%	of O&M Present Worth				$555,431	
O&M Total						**$3,039,945**	
NET PRESENT WORTH						**$3,682,000**	

Definitions:

LS – lump sum.

O&M – operation and maintenance.

[1] Annual O&M cost is the average cost incurred each year for the 30-year time interval.

[2] Present worth is based on a 30-year time interval using an annual discount rate of 7% per EPA Guidance.

Alternative 8 Groundwater Monitoring Net Present Worth Value for FS Study Comparison: $3,690,000

Opinion of Probable Cost for
North End Soils Option 1 – Cap in Place

Item	Quantity	Units	Unit Cost	Capital Cost	Unit Calculation	Unit Cost Source
Excavation and Grading - Utility Space under Road						
Soil Excavation, Haul, and Disposal[1,2]	1,623	CY	$3.00	$4,868	13,459 SF*3' + 1:1 slope	Engineer's estimate - premium cost on low volume
Soil Sampling and Testing	2	each	$500	$1,000	Characterization only	
Common Borrow	1,623	CY	$7.10	$11,522	Same as excavation volume	WSDOT Unit Bid Analysis - April 2011 to April 2012
Soil Compaction	1,623	CY	$1.63	$2,645	Same as borrow	WSDOT Unit Bid Analysis - April 2011 to April 2012
Mobilization	8%	of Capital Cost		$1,603		Similar project
Cover System						
Subgrade Preparation	5,000	SY	$2.00	$10,000		
Geomembrane Liner	8,419	SY	$8.00	$67,356	72,167 SF + 5% extra for termination	Similar project
Tie-in to Existing	400	LF	$10.00	$4,000		
Geotextile Cushion Layer	8,419	SY	$3.00	$25,258	Same area as geomembrane liner	
Drainage Layer	2,806	CY	$7.10	$19,926	1' thick layer on geomembrane liner	Assumed same source/prices as common borrow
Top Cover	2,806	CY	$7.10	$19,926	1' thick layer on geomembrane liner	Assumed same source/prices as common borrow
Surface Water Conveyance	500	LF	$10.00	$5,000		Engineer's estimate - inlcudes TESC
Ground Water Conveyance under Road	750	LF	$10.00	$7,500		Engineer's estimate - includes duscharge point
Mobilization	8%	of Capital Cost		$9,323		Similar project
Subtotal				**$189,928**		
Contingency	25%	of Capital Cost		$47,482		
Construction/Project Management	20%	of Capital Cost		$37,986		
Engineering (Plans, Specifications, & Estimates)	15%	of Capital Cost		$28,489		
Construction Subtotal				**$303,884**		
Sales Tax			8.7%	$26,438		
NET PRESENT WORTH				**$330,000**		

Definitions:

CF – cubic foot.
CY – cubic yard.
SF – square foot.
LF – linear foot.
SY– square yard.
TESC– temporary erosion and sedimentation control.

[1] Soil excavation, haul, and disposal volume provides 3 additional feet of clean soil (total of 5 feet) from surface grade to geomembrane in road alignment.

[2] Soil excavation, haul, and disposal assumes soil excavated is used for grading under geomemebrane along toe of existing cover system.

[3] Road edge volume: (430' + 334') * 3' * 3' * 1/2 = 3438 CF.

Opinion of Probable Cost for
North End Soils Option 2 – Clean Road Corridor

Item	Quantity	Units	Unit Cost	Capital Cost	Unit Calculation	Unit Cost Source
Excavation and Grading - Clean Corridor for Road						
Soil Excavation, Haul, and Disposal[1]	8,296	CY	$2.55	$21,154	26,073 SF * 10' + 1:1 slopes on each side	Engineer's estimate
Soil Sampling and Testing	4	each	$500	$2,000	Characterization only	
Common Borrow	9,296	CY	$7.10	$65,998	Excavation volume + fill to match cover section	WSDOT Unit Bid Analysis - April 2011 to April 2012
Soil Compaction	9,296	CY	$1.63	$15,152	Same as borrow	WSDOT Unit Bid Analysis - April 2011 to April 2012
Mobilization	8%	of Capital Cost		$8,344		Similar project
Cover system						
Subgrade Preparation	2,000	SY	$2.00	$4,000	Liner area minus fill surface	
30-mil PVC Geomembrane Liner	6,236	SY	$8.00	$49,887	53,450 SF + 5% extra for termination	Similar project
Tie-in to Existing	500	LF	$10.00	$5,000		
Geotextile Cushion Layer	6,236	SY	$3.00	$18,708	Same area as geomembrane liner	
Drainage Layer	2,079	CY	$7.10	$14,758	1' thick layer on geomembrane liner	Assumed same source/prices as common borrow
Top Cover	2,079	CY	$7.10	$14,758	1' thick layer on geomembrane liner	Assumed same source/prices as common borrow
Surface Water Conveyance	500	LF	$10.00	$5,000		Engineer's estimate - inlcudes TESC
Mobilization	8%	of Capital Cost		$7,068		Similar project
Subtotal				**$231,827**		
Contingency	25%	of Capital Cost		$57,957		
Construction/Project Management	20%	of Capital Cost		$46,365		
Engineering (Plans, Specifications, & Estimates)	15%	of Capital Cost		$34,774		
Construction Subtotal				**$370,923**		
Sales Tax			8.7%	$32,270		
NET PRESENT WORTH				**$403,000**		

Definitions:

CF – cubic foot.
CY – cubic yard.
PVC – polyvinyl chloride.
SF – square foot.
LF – linear foot.
SY– square yard.
TESC– temporary erosion and sedimentation control.

[1] Soil excavation, haul, and disposal assumes soil excavated is used for grading under geomemebrane along toe of existing cover system.

[2] Fenceline edge volume reduction: (416' + 319') * 10' * 10' * 1/2 = 36,750 CF.

Opinion of Probable Cost for
North End Soils Option 3 – Cap/Removal Hybrid

Item	Quantity	Units	Unit Cost	Capital Cost	Unit Calculation	Unit Cost Source
Excavation and Backfill						
Soil Excavation, Haul, and Disposal[1]	13,537	CY	$1.82	$24,637	36,550 SF x 10' average depth	Engineer's estimate calculated by time & materials
Soil Sampling and Testing	5	each	$500	$2,500	Characterization only	
Common Borrow	13,537	CY	$7.10	$96,113	Same volume as excavated	WSDOT Unit Bid Analysis - April 2011 to April 2012
Soil Compaction	13,537	CY	$1.63	$22,065	Same as borrow	WSDOT Unit Bid Analysis - April 2011 to April 2012
Mobilization	8%	of Capital Cost		$11,625		Similar project
Cover System[2]						
Subgrade Preparation	5,000	SY	$2.00	$10,000		
Geomembrane Liner	6,883	SY	$10.00	$68,833	39,000 SF cap-in-place + 20,000 SF over existing cell + 5%	Similar project
Tie-in to Existing	600	LF	$10.00	$6,000		
Geotextile Cushion Layer	6,883	SY	$3.00	$20,650	Same area as geomembrane liner	
Drainage Layer	2,294	CY	$7.10	$16,291	1' thick layer on geomembrane liner	Assumed same source/prices as common borrow
Top Cover	2,294	CY	$7.10	$16,291	1' thick layer on geomembrane liner	Assumed same source/prices as common borrow
Surface Water Conveyance	750	LF	$10.00	$7,500		Engineer's estimate - inlcudes TESC
Mobilization	8%	of Capital Cost		$8,942		Similar project
Subtotal				$311,447		
Contingency	25%	of Capital Cost		$77,862		
Construction/Project Management	20%	of Capital Cost		$62,289		
Engineering (Plans, Specifications, & Estimates)	15%	of Capital Cost		$46,717		
Construction Subtotal				**$498,316**		
Sales Tax			8.7%	$43,353		
NET PRESENT WORTH				**$542,000**		

Definitions:

CY – cubic yard.
SF – square foot.
LF – linear foot.
SY– square yard.
TESC– temporary erosion and sedimentation control.

[1] Soil excavation, haul, and disposal to uncovered refuse area and toe of covered landfill.

[2] Cover system assumed to be same as existing cover system.

Opinion of Probable Cost for Alternative 4 – Removal (1)

Item	Quantity	Units	Unit Cost	Capital Cost	Unit Calculation	Unit Cost Source
Excavation and Backfill						
Soil Excavation, Haul, and Disposal[2]	26,729	CY	$2.55	$68,158	72,167 SF x 10' avgerage depth	Engineer's estimate calculated by time & materials
Soil Sampling and Testing	25	each	$500	$12,500		
Common Borrow	26,729	CY	$7.10	$189,776	Same volume as excavated	WSDOT Unit Bid Analysis - April 2011 to April 2012
Soil Compaction	26,729	CY	$1.63	$43,568	Same as Borrow	WSDOT Unit Bid Analysis - April 2011 to April 2012
Mobilization	8%	of Capital Cost		$25,120		Similar project
Revenue Loss for Landfill Airspace	26,729	CY	$2.00	$53,458		
Subtotal				$392,580		
Contingency	15%	of Capital Cost		$58,887		
Construction/Project Management	10%	of Capital Cost		$39,258		
Engineering (PS&E)	10%	of Capital Cost		$39,258		
Construction Subtotal				**$529,983**		
Sales Tax			8.7%	$46,109		
NET PRESENT WORTH				**$576,000**		

Definitions:

CY – cubic yard.

SF – square foot.

[1] Includes removal of all contaminated soils and refuse to bedrock in area identified by PGG.

[2] Soil excavation, haul, and disposal assumes materials excavated are placed in a stockpile in landfill active area footprint, placement and compaction of soils by operations staff.

