Draft

Groundwater Quality Data Evaluation, St. Johns Landfill

Prepared for

METRO

April 2007

Prepared by

CH2MHILL

Printed on
Recycled and
Recyclable
Paper

Contents

Section **Page**

Appendixes

Tables

Figures

Executive Summary

The St. Johns Landfill, a closed municipal solid waste facility, is located in North Portland near the confluence of the Willamette and Columbia Rivers. A number of investigations have been performed to evaluate the hydrogeology, groundwater and surface water quality, beneficial use, and potential migration of leachate associated with the facility. This report has been prepared to evaluate the nature and extent of contamination from the landfill as part of the Remedial Investigation (RI) Work Plan for the St. Johns Landfill, developed under the RI/Feasibility Study (RI/FS) Scope of Work of the Consent Order issued to Metro by the Oregon Department of Environmental Quality (DEQ) on October 31, 2003. The RI Work Plan identified the following goals:

- Identify the hazardous substances that have been released to the environment.
- Determine the nature and extent of the contamination in affected groundwater media both on and off the site and identify "hot spots" of contamination as defined in Oregon Administrative Rule (OAR) 340-122-0115(32).
- Determine if the low flow sampling technique for the low-yielding wells is representative and valid for use in the risk assessment.
- Identify the preliminary Locality of Facility (LOF) for the landfill.
- Improve the understanding of the conceptual model for the landfill.
- Determine the need for additional monitoring wells to characterize the nature and extent of contamination of groundwater beneath and surrounding the landfill.

This report reviews the historical St. Johns Landfill groundwater quality data, defines the preliminary LOF, and addresses the other RI/FS goals outlined above.

1.0 Hydrogeologic Setting

Three unconsolidated geologic units have been identified beneath the St. Johns Landfill. From shallowest to deepest are the Overbank Silt (OBS), the Columbia River Sand (CRS), and the Pleistocene Gravel (PG) units. Monitoring wells at the St. Johns landfill are screened in one of these three geologic layers or in refuse. The OBS wells have been subdivided into Upper, Middle (Mid), and Lower units based on the location of the screen interval relative to ground surface and the underlying CRS and PG units.

The Upper OBS is the uppermost hydrogeologic unit and receives recharge from downward percolation of rain fall and landfill leachate. Groundwater is encountered at relatively shallow depths in the OBS, with gradients interpreted to show flow radially from the landfill. Higher liquid levels within a landfill, or a "leachate mound," is an expected condition at a landfill located in a wet region and underlain by low-permeability material. The elevation of the leachate mound at the St. Johns Landfill is highest near waste subarea 5

(CH2M HILL, 2006f). Groundwater in the Lower OBS flows to the northwest during wet conditions and predominately to the northeast during dry season conditions.

The CRS and PG are considered to be one hydrogeologic unit in this report based on similarities in hydraulic conductivity, groundwater elevations, and response to surface water changes. Groundwater flows under confined conditions in the deeper CRS and PG units. In general, groundwater flows from the south to north at the St. Johns Landfill with some minor seasonal fluctuation in the flow direction in the CRS/PG. The CRS and PG aquifers do not appear to be strongly influenced by the leachate mound and seem to correlate well with changes in river stages on the Columbia and Willamette Rivers.

During the wet season, the vertical groundwater gradient is predominantly downward from the Upper OBS to the Lower OBS and downward from the Lower OBS to the CRS/PG unit. This would be the expected flow regime during a period of high precipitation (i.e., recharge through infiltration) in the shallow sediments. During the dry season, an upward vertical gradient exists from the CRS/PG to the Lower OBS in the northern portion of the site while a downward vertical gradient occurs along the southern portion of the site (CH2M HILL, 2006f).