Opinion of Probable Cost for North End Soils Individual Item Costs

Item	Quantity	Units	Unit Cost	Capital Cost	Unit Calculation	Unit Cost Source
Excavation and Grading - to Landfill						
Dump Truck with Driver (11 CY)	5	HR	$120	$600	$75 for truck, $45 for driver	10-minute cycle time
Excavator with Operator	1	HR	$160	$160	$110 for excavator, $50 for operator	
Foreman for Oversite	1	HR	$80	$80	$25 for truck, $55 for foreman	
Per Hour Units Moved	330.00	CY/HR	$2.55	$840		CY/HR = CY/Truck * Cycles/HR * Trucks
Excavation and Grading - to Capping Area						
Dump Truck with Driver (11 CY)	3	HR	$120	$360	$75 for truck, $45 for driver	6-minute cycle time
Excavator with Operator	1	HR	$160	$160	$110 for excavator, $50 for operator	
Foreman for Oversite	1	HR	$80	$80	$25 for truck, $55 for foreman	
Per Hour Units Moved	330.00	CY/HR	$1.82	$600		CY/HR = CY/Truck * Cycles/HR * Trucks
Backfill from Borrow Source						
Dump Truck/Pup with Driver (18 CY)	10	HR	$145	$1,450	$100 for truck/pup, $45 for driver	20-minute cycle time (less than 5 miles)
Dozer	1	HR	$160	$160	$110 for excavator, $50 for operator	
Foreman for Oversite	1	HR	$80	$80	$25 for truck, $55 for foreman	
Per Hour Units Moved	540.00	CY/HR	$3.13	$1,690		CY/HR = CY/Truck * Cycles/HR * Trucks
Backfill from Borrow Source						
Dump Truck/Pup with Driver (18 CY)	15	HR	$145	$2,175	$100 for truck/pup, $45 for driver	30-minute cycle time (less than 10 miles)
Dozer	1	HR	$160	$160	$110 for excavator, $50 for operator	
Foreman for Oversite	1	HR	$80	$80	$25 for truck, $55 for foreman	
Per Hour Units Moved	540.00	CY/HR	$4.47	$2,415		CY/HR = CY/Truck * Cycles/HR * Trucks
Backfill from Borrow Source						
Dump Truck/Pup with Driver (18 CY)	18	HR	$145	$2,610	$100 for truck/pup, $45 for driver	40-minute cycle time (15 miles)
Dozer	1	HR	$160	$160	$110 for excavator, $50 for operator	
Foreman for Oversite	1	HR	$80	$80	$25 for truck, $55 for foreman	
Per Hour Units Moved	540.00	CY/HR	$5.28	$2,850		CY/HR = CY/Truck * Cycles/HR * Trucks

Definitions:
CY – cubic yard.
HR – hour.

APPENDIX H

COC Removal Calculations

Parametrix ENGINEERING . PLANNING . ENVIRONMENTAL SCIENCES

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TECHNICAL MEMORANDUM

Date:	August 31, 2012
To:	Brian Pippin
From:	Christopher MacDonald
Subject:	Initial COC Removal Rate Calculation Methodology for FS
cc:	
Project Number:	555-1860-011
Project Name:	Ephrata Landfill Feasibility Study

The purpose of this technical memorandum is to describe the calculation methodologies used to determine the initial estimated removal rates of organic COCs for the various components being considered in the FS. The methodology for each component type is described separately.

NATURAL ATTENUATION

An estimate of the mass attenuation due to natural degradation processes was performed by PGG and detailed in Section 3.2 of their report “Hydrogeologic and Contaminant Calculations,” dated August 29, 2012.

PUMPING FROM P1, THE HOLE, AND FOR NORTHERLY PLUME CAPTURE

Initial removal rates for all cleanup action components involving pumping were calculated by applying the same method to the specific pumping volume and contaminant load of each location. For each location, the contaminant load per gallon of water was estimated by averaging concentrations from samples of the wells in the area and adding those averaged values for each organic COC to calculate a total mass of organic COC per gallon of water extracted. This mass-per-gallon amount was then multiplied by the volume of water expected for each pumping regime per the recommended volumes in Table 1 in the report “Hydrogeologic and Contaminant Calculations” dated August 29, 2012 from PGG.

For pumping from the P1 zone, samples from wells B-19, B-22, MW-32a, MW-34, and MW-37 were averaged, and that total COC concentration was multiplied by 115,000 gallons per year for seasonal pumping and 250,000 gallons per year for continuous pumping.

For pumping from the Hole, samples from wells EW-1 and EW-2 were averaged, and that total COC concentration was multiplied by 290,000 gallons per year for seasonal pumping and 390,000 gallons per year for continuous pumping.

For northerly plume capture from the Roza aquifer, samples from wells MW-3b, MW-7b, and MW-9b were averaged, and that total COC concentration was multiplied by 3,500,000 gallons per year for continuous pumping.

SOIL VAPOR EXTRACTION

Initial COC removal for SVE is based on *Review of Mathematical Modeling for Evaluating Soil Vapor Extraction Systems, EPA, 1995*. Total mass of COCs in the LNAPL to be removed via SVE was calculated by multiplying the best-estimate volume of LNAPL (1,795 gallons) from Table 15 of the report “Hydrogeologic and Contaminant Calculations” dated August 29, 2012, from PGG by the average LNAPL density (0.87 kg/L) per PGG’s email on 8/21/2012. This total mass of LNAPL was multiplied by the average percentage of LNAPL that comprises Method 8260 VOCs, which estimates the amount of the LNAPL that comprises COCs. This total estimated organic COC mass, 1,430 kg, was input in the SVE extraction model assuming 50 percent total removal efficiency.

MANUAL LNAPL REMOVAL

Organic COC removal by passive absorption was calculated by averaging the removal rates in 2009 and 2010 from monitoring wells MW-34 and MW-36 as shown in Figure 5 of the technical memorandum from PGG dated February 8, 2011 on groundwater extraction and LNAPL removal. The average removal rate in gallons was then converted to kg by multiplying by the average LNAPL density per PGG’s email on 8/21/2012. This mass was then converted to COC mass by multiplying by 0.24 (the fraction LNAPL that comprises Method 8260 VOCs, which include most of the COCs in the LNAPL).

NORTH END SOILS

Organic COC removal from the north end soils was calculated assuming the concentration of the entire soil mass was equal to the average concentration of the following samples from the north end soil area: B-8-4_5, T-3-7_3, T-4-4, T-5-7, T-5-7_2, T-5-8, T-6-4, T-7-2_3, T-8-4, T-9-6_4, T-10-4_2, T-11-4, T-12-5, T-12-5_5, T-12-7, T-13-4, T-13-5_5, and T-13-6. The resulting average concentration in mg/kg was multiplied by the mass of soil (assuming 1.5 tons/CY or 1,361 kg/CY) to be removed for each of the four cleanup action component options considered for north end soils, resulting in a total mass of contaminant removed.

Intitial COC Removal Rate Summary

		Initial COC Removal By Component (kg/yr)				
Constituent	**CAS ID**	P1 Zone - Seasonal	P1 Zone - Continuous	The Hole - Seasonal	The Hole - Continuous	Northerly Plume Capture
Chloride	16887006	103.45	224.90	2,468.75	3,320.05	11,550.244
Nitrate+Nitrite as Nitrogen	17778880	1.288	2.801	0.016	0.021	57.674
Sulfate	14808798	45.09	98.02	1,403.92	1,888.03	12,455.530
Total Dissolved Solids		652.19	1,417.81	7,400.16	9,951.94	47,846.378
Arsenic, Dissolved		0.0048	0.0104	0.0078	0.0105	0.049
Iron, Total	7439896	13.58	29.51	36.68	49.33	68.678
Manganese, Total	7439965	2.30	5.00	24.20	32.54	160.673
1,1,1-Trichloroethane	71556	0.678	1.474			
1,1,2-Trichloroethane	79005	0.013	0.028	0.001	0.001	
1,1-Dichloroethane	75343	0.682	1.483	0.014	0.018	0.121
1,1-Dichloroethene	75354	0.021	0.045	0.000	0.001	0.008
1,2,4-Trimethylbenzene	95636	0.231	0.502			
1,2-Dichloroethane (EDC)	107062	0.109	0.238	0.001	0.001	0.016
1,2-Dichloropropane	78875	0.082	0.179	0.001	0.002	0.092
1,3,5-Trimethylbenzene	108678	0.097	0.211			
1,3-Dichlorobenzene	541731	0.002	0.005			0.004
2-Butanone	78933	10.069	21.889			
2-Hexanone	591786	0.269	0.584			
2-Methylphenol	95487	0.070	0.151			
4-Isopropyltoluene	99876	0.001	0.002			
4-Methyl-2-Pentanone (MIBK)	108101	6.314	13.725			
4-Methylphenol	106445	0.148	0.322			
Acetone	67641	19.349	42.064	0.016	0.021	0.073
Benzene	71432	0.033	0.072	0.003	0.004	0.018
Bis(2-ethylhexyl) Phthalate	117817	0.010	0.021			0.032
Bromobenzene	108861	0.003	0.007	0.000	0.000	0.005
Chloroethane	75003	0.050	0.108	0.004	0.005	0.440
Chloroform	67663	0.029	0.063			
Chloromethane	74873			0.000	0.000	
cis-1,2-Dichloroethene	156592	0.476	1.035	0.027	0.036	0.278
Ethylbenzene	100414	0.897	1.951	0.000	0.001	0.003
Methylene Chloride	75092	0.349	0.758	0.001	0.001	0.021
Naphthalene	91203	0.046	0.100			0.008
n-Butylbenzene	104518	0.004	0.008			
o-Xylene	95476	0.889	1.932	0.000	0.000	0.003
sec-Butylbenzene	135988	0.003	0.006			0.003
Tetrachloroethene (PCE)	127184	0.079	0.172	0.000	0.000	0.019
Toluene	108883	16.710	36.327	0.000	0.000	
Trichloroethene (TCE)	79016	0.065	0.142	0.001	0.001	0.014
Vinyl Chloride	75014	0.082	0.178	0.067	0.090	0.233
Xylene Isomers, M+P		2.332	5.070			
Organics Subtotal (kg/yr)		60	131	0.14	0.18	1.39

P1 Zone

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)										Contaminant Load (kg/yr)		115,000.00	Seasonal GW removal volume (gpy)
Constituent	**CAS ID**	**Units**	MW-34p1	B-19-P1	B-22-P1	MW32a	MW-37p1	AVERAGE	Typ. RL	Seasonal	Continuous	250,000.00	Continuous GW removal volume (gpy)
Depth to Water		feet					20.658						
Dissolved Oxygen	7782447	mg/L					4.51						
Hydrogen Sulfide		mg/L											
Oxidation Reduction Potential		mV					104.25						
pH		std. units		6.75	6.42		6.0675						
Specific Conductance @ 25C		umhos/cm		5480	5390		1562.5						
Temperature, 0 F		0 F			62.6		61.305						
Inorganics													
Alkalinity (as CaCO3)		mg/L	1228.5714			962.25	478.33333						
Ammonia as Nitrogen, Total	17778880	mg/L as N	33.3			0.897	0.061						
Bicarbonate As CaCO3		mg/L	1228.5714			962.25	478.33333						
Carbonate as CaCO3	471341	mg/L	ND			ND	ND						
Carbonate as CO3	3812326	mg/L	ND			ND	ND						
Chemical Oxygen Demand (COD)		mg/L											
Chloride	16887006	mg/L	551.28571			77.625	84.025	237.6452		103.4520	224.8956		
Nitrate as Nitrogen	17778880	mg/L as N	0.13			0.025	8.225						
Nitrate+Nitrite as Nitrogen	17778880	mg/L as N	0.1036667			0.025	8.75	2.959556	0.01	1.2884	2.8008		
Nitrite as Nitrogen	17778880	mg/L as N	0.1054			ND	0.5245						
Sulfate	14808798	mg/L	48.2			72.45	190.075	103.575		45.0884	98.0182		
Total Dissolved Solids		mg/L	2368.5714			1210	916	1498.19		652.1938	1,417.8126		
Metals													
Antimony, Dissolved	7440360	ug/L	ND			ND	ND						
Arsenic, Dissolved		ug/L	15.916667			15.033333	2	10.98333		0.0048	0.0104		
Barium, Dissolved	7440393	ug/L	484			310	129						
Beryllium, Dissolved	7440417	ug/L	ND			ND	ND						
Cadmium, Dissolved	7440439	ug/L	ND			ND	ND						
Calcium, Total	7440702	mg/L	254.85714			215	124						
Chromium, Dissolved	7440473	ug/L	ND			ND	ND						
Cobalt, Dissolved	7440484	ug/L	32			22	ND						
Copper, Dissolved	7440508	ug/L	4			ND	ND						
Iron, Dissolved	7439896	ug/L	67816.667			14933.333	ND						
Iron, Total	7439896	ug/L	81533.333			11726.667	296.66667	31185.56	50	13.5757	29.5125		
Lead, Dissolved	7439921	ug/L	ND			ND	ND						
Magnesium, Total	7439954	mg/L	151.14286			86.25	52.433333						
Manganese, Dissolved	7439965	ug/L	8088.3333			8426.6667	185						
Manganese, Total	7439965	ug/L	9008.3333			6576.6667	249.66667	5278.222		2.2977	4.9950		
Nickel, Dissolved	7440020	ug/L	50			ND	ND						
Potassium, Total	7440097	mg/L	60.414286			27.825	8.0233333						
Selenium, Dissolved	7782492	ug/L	2			0.7	1.5						
Silver, Dissolved	7440224	ug/L	ND			ND	ND						
Sodium, Total	7440235	mg/L	293.71429			78.95	115.13333						
Thallium, Dissolved	7440280	ug/L	ND			ND	ND						
Vanadium, Dissolved	7440622	ug/L	7.5			4	3						
Zinc, Dissolved	7440666	ug/L	ND			ND	ND						
Organics													
1,1,1,2-Tetrachloroethane	630206	ug/L	ND	ND	ND	ND	ND						

P1 Zone

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)										Contaminant Load (kg/yr)		115,000.00	Seasonal GW removal volume (gpy)
Constituent	**CAS ID**	**Units**	MW-34p1	B-19-P1	B-22-P1	MW32a	MW-37p1	AVERAGE	Typ. RL	Seasonal	Continuous	250,000.00	Continuous GW removal volume (gpy)
1,1,1-Trichloroethane	71556	ug/l	2217.1429	ND	3900	101.75	11.125	1557.504	0.2	0.6780	1.4739		
1,1,2,2-Tetrachloroethane	79345	ug/L	ND	ND	ND	ND	ND						
1,1,2-Trichloroethane	79005	ug/L	20.5	ND	68	0.9	ND	29.8	0.2	0.0130	0.0282		
1,1,2-Trichlorotrifluoroethane	76131	ug/L	33	ND	ND	3.85	ND						
1,1-Dichloroethane	75343	ug/L	2728.5714	550	4400	135.75	19.225	1566.709		0.6820	1.4827		
1,1-Dichloroethene	75354	ug/L	29.5	ND	150	6.15	4.075	47.43125	1	0.0206	0.0449		
1,1-Dichloropropene	563586	ug/L	ND	ND	ND	ND	ND						
1,2,3-Trichlorobenzene	87616	ug/L	ND	ND	ND	ND	ND						
1,2,3-Trichloropropane	96184	ug/L	ND	ND	ND	ND	ND						
1,2,4-Trichlorobenzene	120821	ug/L	ND	ND	ND	ND	ND						
1,2,4-Trimethylbenzene	95636	ug/L	665	18	1400	38	ND	530.25	0.2	0.2308	0.5018		
1,2-Dibromo-3-chloropropane	96128	ug/L	ND	ND	ND	ND	ND						
1,2-Dichlorobenzene	95501	ug/L	84.5	4.6	ND	0.75	ND						
1,2-Dichloroethane (EDC)	107062	ug/L	526	16	710	4.5	0.6	251.42		0.1094	0.2379		
1,2-Dichloropropane	78875	ug/L	482	26	360	38.5	40	189.3		0.0824	0.1791		
1,3,5-Trimethylbenzene	108678	ug/L	253.33333	2.2	620	14.775	ND	222.5771	0.2	0.0969	0.2106		
1,3-Dichlorobenzene	541731	ug/L	5.65	ND	ND	ND	ND	5.65	0.2	0.0025	0.0053		
1,3-Dichloropropane	142289	ug/L	ND	ND	ND	ND	ND						
1,4-Dichlorobenzene	106467	ug/L	35	4.9	ND	0.6	ND						
1-Methylnaphthalene	90120	ug/L	16										
2,2-Dichloropropane	594207	ug/L	ND	ND	ND	ND	ND						
2,2-Oxybis(1-Chloropropane)	540545	ug/L	ND										
2,4,5-T	93765	ug/L	ND										
2,4,5-TP (Silvex)	93721	ug/L	1Y										
2,4,5-Trichlorophenol	95954	ug/L	ND										
2,4,6-Trichlorophenol	88062	ug/L	ND	`									
2,4-D	94757	ug/L	ND										
2,4-DB	94826	ug/L	ND										
2,4-Dichlorophenol	120832	ug/L	ND										
2,4-Dimethylphenol	105679	ug/L	ND										
2,4-Dinitrophenol	51285	ug/L	ND										
2,4-Dinitrotoluene	121142	ug/L	ND										
2,6-Dinitrotoluene	606202	ug/L	ND										
2-Butanone	78933	ug/L	39366.667	ND	30000	24	ND	23130.22	5	10.0691	21.8893		
2-Chloroethylvinylether	110758	ug/L	ND	ND	ND	ND	ND						
2-Chloronaphthalene	91587	ug/L	ND										
2-Chlorophenol	95578	ug/L	ND										
2-Chlorotoluene	95498	ug/L	ND	ND	ND	ND	ND						
2-Hexanone	591786	ug/L	585	ND	650	ND	ND	617.5	5	0.2688	0.5844		
2-Methyl-4,6-dinitrophenol	534521	ug/L	ND										
2-Methylnaphthalene	91576	ug/L	27										
2-Methylphenol	95487	ug/L	160					160	1	0.0697	0.1514		
2-Nitroaniline	88744	ug/L	ND										
2-Nitrophenol	88755	ug/L	ND										
3,3'-Dichlorobenzidine	91941	ug/L	ND										
3-Nitroaniline	99092	ug/L	ND										

P1 Zone

115,000.00 Seasonal GW removal volume (gpy)
250,000.00 Continuous GW removal volume (gpy)

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)