2.0 Nature and Extent of Landfill-Related Constituents in Groundwater

The nature and extent of landfill-related constituents in groundwater was evaluated by characterizing background water quality conditions, identifying potential sources of contamination, investigating the horizontal and vertical extent of landfill-related constituents, and evaluating changes in the extent of landfill-related constituents. Highlights from the nature and extent evaluation are as follows:

- Potential sources in the area include the St. Johns Landfill, offsite industrial properties, and drywells in the area used by the City of Portland for stormwater management. The offsite industrial properties are located upgradient of the landfill and volatile organic compounds (VOCs) have been detected in groundwater beneath those facilities.
- An initial screening of leachate and groundwater data collected between 2004 and 2005 was conducted to obtain a preliminary understanding of potential impacts from the landfill to groundwater. Constituents were screened against Oregon DEQ Level II Ecological Screening Values and U.S. Environmental Protection Agency (EPA) Region 6 Preliminary Remediation Goals. Screening level exceedances include general chemistry constituents nitrate and nitrite, 14 of 21 metals, semivolatile organic compound (SVOC) constituent bis-(2-ethylhexyl) phthalate, and VOC constituents 1,4-dichlorobenzene, m,p-xylene, tetrachloroethene, and trichloroethene. Exceedances of screening level values do not necessarily indicate landfill impacts to groundwater, nor the presence of risk to potential human or ecological receptors. Elevated levels of some constituents exist in background wells, suggesting impacts from upgradient offsite sources or naturally occurring constituents in groundwater.
- The occurrence of organic compounds in landfill leachate and groundwater monitoring wells was reviewed to evaluate the nature and extent of VOC constituents. Two different

categories of VOCs are detected in the St. Johns Landfill monitoring wells: aromatic compounds and aliphatic compounds. Between 2001 and 2005, aromatic compounds (benzenes, xylenes, and toluenes) were the most commonly detected constituents in landfill leachate, while cis-1,2-dichloroethene was the only aliphatic compound detected in landfill leachate. Between 2004 and 2006, aromatic indicator constituents were detected in 7 of the 12 Upper OBS monitoring wells, in no Mid OBS monitoring wells, in one of six Lower OBS monitoring wells (D-1C), and in no CRS/PG monitoring wells. No aliphatic compounds were detected in the Upper, Middle, or Lower OBS monitoring wells. Between 2004 and 2006, aliphatic compounds detected in the CRS/PG monitoring wells included tetrachloroethene, trichloroethene, 1,1-dichloroethene, cis-1,2 dichloroethene, trans-1,2 dichloroethene, 1,1,-trichloroethane, and 1,1-dichloroethane. All of the wells with aliphatic compound detections are located on the upgradient, eastern side of the landfill, indicating that, while landfill-related organic compounds appear to be influencing shallower groundwater conditions beneath the landfill, one or more offsite sources are contributing VOC contamination to the CRS/PG.

- For determination of leachate influence on groundwater, commonly used indicators of landfill leachate were employed, including total dissolved solids (TDS), chloride, ammonia, alkalinity, and chemical oxygen demand (COD). These indicators commonly occur in leachate from municipal landfills. Based on the available leachate and groundwater data for these constituents, the following observations were made:
  - Landfill leachate has influenced all Upper OBS monitoring wells located within the landfill footprint.
  - Landfill leachate has influenced two Mid OBS wells (D-1B and D-3B).
  - Landfill leachate has influenced two Lower OBS wells (D-1C and G-1).
  - Landfill leachate has influenced two CRS/PG wells (G-7 and K-6).

3.0 Locality of Facility Determination

The preliminary LOF for the Upper and Mid OBS is limited to the adjoining surface water features and shallow groundwater surrounding the landfill. Groundwater quality data suggest that the Upper and Mid OBS are hydraulically connected to the nearby surface water features and therefore have the potential to impact ambient surface water quality of the Columbia Slough.

The second LOF includes the Lower OBS and CRS/PG sediments below and downgradient of the landfill. Current understanding of the groundwater flow system indicates that the LOF would consist of the area north and west of the site in the CRS/PG. Lower OBS and CRS/PG wells along the eastern and southern border of the landfill have not shown impacts from leachate. Lower OBS wells and PG wells along the southern (D4-B), northern (G-7), and western perimeter (D1-C and G-6) have shown aromatic compound detections in the past, but have not indicated the presence of aromatics since 1997. Currently, not enough information is available regarding potential offsite migration of leachate in this portion of the facility to propose a final LOF in the Lower OBS, CRS and PG. Conservative identification of the potential receptors would include human receptors from water wells used for domestic drinking water (though such theoretical wells were not identified during the beneficial use survey) and ecological receptors where groundwater discharges to the Willamette and Columbia Rivers.