										Contaminant Load (kg/yr)	
Constituent	**CAS ID**	**Units**	MW-34p1	B-19-P1	B-22-P1	MW32a	MW-37p1	AVERAGE	Typ. RL	Seasonal	Continuous
4,4-DDD	72548	ug/L	ND								
4,4-DDE	72559	ug/L	ND								
4,4-DDT	50293	ug/L	ND								
4-Bromophenyl Phenyl Ether	101553	ug/L	ND								
4-Chloro-3-methylphenol	59507	ug/L	ND								
4-Chloroaniline	106478	ug/L	ND								
4-Chlorophenyl Phenyl Ether	7005723	ug/l	ND								
4-Chlorotoluene	106434	ug/L	ND	ND	ND	ND	ND				
4-Isopropyltoluene	99876	ug/L	ND	ND	ND	1.85	ND	1.85	0.2	0.0008	0.0018
4-Methyl-2-Pentanone (MIBK)	108101	ug/L	21500	ND	22000	9.7	ND	14503.23	5	6.3136	13.7251
4-Methylphenol	106445	ug/L	340					340	1	0.1480	0.3218
4-Nitroaniline	100016	ug/L	ND								
4-Nitrophenol	100027	ug/L	ND								
Acenaphthene	83329	ug/L	ND								
Acenaphthylene	208968	ug/L	ND								
Acetone	67641	ug/L	136000	25	86000	210	7.8	44448.56	5	19.3494	42.0639
Acrolein	107028	ug/L	ND	ND	ND	ND	ND				
Acrylonitrile	107131	ug/L	ND	ND	ND	ND	ND				
Aldrin	309002	ug/L	0.29								
alpha Chlordane	5103719	ug/L	ND								
alpha-BHC	319846	ug/L	ND								
Anthracene	120127	ug/L	ND								
Benz(a)anthracene	56553	ug/L	ND								
Benzene	71432	ug/L	141	19	220	1.8	0.2	76.4	1	0.0333	0.0723
Benzo(a)pyrene	50328	ug/L	ND								
Benzo(b)fluoranthene	205992	ug/L	ND								
Benzo(g,h,i)perylene	191242	ug/L	ND								
Benzo(k)fluoranthene	207089	ug/L	ND								
Benzoic Acid	65850	ug/L	500								
Benzyl Alcohol	100516	ug/L	20								
beta-BHC	319857	ug/L	ND								
Bis(2-chloroethoxy)methane	111911	ug/L	ND								
Bis(2-chloroethyl) Ether	111444	ug/L	ND								
Bis(2-ethylhexyl) Phthalate	117817	ug/L	22					22	1	0.0096	0.0208
Bromobenzene	108861	ug/L	7.3	ND	ND	ND	ND	7.3	0.2	0.0032	0.0069
Bromochloromethane	74975	ug/L	ND	ND	ND	ND	ND				
Bromodichloromethane	75274	ug/L	ND	ND	ND	ND	ND				
Bromoethane	74964	ug/L	ND	ND	ND	ND	ND				
Bromoform	75252	ug/L	ND	ND	ND	ND	ND				
Bromomethane	74839	ug/L	ND	ND	ND	ND	ND				
Butylbenzyl Phthalate	85687	ug/L	10								
Carbazole	86748	ug/L	ND								
Carbon Disulfide	75150	ug/L	ND	ND	ND	0.3	ND				
Carbon Tetrachloride	56235	ug/L	ND	ND	ND	ND	ND				
Chlorobenzene	108907	ug/L	ND	1.3	ND	ND	ND				
Chloroethane	75003	ug/L	73	440	52	2.8666667	2.4	114.0533		0.0496	0.1079

P1 Zone

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)										Contaminant Load (kg/yr)		115,000.00	Seasonal GW removal volume (gpy)
Constituent	**CAS ID**	**Units**	MW-34p1	B-19-P1	B-22-P1	MW32a	MW-37p1	AVERAGE	Typ. RL	Seasonal	Continuous	250,000.00	Continuous GW removal volume (gpy)
Chloroform	67663	ug/L	34	ND	230	2.1	2.1	67.05	0.2	0.0292	0.0635		
Chloromethane	74873	ug/L	ND	ND	ND	ND	ND		0.5				
Chrysene	218019	ug/L	ND										
cis-1,2-Dichloroethene	156592	ug/L	2441.4286	1.2	3000	17.5	8.3	1093.686		0.4761	1.0350		
cis-1,3-Dichloropropene	10061015	ug/L	ND	ND	ND	ND	ND						
Dalapon	75990	ug/L	ND										
delta-BHC	319868	ug/L	ND										
Dibenz(a,h)anthracene	53703	ug/L	ND										
Dibenzofuran	132649	ug/L	ND										
Dibromochloromethane	124481	ug/L	ND	ND	ND	ND	ND						
Dibromomethane	74953	ug/L	ND	ND	ND	ND	ND						
Dicamba	1918009	ug/L	ND										
Dichloroprop	120365	ug/L	ND										
Dieldrin	60571	ug/L	ND										
Diethyl Phthalate	84662	ug/L	19										
Dimethyl Phthalate	131113	ug/L	ND										
Di-n-butyl Phthalate	84742	ug/L	ND										
Di-n-Octyl phthalate	117840	ug/L	ND										
Dinoseb	88857	ug/L	ND										
Endosulfan I	959988	ug/L	ND										
Endosulfan II	33213659	ug/L	ND										
Endosulfan Sulfate	1031078	ug/L	ND										
Endrin	72208	ug/L	ND										
Endrin Aldehyde	7421934	ug/L	ND										
Endrin Ketone	53494705	ug/L	ND										
Ethane		ug/L	ND			ND	ND						
Ethene		ug/L	253			9.4	ND						
Ethylbenzene	100414	ug/L	4614.2857	16	5600	77.75	0.4	2061.687	0.2	0.8975	1.9511		
Ethylene Dibromide (EDB)	106934	ug/L	ND	ND	ND	ND	ND						
Fluoranthene	206440	ug/L	ND										
Fluorene	86737	ug/L	ND										
gamma Chlordane	5103742	ug/L	ND										
gamma-BHC (Lindane)	58899	ug/L	ND										
Heptachlor	76448	ug/L	ND										
Heptachlor Epoxide	1024573	ug/L	ND										
Hexachlorobenzene	118741	ug/L	ND										
Hexachlorobutadiene	87683	ug/L	ND	ND	ND	ND	ND						
Hexachlorocyclopentadiene	77474	ug/L	ND										
Hexachloroethane	67721	ug/L	ND										
Hexane		ug/L	ND	1	ND	ND	ND						
Indeno(1,2,3-cd)pyrene	193395	ug/L	ND										
Isophorone	78591	ug/L	ND										
Isopropylbenzene (Cumene)	98828	ug/L	86.5	1.5	220	4.225	ND						
MCPA	94746	ug/L	ND										
Methane		ug/L	7080			380	ND						
Methoxychlor	72435	ug/L	ND										

P1 Zone

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)

115,000.00 Seasonal GW removal volume (gpy)
250,000.00 Continuous GW removal volume (gpy)

Constituent	**CAS ID**	**Units**	MW-34p1	B-19-P1	B-22-P1	MW32a	MW-37p1	AVERAGE	Typ. RL	Contaminant Load (kg/yr) Seasonal	Contaminant Load (kg/yr) Continuous
Methyl Iodide	74884	ug/L	ND	ND	ND	ND	ND				
Methylene Chloride	75092	ug/l	398	3.3	2800	2	ND	800.825	0.5	0.3486	0.7579
Naphthalene	91203	ug/L	200	ND	ND	11.05	ND	105.525	0.5	0.0459	0.0999
n-Butylbenzene	104518	ug/L	8.3	ND	ND	ND	ND	8.3	0.2	0.0036	0.0079
Nitrobenzene	98953	ug/L	ND								
N-Nitrosodi-n-propylamine	621647	ug/L	ND								
N-Nitrosodiphenylamine	86306	ug/L	ND								
n-Propylbenzene	103651	ug/L	135	1.1	390	5.95	ND				
o-Xylene	95476	ug/L	3900	5.8	6200	102.5	0.3	2041.72	0.2	0.8888	1.9322
Pentachlorophenol	87865	ug/L	ND								
Phenanthrene	85018	ug/L	ND								
Phenol	108952	ug/L	76								
Pyrene	129000	ug/L	ND								
sec-Butylbenzene	135988	ug/L	6.6	ND	ND	ND	ND	6.6	0.2	0.0029	0.0062
Styrene	100425	ug/L	17	ND	160	ND	ND				
tert-Butylbenzene	98066	ug/L	ND	ND	ND	ND	ND				
Tetrachloroethene (PCE)	127184	ug/L	13.4	1U	700	6.1575	5.375	181.2331	0.2	0.0789	0.1715
Toluene	108883	ug/L	61714.286	4.5	130000	209.25	4.2	38386.45	0.2	16.7104	36.3270
Toxaphene	8001352	ug/L	ND								
trans-1,2-Dichloroethene	156605	ug/L	16	1.6	ND	0.078	0.02				
trans-1,3-Dichloropropene	10061026	ug/L	ND	ND	ND	ND	ND				
trans-1,4-Dichloro-2-butene	110576	ug/L	ND	ND	ND	ND	ND				
Trichloroethene (TCE)	79016	ug/L	10.95	ND	580	5.7733333	5.025	150.4371	1	0.0655	0.1424
Trichlorofluoromethane	75694	ug/l	ND	ND	ND	ND	ND				
Vinyl Acetate	108054	ug/L	ND	ND	ND	ND	ND				
Vinyl Chloride	75014	ug/L	354.66667	12	550	21.45	0.31475	187.6863		0.0817	0.1776
Xylene Isomers, M+P		ug/L	10585.714	4.8	16000	196.66667	0.7	5357.576	0.4	2.3323	5.0701
Ortho-Phosphorus		mg-P/L									
Total Phosphorus		mg-P/L	0.59								

Initial Annual COC Removal Rates (kg/yr)

	Seasonal	Continuous	
Organic	**60.19**	**130.85**	
		14.30	Estimate of COC mass from entrained LNAPL
		145.15	

1.0% Assumed LNAPL to water mix rate
0.80 kg/gal LNAPL, 8260 VOC concentration as estimate of COC concentration
1430 kg 8260 VOC in LNAPL
1795 gal LNAPL

The Hole

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)						Contaminant Load (kg/yr)		290,000.00	Seasonal GW removal volume (gpy)
Constituent	Units	EW-1	EW-2	AVERAGE	Typ. RL	Seasonal	Continuous	390,000.00	Continuous GW removal volume (gpy)
Depth to Water	feet	58.08	31.14						
Dissolved Oxygen	mg/L	1.34							
Hydrogen Sulfide	mg/L	0.01	0.00						
Oxidation Reduction Potential	mV	-87.75	-182.00						
pH	std. units	6.69	6.68						
Specific Conductance @ 25C	umhos/cm	8861.89	8560.00						
Temperature, 0 F	0 F	70.66	59.40						
Inorganics									
Alkalinity (as CaCO3)	mg/L	1287.50							
Ammonia as Nitrogen, Total	mg/L as N								
Bicarbonate As CaCO3	mg/L	1270.00							
Carbonate as CaCO3	mg/L	ND							
Carbonate as CO3	mg/L	ND							
Chemical Oxygen Demand (COD)	mg/L								
Chloride	mg/L	2248.89		2248.89		2468.75	3320.05		
Nitrate as Nitrogen	mg/L as N	0.01							
Nitrate+Nitrite as Nitrogen	mg/L as N	0.01		0.01	0.01	0.02	0.02		
Nitrite as Nitrogen	mg/L as N	0.02							
Sulfate	mg/L	1278.89		1278.89		1403.92	1888.03		
Total Dissolved Solids	mg/L	6741.11		6741.11		7400.16	9951.94		
Metals									
Antimony, Dissolved	ug/L	ND	ND						
Arsenic, Dissolved	ug/L	11.17	3.00	7.08		0.01	0.01		
Barium, Dissolved	ug/L	270.00	80.00						
Beryllium, Dissolved	ug/L	ND	ND						
Cadmium, Dissolved	ug/L	ND	ND						
Calcium, Total	mg/L	612.75	672.00						
Chromium, Dissolved	ug/L	ND	ND						
Cobalt, Dissolved	ug/L	90.00	60.00						
Copper, Dissolved	ug/L	ND	ND						
Iron, Dissolved	ug/L	3880.00							
Iron, Total	ug/L	33412.50	ND	33412.50	50.00	36.68	49.33		
Lead, Dissolved	ug/L	ND	ND						
Magnesium, Total	mg/L	390.63	368.00						
Manganese, Dissolved	ug/L	23100.00							
Manganese, Total	ug/L	24887.50	19200.00	22043.75		24.20	32.54		
Nickel, Dissolved	ug/L	ND	160.00						
Potassium, Total	mg/L	234.38	102.00						

The Hole

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)						Contaminant Load (kg/yr)		290,000.00	Seasonal GW removal volume (gpy)
Constituent	Units	EW-1	EW-2	AVERAGE	Typ. RL	Seasonal	Continuous	390,000.00	Continuous GW removal volume (gpy)
Selenium, Dissolved	ug/L	ND	ND						
Silver, Dissolved	ug/L	ND	ND						
Sodium, Total	mg/L	1095.88	812.00						
Thallium, Dissolved	ug/L	1.00	ND						
Vanadium, Dissolved	ug/L	ND	20.00						
Zinc, Dissolved	ug/L	120.00	ND						
Organics									
1,1,1,2-Tetrachloroethane	ug/L	ND							
1,1,1-Trichloroethane	ug/l	ND			0.20				
1,1,2,2-Tetrachloroethane	ug/L	0.02							
1,1,2-Trichloroethane	ug/L	0.80		0.80	0.20	0.0009	0.0012		
1,1,2-Trichlorotrifluoroethane	ug/L	ND							
1,1-Dichloroethane	ug/L	12.50		12.50		0.0137	0.0185		
1,1-Dichloroethene	ug/L	0.38		0.38	1.00	0.0004	0.0006		
1,1-Dichloropropene	ug/L	ND							
1,2,3-Trichlorobenzene	ug/L	ND							
1,2,3-Trichloropropane	ug/L	ND							
1,2,4-Trichlorobenzene	ug/L	ND							
1,2,4-Trimethylbenzene	ug/L	ND			0.20				
1,2-Dibromo-3-chloropropane	ug/L	ND							
1,2-Dichlorobenzene	ug/L	1.04							
1,2-Dichloroethane (EDC)	ug/L	0.50		0.50		0.0005	0.0007		
1,2-Dichloropropane	ug/L	1.08		1.08		0.0012	0.0016		
1,3,5-Trimethylbenzene	ug/L	ND			0.20				
1,3-Dichlorobenzene	ug/L	ND			0.20				
1,3-Dichloropropane	ug/L	ND							
1,4-Dichlorobenzene	ug/L	2.59							
1-Methylnaphthalene	ug/L								
2,2-Dichloropropane	ug/L	ND							
2,2-Oxybis(1-Chloropropane)	ug/L								
2,4,5-T	ug/L								
2,4,5-TP (Silvex)	ug/L								
2,4,5-Trichlorophenol	ug/L								
2,4,6-Trichlorophenol	ug/L								
2,4-D	ug/L								
2,4-DB	ug/L								
2,4-Dichlorophenol	ug/L								
2,4-Dimethylphenol	ug/L								

The Hole

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)

290,000.00 Seasonal GW removal volume (gpy)
390,000.00 Continuous GW removal volume (gpy)

						Contaminant Load (kg/yr)	
Constituent	Units	EW-1	EW-2	AVERAGE	Typ. RL	Seasonal	Continuous
2,4-Dinitrophenol	ug/L						
2,4-Dinitrotoluene	ug/L						
2,6-Dinitrotoluene	ug/L						
2-Butanone	ug/L	ND			5.00		
2-Chloroethylvinylether	ug/L	ND					
2-Chloronaphthalene	ug/L						
2-Chlorophenol	ug/L						
2-Chlorotoluene	ug/L	ND					
2-Hexanone	ug/L	ND			5.00		
2-Methyl-4,6-dinitrophenol	ug/L						
2-Methylnaphthalene	ug/L						
2-Methylphenol	ug/L				1.00		
2-Nitroaniline	ug/L						
2-Nitrophenol	ug/L						
3,3'-Dichlorobenzidine	ug/L						
3-Nitroaniline	ug/L						
4,4-DDD	ug/L	ND	ND				
4,4-DDE	ug/L	ND	ND				
4,4-DDT	ug/L	ND	ND				
4-Bromophenyl Phenyl Ether	ug/L						
4-Chloro-3-methylphenol	ug/L						
4-Chloroaniline	ug/L						
4-Chlorophenyl Phenyl Ether	ug/l						
4-Chlorotoluene	ug/L	ND					
4-Isopropyltoluene	ug/L	ND			0.20		
4-Methyl-2-Pentanone (MIBK)	ug/L	ND			5.00		
4-Methylphenol	ug/L				1.00		
4-Nitroaniline	ug/L						
4-Nitrophenol	ug/L						
Acenaphthene	ug/L						
Acenaphthylene	ug/L						
Acetone	ug/L	14.23		14.23	5.00	0.0156	0.0210
Acrolein	ug/L	ND					
Acrylonitrile	ug/L	ND					
Aldrin	ug/L	ND	ND				
alpha Chlordane	ug/L	ND	ND				
alpha-BHC	ug/L	ND	ND				
Anthracene	ug/L						

The Hole

290,000.00 Seasonal GW removal volume (gpy)
390,000.00 Continuous GW removal volume (gpy)

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)						Contaminant Load (kg/yr)	
Constituent	Units	EW-1	EW-2	AVERAGE	Typ. RL	Seasonal	Continuous
Benz(a)anthracene	ug/L						
Benzene	ug/L	2.39		2.39	1.00	0.0026	0.0035
Benzo(a)pyrene	ug/L						
Benzo(b)fluoranthene	ug/L						
Benzo(g,h,i)perylene	ug/L						
Benzo(k)fluoranthene	ug/L						
Benzoic Acid	ug/L						
Benzyl Alcohol	ug/L						
beta-BHC	ug/L	.17Y	ND				
Bis(2-chloroethoxy)methane	ug/L						
Bis(2-chloroethyl) Ether	ug/L						
Bis(2-ethylhexyl) Phthalate	ug/L				1.00		
Bromobenzene	ug/L	0.20		0.20	0.20	0.0002	0.0003
Bromochloromethane	ug/L	ND					
Bromodichloromethane	ug/L	ND					
Bromoethane	ug/L	ND					
Bromoform	ug/L	ND					
Bromomethane	ug/L	ND					
Butylbenzyl Phthalate	ug/L						
Carbazole	ug/L						
Carbon Disulfide	ug/L	ND					
Carbon Tetrachloride	ug/L	ND					
Chlorobenzene	ug/L	0.58					
Chloroethane	ug/L	3.34		3.34		0.0037	0.0049
Chloroform	ug/L	ND			0.20		
Chloromethane	ug/L	0.30		0.30	0.50	0.0003	0.0004
Chrysene	ug/L						
cis-1,2-Dichloroethene	ug/L	24.24		24.24		0.0266	0.0358
cis-1,3-Dichloropropene	ug/L	ND					
Dalapon	ug/L						
delta-BHC	ug/L	ND	ND				
Dibenz(a,h)anthracene	ug/L						
Dibenzofuran	ug/L						
Dibromochloromethane	ug/L	ND					
Dibromomethane	ug/L	ND					
Dicamba	ug/L						
Dichloroprop	ug/L						
Dieldrin	ug/L	ND	ND				