4.0 Beneficial Use Determination

Preliminary beneficial uses for groundwater in the shallow OBS aquifer are limited to recharge to surface water (Columbia Slough, Smith and Bybee Wetlands, and Willamette and Columbia Rivers) and recharge to deeper groundwater (i.e., the CRS/PG aquifer). Preliminary beneficial uses for groundwater in the CRS/PG aquifer are limited to recharge to surface water (Columbia Slough, Smith and Bybee Wetlands, and Willamette and Columbia Rivers), irrigation, and industrial use.

5.0 Recommendations

Based on evaluations of groundwater quality and flow, a survey of groundwater beneficial use, a preliminary determination of the LOF, and potential sources of contamination, five additional monitoring wells are recommended to further assess the nature and extent of groundwater contamination associated with the St. Johns Landfill. Data collected from these wells will improve the characterization of groundwater gradients and help determine whether offsite sources are affecting groundwater quality near the landfill. Following is a description of the proposed wells:

- An OBS and CRS/PG well pair similar in construction to the G-4 and G-5 well clusters, located offsite across the North Slough to the northeast of the D-1 well cluster. Based on historical and recent groundwater gradients in the CRS/PG, and observed water quality data at G-7, the potential exists in this area for offsite migration of leachate constituents.
- A Lower OBS well located offsite near PG well G-6. This location is generally cross-gradient or downgradient to groundwater flow in the Lower OBS, and there are no existing OBS wells in the southwest portion of the landfill.
- A Lower OBS and CRS/PG well pair located onsite in the southwest corner of the landfill, near the D-3 well cluster (Upper and Mid OBS).

Groundwater Quality Data Evaluation, St. Johns Landfill

PREPARED FOR: Paul Vandenberg/Metro

PREPARED BY: Rob Healy (R.G.)/CH2M HILL
Chris Augustine/CH2M HILL

REVIEWED BY: Paul Burnet/CH2M HILL
Ken Shump/CH2M HILL

DATE: April 5, 2007

PROJECT NUMBER: 332096.01.03

1.0 Introduction

The St. Johns Landfill is a closed, 236-acre municipal solid waste landfill located in North Portland approximately 2 miles from the confluence of the Willamette and Columbia Rivers (Figure 1). The landfill operated from the 1930s until its closure in 1991. The older section of the facility was unlined and reportedly received municipal, commercial, and industrial waste as well as municipal solid waste incinerator ash. Landfill practices evolved over time to include waste compaction and daily cover, and newer cells at the landfill were constructed with engineered liners. A groundwater monitoring network was installed in the 1970s to monitor the quality of groundwater near the landfill. A landfill gas collection system was installed in 1996 with collected gas either flared onsite or piped to Ash Grove cement where it is used as fuel in a lime kiln. Based on the results of monitoring and the observed presence of seeps along the landfill perimeter, the Oregon Department of Environmental Quality (DEQ) placed the St. Johns Landfill on its Confirmed Release and Inventory List in 1995.

A number of investigations have been performed to evaluate the hydrogeology, groundwater and surface water quality, beneficial use, and potential migration of leachate associated with the St. Johns Landfill. The investigations most pertinent to this groundwater quality evaluation are as follows:

- *Smith and Bybee Lakes Environmental Studies Summary Report*, Fishman Environmental Services, 1987
- *St. Johns Landfill Water Quality Impact Investigation and Environmental Management Options*, Sweet Edwards/EMCON, 1989
- *St. Johns Landfill Groundwater Modeling System: Predicting Leachate Mounding, Fluxes, and Offsite Migration*, PSU, 1995

- *Assessment of the PSU Groundwater Flow Model of St. Johns Landfill, Portland, Oregon*, EMCON, 1997
- Annual Environmental Monitoring Reports, CH2M HILL 2005, 2004; Parametrix 2002, 2003
- *Preliminary Beneficial Land and Water Use Survey, St. Johns Landfill Remedial Investigation/ Feasibility Study (RI/FS)*, CH2M HILL, 2006
- *St. Johns Landfill Groundwater Elevation Data Set Evaluation*, Draft, CH2M HILL, November 3, 2006

The Remedial Investigation (RI) Work Plan for the St. Johns Landfill was developed under the RI/Feasibility Study (RI/FS) Scope of Work of the Consent Order issued to Metro by DEQ on October 31, 2003. The RI Work Plan identified the following goals:

- Identify the hazardous substances that have been released to the environment.
- Determine the nature and extent of the contamination in affected groundwater media both on and off the site and identify "hot spots" of contamination as defined in Oregon Administrative Rule (OAR) 340-122-0115(32).
- Determine if the low flow sampling technique for the low-yielding wells is representative and valid for use in the risk assessment.
- Identify the preliminary Locality of Facility (LOF) for the landfill.
- Improve the understanding of the conceptual model for the landfill.
- Determine the need for additional monitoring wells to characterize the nature and extent of contamination of groundwater beneath and surrounding the landfill.