The Hole

290,000.00 Seasonal GW removal volume (gpy)
390,000.00 Continuous GW removal volume (gpy)

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)						Contaminant Load (kg/yr)	
Constituent	Units	EW-1	EW-2	AVERAGE	Typ. RL	Seasonal	Continuous
Diethyl Phthalate	ug/L						
Dimethyl Phthalate	ug/L						
Di-n-butyl Phthalate	ug/L						
Di-n-Octyl phthalate	ug/L						
Dinoseb	ug/L						
Endosulfan I	ug/L	ND	ND				
Endosulfan II	ug/L	ND	ND				
Endosulfan Sulfate	ug/L	ND	ND				
Endrin	ug/L	ND	ND				
Endrin Aldehyde	ug/L	ND	ND				
Endrin Ketone	ug/L	ND	ND				
Ethane	ug/L						
Ethene	ug/L						
Ethylbenzene	ug/L		0.40	0.40	0.20	0.0004	0.0006
Ethylene Dibromide (EDB)	ug/L	ND					
Fluoranthene	ug/L						
Fluorene	ug/L						
gamma Chlordane	ug/L	ND	ND				
gamma-BHC (Lindane)	ug/L	ND	ND				
Heptachlor	ug/L	ND	ND				
Heptachlor Epoxide	ug/L	ND	ND				
Hexachlorobenzene	ug/L						
Hexachlorobutadiene	ug/L	ND					
Hexachlorocyclopentadiene	ug/L						
Hexachloroethane	ug/L						
Hexane	ug/L		0.30				
Indeno(1,2,3-cd)pyrene	ug/L						
Isophorone	ug/L						
Isopropylbenzene (Cumene)	ug/L		0.30				
MCPA	ug/L						
Methane	ug/L						
Methoxychlor	ug/L	ND	ND				
Methyl Iodide	ug/L	ND					
Methylene Chloride	ug/l		0.79	0.79	0.50	0.0009	0.0012
Naphthalene	ug/L	ND			0.50		
n-Butylbenzene	ug/L	ND			0.20		
Nitrobenzene	ug/L						
N-Nitrosodi-n-propylamine	ug/L						

The Hole

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)						Contaminant Load (kg/yr)	
Constituent	Units	EW-1	EW-2	AVERAGE	Typ. RL	Seasonal	Continuous
N-Nitrosodiphenylamine	ug/L						
n-Propylbenzene	ug/L	ND					
o-Xylene	ug/L	0.30		0.30	0.20	0.0003	0.0004
Pentachlorophenol	ug/L						
Phenanthrene	ug/L						
Phenol	ug/L						
Pyrene	ug/L						
sec-Butylbenzene	ug/L	ND			0.20		
Styrene	ug/L	ND					
tert-Butylbenzene	ug/L	ND					
Tetrachloroethene (PCE)	ug/L	0.05		0.05	0.20	0.0001	0.0001
Toluene	ug/L	0.20		0.20	0.20	0.0002	0.0003
Toxaphene	ug/L	ND	ND				
trans-1,2-Dichloroethene	ug/L	0.75					
trans-1,3-Dichloropropene	ug/L	ND					
trans-1,4-Dichloro-2-butene	ug/L	ND					
Trichloroethene (TCE)	ug/L	0.72		0.72	1.00	0.0008	0.0011
Trichlorofluoromethane	ug/l	ND					
Vinyl Acetate	ug/L	ND					
Vinyl Chloride	ug/L	60.78		60.78		0.0667	0.0897
Xylene Isomers, M+P	ug/L	ND			0.40		
Ortho-Phosphorus	mg-P/L	0.00					
Total Phosphorus	mg-P/L	0.03					
				Initial Annual COC Removal Rates (kg/yr)			
					Organic	**0.14**	**0.18**

290,000.00 Seasonal GW removal volume (gpy)
390,000.00 Continuous GW removal volume (gpy)

Northerly Plume Capture

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)							Contaminant Load		
		MW-3b	MW-7b	MW-9b	AVERAGE	Typ. RL	(kg/yr)	3,500,000.00	gpy
Depth to Water	feet	31.21	30.33	36.50					
Dissolved Oxygen	mg/L	2.51	2.21	0.94					
Hydrogen Sulfide	mg/L	0.00	0.00	0.00					
Oxidation Reduction Potential	mV	-74.33	-45.67	42.00					
pH	std. units	6.70	6.76	6.84					
Specific Conductance @ 25C	umhos/cm	5860.93	4754.29	3840.20					
Temperature, 0 F	0 F	59.51		61.40					
Inorganics									
Alkalinity (as CaCO3)	mg/L	1251.25	1013.93	852.87					
Ammonia as Nitrogen, Total	mg/L as N	3.09	0.10	0.18					
Bicarbonate As CaCO3	mg/L	1251.25	1013.93	852.87					
Carbonate as CaCO3	mg/L	ND	ND	ND					
Carbonate as CO3	mg/L	ND	ND	ND					
Chemical Oxygen Demand (COD)	mg/L	163.00		37.40					
Chloride	mg/L	1088.50	936.67	590.20	871.79		11,550.2438		
Nitrate as Nitrogen	mg/L as N	0.01	0.07	12.77					
Nitrate+Nitrite as Nitrogen	mg/L as N	0.01	0.08	12.97	4.35	0.01	57.6736		
Nitrite as Nitrogen	mg/L as N	0.02	0.01	0.22					
Sulfate	mg/L	1312.69	939.27	568.40	940.12		12,455.5301		
Total Dissolved Solids	mg/L	4619.38	3628.00	2586.67	3611.35		47,846.3782		
Metals									
Antimony, Dissolved	ug/L	ND	ND	ND					
Arsenic, Dissolved	ug/L	2.91	1.37	6.83	3.70		0.0490		
Barium, Dissolved	ug/L	116.44	92.93	54.67					
Beryllium, Dissolved	ug/L	ND	ND	ND					
Cadmium, Dissolved	ug/L	ND	ND	ND					
Calcium, Total	mg/L	531.25	562.67	360.73					
Chromium, Dissolved	ug/L	ND	ND	ND					
Cobalt, Dissolved	ug/L	8.00	13.71	19.27					
Copper, Dissolved	ug/L	7.00	9.50	20.27					
Iron, Dissolved	ug/L	8245.00	2432.73	ND					
Iron, Total	ug/L	7860.63	2506.67	ND	5183.65	50	68.6776		
Lead, Dissolved	ug/L	ND	ND	ND					
Magnesium, Total	mg/L	308.00	231.40	137.89					
Manganese, Dissolved	ug/L	19258.33	14300.00	3460.91					
Manganese, Total	ug/L	17981.25	14126.67	4274.00	12127.31		160.6735		
Nickel, Dissolved	ug/L	61.25	58.67	58.00					

Northerly Plume Capture

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)							Contaminant Load	
		MW-3b	MW-7b	MW-9b	AVERAGE	Typ. RL	(kg/yr)	3,500,000.00 gpy
Potassium, Total	mg/L	40.88	15.36	21.57				
Selenium, Dissolved	ug/L	3.17	3.00	3.27				
Silver, Dissolved	ug/L	ND	24.00	ND				
Sodium, Total	mg/L	586.88	369.80	313.80				
Thallium, Dissolved	ug/L	ND	ND	ND				
Vanadium, Dissolved	ug/L	4.33	ND	20.60				
Zinc, Dissolved	ug/L	10.00	10.00	ND				
Organics								
1,1,1,2-Tetrachloroethane	ug/L	ND	ND	ND				
1,1,1-Trichloroethane	ug/l	ND	ND	ND		0.2		
1,1,2,2-Tetrachloroethane	ug/L	ND	ND	ND				
1,1,2-Trichloroethane	ug/L	ND	ND	ND		0.2		
1,1,2-Trichlorotrifluoroethane	ug/L	ND	ND	ND				
1,1-Dichloroethane	ug/L	9.24	15.41	2.80	9.15		0.1212	
1,1-Dichloroethene	ug/L	0.73	0.80	0.21	0.58	1	0.0077	
1,1-Dichloropropene	ug/L	ND	ND	ND				
1,2,3-Trichlorobenzene	ug/L	ND	ND	ND				
1,2,3-Trichloropropane	ug/L	ND	ND	ND				
1,2,4-Trichlorobenzene	ug/L	ND	ND	ND				
1,2,4-Trimethylbenzene	ug/L	ND	ND	ND		0.2		
1,2-Dibromo-3-chloropropane	ug/L	ND	ND	ND				
1,2-Dichlorobenzene	ug/L	1.60	2.49	0.30				
1,2-Dichloroethane (EDC)	ug/L	1.30	1.95	0.38	1.21		0.0161	
1,2-Dichloropropane	ug/L	9.41	8.94	2.43	6.93		0.0918	
1,3,5-Trimethylbenzene	ug/L	ND	ND	ND		0.2		
1,3-Dichlorobenzene	ug/L	0.30	0.23	ND	0.27	0.2	0.0035	
1,3-Dichloropropane	ug/L	ND	ND	ND				
1,4-Dichlorobenzene	ug/L	1.65	1.89	0.46				
1-Methylnaphthalene	ug/L	ND	ND	ND				
2,2-Dichloropropane	ug/L	ND	ND	ND				
2,2-Oxybis(1-Chloropropane)	ug/L	ND	ND	ND				
2,4,5-T	ug/L							
2,4,5-TP (Silvex)	ug/L							
2,4,5-Trichlorophenol	ug/L	ND	ND	ND				
2,4,6-Trichlorophenol	ug/L	ND	ND	ND				
2,4-D	ug/L							
2,4-DB	ug/L							