This memorandum reviews the historical St. Johns Landfill groundwater quality data, defines the preliminary LOF, and addresses the RI/FS goals outlined above. The evaluation is organized into the following sections:

- Site Hydrogeology
- Summary of Water Quality Monitoring Program
- Groundwater Data Quality Assurance Evaluation
- Nature and Extent of Landfill-Related Constituents in Groundwater
- Locality of Facility Determination
- Summary of Beneficial Land and Water Use
- Conclusions and Recommendations
- References

2.0 Site Hydrogeology

Three unconsolidated geologic units have been identified beneath the St. Johns Landfill. From shallowest to deepest are the Overbank Silt (OBS), the Columbia River Sand (CRS), and the Pleistocene Gravel (PG) units. Monitoring wells at the St. Johns landfill are screened in one of these three geologic layers or in refuse. Three more geologic units are present beneath the PG comprising the deeper regional geologic units in the Portland Basin. From top to bottom, they are the Troutdale Formation, undifferentiated sediments, and the Columbia River Basalt Group. The following subsections describe the three shallowest hydrogeologic units that are included in the site groundwater quality monitoring program. Figure 2 shows the location of active well locations at the St. Johns Landfill. The variation in the thickness of the OBS, CRS, and PG along the northeast and southwest boundaries of the landfill is shown in Figure 3.

2.1 Overbank Silt

The OBS was deposited by intermittent flooding of the Columbia River. Each flood event left a layer of sediment, causing stratification in the floodplain deposits. This unit consists mostly of low permeability, fine-grained silty clay, clayey silt, sandy silt and silty sand. The lower portion of the OBS has been observed to have more fine sand than the Upper and Mid OBS.

Thickness of the OBS at the site varies. It is thickest to the west of the St. Johns Landfill, and is thinnest in the Smith and Bybee Wetlands area to the northeast. Beneath the landfill, thickness varies from 20 to 40 feet on the north and northeast side, 50 to 100 feet on its southern and eastern sides, and 80 to 150 feet directly below the St. Johns Landfill interior and western boundary (Fishman Environmental Services, 1987).

Groundwater appears to flow under unconfined conditions in the Upper and Mid OBS sediments and under unconfined to semiconfined conditions in the Lower OBS sediments (based on an observed upward hydraulic component). Horizontal hydraulic conductivity estimated from slug tests of wells completed in the OBS is approximately 1×10^{-5} centimeter per second (cm/sec). Vertical hydraulic conductivity is estimated to be approximately 2×10^{-7} cm/sec to 5×10^{-7} cm/sec (CH2M HILL, 2006f).

2.2 Columbia River Sand

The CRS consists of fine to medium sand deposited by the ancestral Columbia River and incised into the PG. The thickness of the CRS ranges from 0 to 40 feet and is relatively thin or not present near the eastern portion of the St. Johns Landfill. Although locally it is a laterally discontinuous unit, regionally the CRS follows a general west-northwest trend paralleling the present day Columbia River (Hartford and McFarland, 1989). Boring logs show that the CRS may be composed of two layers: upper silty sand to fine sand unit locally overlying a clean medium to coarse sand. The upper unit occurs beneath the southern and northwest sides of the St. Johns Landfill, where it ranges in thickness from less than 1 foot to up to 35 feet. The lower unit is generally absent below the silty sand along the southern and northwest sides of the St. Johns Landfill. Groundwater in the CRS and PG flows under unconfined conditions near the Willamette River and transitions to confined conditions beneath the St. Johns Landfill (Li et al., 1995; EMCON, 1997). CRS hydraulic conductivity ranges from 1×10^{-5} cm/sec to 0.03 cm/sec (EMCON, 1997, Sweet Edwards/EMCON, 1989; and Li et al., 1995).