Northerly Plume Capture

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)							Contaminant Load	
		MW-3b	MW-7b	MW-9b	AVERAGE	Typ. RL	(kg/yr)	3,500,000.00 gpy
2,4-Dichlorophenol	ug/L	ND	ND	ND				
2,4-Dimethylphenol	ug/L	ND	ND	ND				
2,4-Dinitrophenol	ug/L	ND	ND	ND				
2,4-Dinitrotoluene	ug/L	ND	ND	ND				
2,6-Dinitrotoluene	ug/L	ND	ND	ND				
2-Butanone	ug/L	ND	ND	ND		5		
2-Chloroethylvinylether	ug/L	ND	ND	ND				
2-Chloronaphthalene	ug/L	ND	ND	ND				
2-Chlorophenol	ug/L	ND	ND	ND				
2-Chlorotoluene	ug/L	ND	ND	ND				
2-Hexanone	ug/L	ND	ND	ND		5		
2-Methyl-4,6-dinitrophenol	ug/L	ND	ND	ND				
2-Methylnaphthalene	ug/L	ND	ND	ND				
2-Methylphenol	ug/L	ND	ND	ND		1		
2-Nitroaniline	ug/L	ND	ND	ND				
2-Nitrophenol	ug/L	ND	ND	ND				
3,3'-Dichlorobenzidine	ug/L	ND	ND	ND				
3-Nitroaniline	ug/L	ND	ND	ND				
4,4-DDD	ug/L							
4,4-DDE	ug/L							
4,4-DDT	ug/L							
4-Bromophenyl Phenyl Ether	ug/L	ND	ND	ND				
4-Chloro-3-methylphenol	ug/L	ND	ND	ND				
4-Chloroaniline	ug/L	ND	ND	ND				
4-Chlorophenyl Phenyl Ether	ug/l	ND	ND	ND				
4-Chlorotoluene	ug/L	ND	ND	ND				
4-Isopropyltoluene	ug/L	ND	ND	ND		0.2		
4-Methyl-2-Pentanone (MIBK)	ug/L	ND	ND	ND		5		
4-Methylphenol	ug/L	ND	ND	ND		1		
4-Nitroaniline	ug/L	ND	ND	ND				
4-Nitrophenol	ug/L	ND	ND	ND				
Acenaphthene	ug/L	ND	ND	ND				
Acenaphthylene	ug/L	ND	ND	ND				
Acetone	ug/L	8.05	4.27	4.27	5.53	5	0.0732	
Acrolein	ug/L	ND	ND	ND				
Acrylonitrile	ug/L	ND	ND	ND				
Aldrin	ug/L							

Northerly Plume Capture

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)							Contaminant Load		
		MW-3b	MW-7b	MW-9b	AVERAGE	Typ. RL	(kg/yr)	3,500,000.00	gpy
alpha Chlordane	ug/L								
alpha-BHC	ug/L								
Anthracene	ug/L	ND	ND	ND					
Benz(a)anthracene	ug/L	ND	ND	ND					
Benzene	ug/L	2.28	1.43	0.38	1.36	1	0.0180		
Benzo(a)pyrene	ug/L	ND	ND	ND					
Benzo(b)fluoranthene	ug/L	ND	ND	ND					
Benzo(g,h,i)perylene	ug/L	ND	ND	ND					
Benzo(k)fluoranthene	ug/L	ND	ND	ND					
Benzoic Acid	ug/L	ND	ND	ND					
Benzyl Alcohol	ug/L	ND	ND	ND					
beta-BHC	ug/L								
Bis(2-chloroethoxy)methane	ug/L	ND	ND	ND					
Bis(2-chloroethyl) Ether	ug/L	ND	ND	ND					
Bis(2-ethylhexyl) Phthalate	ug/L	ND	2.40	ND	2.40	1	0.0318		
Bromobenzene	ug/L	0.28	0.43	ND	0.36	0.2	0.0047		
Bromochloromethane	ug/L	ND	ND	ND					
Bromodichloromethane	ug/L	ND	ND	ND					
Bromoethane	ug/L	3.10	ND	ND					
Bromoform	ug/L	ND	ND	ND					
Bromomethane	ug/L	ND	ND	ND					
Butylbenzyl Phthalate	ug/L	ND	ND	ND					
Carbazole	ug/L	ND	ND	ND					
Carbon Disulfide	ug/L	0.30	ND	ND					
Carbon Tetrachloride	ug/L	ND	ND	ND					
Chlorobenzene	ug/L	0.76	0.77	0.20					
Chloroethane	ug/L	40.31	58.29	0.93	33.18		0.4396		
Chloroform	ug/L	ND	ND	ND		0.2			
Chloromethane	ug/L	ND	ND	ND		0.5			
Chrysene	ug/L	ND	ND	ND					
cis-1,2-Dichloroethene	ug/L	34.19	19.67	9.03	20.96		0.2777		
cis-1,3-Dichloropropene	ug/L	ND	ND	ND					
Dalapon	ug/L								
delta-BHC	ug/L								
Dibenz(a,h)anthracene	ug/L	ND	ND	ND					
Dibenzofuran	ug/L	ND	ND	ND					
Dibromochloromethane	ug/L	ND	ND	ND					

Northerly Plume Capture

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)							Contaminant Load	
		MW-3b	MW-7b	MW-9b	AVERAGE	Typ. RL	(kg/yr)	3,500,000.00 gpy
Dibromomethane	ug/L	ND	ND	ND				
Dicamba	ug/L							
Dichloroprop	ug/L							
Dieldrin	ug/L							
Diethyl Phthalate	ug/L	2.17	1.90	ND				
Dimethyl Phthalate	ug/L	ND	ND	ND				
Di-n-butyl Phthalate	ug/L	ND	ND	ND				
Di-n-Octyl phthalate	ug/L	ND	ND	ND				
Dinoseb	ug/L							
Endosulfan I	ug/L							
Endosulfan II	ug/L							
Endosulfan Sulfate	ug/L							
Endrin	ug/L							
Endrin Aldehyde	ug/L							
Endrin Ketone	ug/L							
Ethane	ug/L	ND	1.60	ND				
Ethene	ug/L	3.20	2.60	ND				
Ethylbenzene	ug/L	0.20	ND	ND	0.20	0.2	0.0026	
Ethylene Dibromide (EDB)	ug/L	ND	ND	ND				
Fluoranthene	ug/L	ND	ND	ND				
Fluorene	ug/L	ND	ND	ND				
gamma Chlordane	ug/L							
gamma-BHC (Lindane)	ug/L							
Heptachlor	ug/L							
Heptachlor Epoxide	ug/L							
Hexachlorobenzene	ug/L	ND	ND	ND				
Hexachlorobutadiene	ug/L	ND	ND	ND				
Hexachlorocyclopentadiene	ug/L	ND	ND	ND				
Hexachloroethane	ug/L	ND	ND	ND				
Hexane	ug/L							
Indeno(1,2,3-cd)pyrene	ug/L	ND	ND	ND				
Isophorone	ug/L	ND	ND	ND				
Isopropylbenzene (Cumene)	ug/L	0.20	ND	ND				
MCPA	ug/L							
Methane	ug/L	410.00	201.00	16.40				
Methoxychlor	ug/L							
Methyl Iodide	ug/L	ND	ND	ND				

Northerly Plume Capture

Groundwater Monitoring Data From PGG Filtered For COCs (Shaded Rows)							Contaminant Load	
		MW-3b	MW-7b	MW-9b	AVERAGE	Typ. RL	(kg/yr)	3,500,000.00 gpy
Methylene Chloride	ug/l	1.84	2.47	0.55	1.62	0.5	0.0215	
Naphthalene	ug/L	0.60	ND	ND	0.60	0.5	0.0079	
n-Butylbenzene	ug/L	ND	ND	ND		0.2		
Nitrobenzene	ug/L	ND	ND	ND				
N-Nitrosodi-n-propylamine	ug/L	ND	ND	ND				
N-Nitrosodiphenylamine	ug/L	ND	ND	ND				
n-Propylbenzene	ug/L	0.30	ND	ND				
o-Xylene	ug/L	0.26	0.23	ND	0.25	0.2	0.0033	
Pentachlorophenol	ug/L	ND	ND	ND				
Phenanthrene	ug/L	ND	ND	ND				
Phenol	ug/L	ND	ND	ND				
Pyrene	ug/L	ND	ND	ND				
sec-Butylbenzene	ug/L	0.20	ND	ND	0.20	0.2	0.0026	
Styrene	ug/L	ND	ND	ND				
tert-Butylbenzene	ug/L	ND	ND	ND				
Tetrachloroethene (PCE)	ug/L	0.17	0.37	3.83	1.46	0.2	0.0193	
Toluene	ug/L	ND	ND	ND		0.2		
Toxaphene	ug/L							
trans-1,2-Dichloroethene	ug/L	0.61	0.52	0.23				
trans-1,3-Dichloropropene	ug/L	ND	ND	ND				
trans-1,4-Dichloro-2-butene	ug/L	ND	ND	ND				
Trichloroethene (TCE)	ug/L	1.24	1.01	0.93	1.06	1	0.0140	
Trichlorofluoromethane	ug/l	ND	ND	ND				
Vinyl Acetate	ug/L	ND	ND	ND				
Vinyl Chloride	ug/L	29.59	16.75	6.53	17.62		0.2335	
Xylene Isomers, M+P	ug/L	ND	ND	ND		0.4		
Ortho-Phosphorus	mg-P/L							
Total Phosphorus	mg-P/L							

Initial Annual COC Removal Rates (kg/yr)

Organic	**1.39**

Soil Vapor Extraction

m_0	1430	
k	0.0045	(range of 0.0045 to 0.0067 in ref.)

Assumed m_a

50%	715
80%	286
90%	143
99%	14

Concentration form is directly from Maxim memo to Wyoming DEQ re Conoco site. Citation in Maxim memo is *Review of Mathematical Modeling For Evaluating Soil Vapor Extraction Systems, EPA, 1995*.

From Maxim letter

$C_t = (C_0 - C_a)e^{-kt} + C_a$ - or - $m_t = (m_0 - m_a)e^{-kt} + m_a$

Mass form by BKP

Where:
C_t - VOC concentration at time t
C_0 - initial VOC concentration
C_a - asymptotic (e.g. not extractable) VOC concentration
k - rate constant (day^{-1})

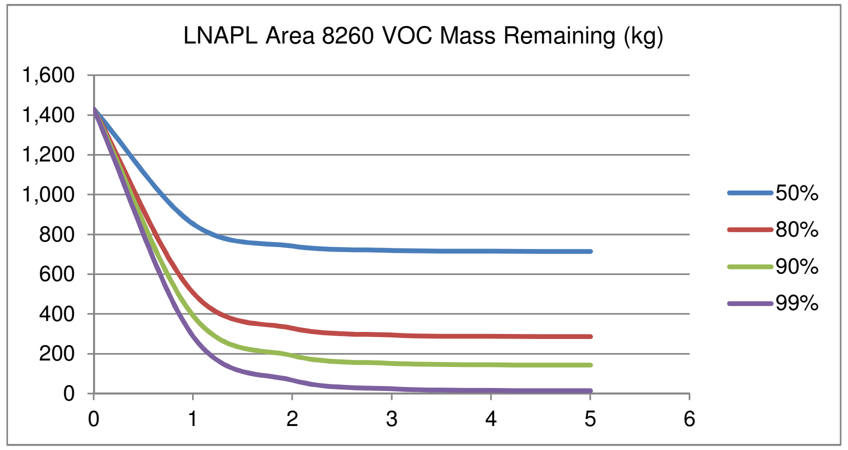
Notes:
1. Assumptions that a certain percentage removal is possible should be reflected in the value of m_a. - BKP 8/24/2012
2. Since matrix is constant, mass can be substituted for concentration. - BKP 8/24/2012
3. Actually calculating 8360 VOC removal.
4. COC mass partitioned to soil and dissolved in groundwater is negligible compared to LNAPL COC mass.

1795	gal LNAPL	Table 15, hydrogeologic calculations, best estimate
0.87	kg/L	PGG's LNAPL calculations (VOC_NAPL_2011 & 2009 tabs)
3.7853	L/gal	
5883.927	kg LNAPL, (gal LNAPL) x (kg/L) x (L/gal)	
22.37%	mass of LNAPL is 8260 VOC	(from VOC_NAPL_2011)
26.23%	mass of LNAPL is 8260 VOC	(from VOC_NAPL_2009)
24%	average percentage	math
1430	m_0, kg 8260 VOC, best estimate for LNAPL area	math

Mass calculations, BKP, 8/24/2012

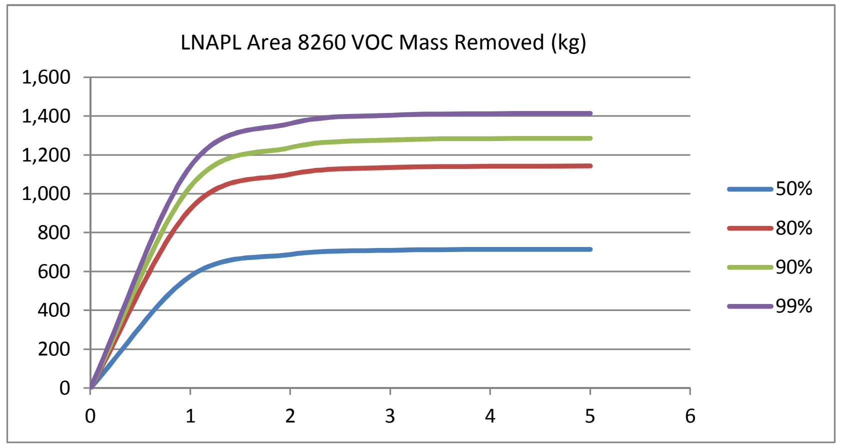
LNAPL Area 8260 VOC Mass Remaining For Various Removal Efficiencies

	Removal efficiency			
	50%	80%	90%	99%
m_a (kg)	714.9	286.0	143.0	14.30
Year	LNAPL area COC mass remaining (kg)			
0	1,430	1,430	1,430	1,430
1	853	507	392	288
2	742	329	191	67
3	720	294	152	25
4	716	288	145	17
5	715	286	143	15



LNAPL Area 8260 VOC Mass Removed For Various Removal Efficiencies

	Removal efficiency			
	50%	80%	90%	99%
ma (kg)	714.9	286.0	143.0	14.3
Year	LNAPL area COC mass removed (kg)			
0	0	0	0	0
1	**577**	923	1,038	1,142
2	688	1,101	1,239	1,363
3	710	1,136	1,278	1,405
4	714	1,142	1,285	1,413
5	715	1,144	1,286	1,415



North End Soils

Constituent (Detections Only)	**Average Concentration**	**Units**	**B-8-4_5**	**T-3-7_3**	**T-4-4**	**T-5-7**	**T-5-7_2**	**T-5-8**	**T-6-4**	**T-7-2_3**	**T-8-4**	**T-9-6_4**	**T-10-4_2**	**T-11-4**	**T-12-5**	**T-12-5_5**	**T-12-7**	**T-13-4**	**T-13-5_5**	**T-13-6**
1,2-Dichloropropane	0.004	mg/kg	0.0038	0.0006U	0.0012U	0.037U	0.036U	0.043U	0.0012U	0.0016U	0.0013U	0.0012U	0.0013U	0.0012U	0.06U	0.077U	0.12U	0.083U	0.11U	0.0012U
1,4-Dichlorobenzene	1.250	mg/kg	0.0025U	0.0006U	0.0012U	0.037U	0.036U	0.043U	0.0012U	0.0016U	0.0013U	0.0012U	0.0013U	0.0012U	0.06U	0.077U	0.12U	2.2	1.5	0.049
Benzene	0.033	mg/kg	0.012	0.0006U	0.0052	0.037U	0.036U	0.043U	0.0096	0.0079	0.0016	0.0012U	0.017	0.01	0.06U	0.077U	0.23	0.083U	0.11U	0.0062
cis-1,2-Dichloroethene	0.786	mg/kg	0.043	0.0006U	0.0012U	0.8	1	0.047	0.0012U	0.0016U	0.0013U	0.0012U	0.0013U	0.0012U	0.06U	0.077U	0.12U	0.083U	2.8	0.028
Ethylbenzene	0.220	mg/kg	0.0065	0.0006U	0.0012U	0.037U	0.036U	0.043U	0.0016	0.0016U	0.0013U	0.0012U	0.0014	0.0026	0.39	0.26	0.42	0.11	1	0.012
o-Xylene	0.321	mg/kg	0.0056	0.0006U	0.0012U	0.037U	0.036U	0.043U	0.0012U	0.0016U	0.0013U	0.0012U	0.0013U	0.0012U	0.21	0.077U	0.15	0.15	1.4	0.012
Tetrachloroethene (PCE)	0.498	mg/kg	0.019	0.0006U	0.0012U	0.037U	0.036U	0.043U	0.047	0.0025	0.0013	0.0012U	0.008	0.011	0.06U	0.077U	0.12U	0.36	4	0.033
Toluene	0.228	mg/kg	0.016	0.0006U	0.0015	0.037U	0.036U	0.043U	0.0072	0.0037	0.0014	0.0012U	0.0081	0.0093	0.09	0.15	0.26	0.1	2.3	0.021
Trichloroethene (TCE)	0.494	mg/kg	0.015	0.0006U	0.0012U	0.95	1.1	0.63	0.0012U	0.0016U	0.0013U	0.0012U	0.0013U	0.0012U	0.06U	0.077U	0.13	0.083U	0.63	0.0032
Vinyl Chloride	0.117	mg/kg	0.069	0.0006U	0.0012U	0.037U	0.036U	0.043U	0.0012U	0.0016U	0.0013U	0.0012U	0.0013U	0.0012U	0.06U	0.077U	0.12U	0.083U	0.28	0.0033
Xylene Isomers, M+P	0.445	mg/kg	0.016	0.0006U	0.0012U	0.037U	0.036U	0.043U	0.0012U	0.002	0.0013U	0.0012U	0.0013U	0.0014	0.37	0.23	0.4	0.26	2.7	0.022
Total Average COCs Detected:	4.397	mg/kg																		

Alternative	Soil Removed (CY)	Convert to kg	Contaminate removed (mg)	Contaminate removed (kg)
Cap	1623	2,208,903	9,712,805.4	9.71
Clean Cor.	8296	11,290,856	49,647,217.2	49.65
Clean Cor. and north	13537	18,423,857	81,011,858.6	81.01
Full removal	26729	36,378,169	159,959,072.8	159.96

1: Assumed 1.5 TN/CY or 1,361 kg/CY