2.3 Pleistocene Gravel

The PG unit is composed chiefly of unconsolidated sand and gravel and directly underlies the OBS where the CRS is absent. No site wells fully penetrate the PG; however, the estimated thickness ranges from 60 to 100 feet. The PG layer was formed from as many as 40 Pleistocene catastrophic flood events of the Columbia River. Near the present channel of the Columbia River is a coarser-grained unit of the PG, which consists of a basaltic sand and gravel unit with varied amounts of cobbles and boulders that range up to 12 feet in diameter. At the site, the PG unit has been characterized as being deposited in an apparent steep-sided deep trough or channel that directly underlies the landfill. A ridge in the PG is present approximately 500 to 1,000 feet to the north of the landfill and extends up to within a few feet of the bottom of Bybee Wetland (Fishman Environmental Services, 1987; Li et al., 1995). Horizontal hydraulic conductivity of the PG unit ranges from 5 x 10^{-2} cm/sec to 1 x 10^{-1} cm/sec (EMCON, 1997, Sweet Edwards/EMCON, 1989; and Li et al., 1995).

2.4 Groundwater Hydraulics

The hydraulic gradient within each hydrogeologic unit beneath the landfill is controlled by a combination of factors that include hydraulic conductivity, sediment thickness, influence of surface water bodies, changing river stage and tidal fluctuations, leachate elevations, landfill gas pressure, and seasonal fluctuation from infiltration of precipitation.

CH2M HILL (2006f) reviewed groundwater elevation data from 2004 and 2005 to determine horizontal and vertical hydraulic gradients in the Upper OBS, Lower OBS, and CRS/PG hydrogeologic units. During that review, the Upper OBS hydraulic gradient was inferred to be influenced strongly by leachate mounding and received only minor influence from nearby surface water features. The CRS and PG aquifers did not appear to be strongly influenced by the leachate mound and appeared to correlate well with changes in river stages on the Columbia and Willamette Rivers. As a result of the similarity in hydraulic conductivity, groundwater elevations, and response to surface water changes, the CRS and PG are considered to be one hydrogeologic unit in this report.

The Upper OBS is the uppermost hydrogeologic unit and receives recharge from downward percolation of rain fall and landfill leachate. A leachate mound is an expected condition at a landfill located in a wet region and underlain by low-permeability material. Previous reports documented the occurrence of leachate mounding across the facility prior to the abandonment of monitoring well locations within the St. Johns Landfill footprint (Fishman Environmental Services, 1987; Sweet Edwards/EMCON, 1989; Li and Lowry, 1995; EMCON, 1997). However, leachate levels and landfill gas production have been steadily decreasing over time. The shallow OBS sediments gain water from the Columbia Slough during periods of high slough stage (generally the rainy season) and lose water to the Columbia Slough and North Slough during periods of low slough stage (CH2M HILL, 2006c; 2006f). Leachate mounding also may influence the groundwater levels in the shallow OBS sediments.

Groundwater in the Upper OBS is interpreted to flow radially from the leachate mound, which is highest near subarea 5 (CH2M HILL, 2006f). The minimum gradient across the site (K-6a to D1-A) varied seasonally from 7.92 feet per mile (ft/mile) (0.0015 feet per foot [ft/ft]) during the wet season to 3.2 ft/mile (0.0006 ft/ft) during the dry and the gradient may be higher locally based on the inferred influence of the leachate mound. Groundwater velocity calculations indicate that groundwater in the OBS flows horizontally at a rate of about 0.009 ft/year. The seasonal fluctuation in groundwater elevation in the Upper OBS is approximately 3 to 4 feet across the landfill. Groundwater in the Upper OBS flows under unconfined conditions (CH2M HILL, 2006f). Because of the difference in propagation of head changes in unconfined aquifers, groundwater levels in the OBS do not respond as efficiently to tidal fluctuations in the Columbia Slough and are likely more strongly influenced by the leachate mound.

Groundwater in the Lower OBS flows to the northwest during wet conditions and is relatively consistent (CH2M HILL, 2006f). During dry season conditions the groundwater flow is predominately to the northeast in the Lower OBS. During the winter months, the average horizontal gradient for the Lower OBS is 4.2 ft/mile (0.0008 ft/ft) compared with approximately 2.6 ft/mile (0.0005 ft/ft) during the dry season. The Lower OBS have seasonal fluctuations of approximately 1 to 2 feet in groundwater elevations. The slightly higher permeability of the Lower OBS relative to the Upper OBS suggests that the leachate mound has a weaker influence on groundwater flow direction in the Lower OBS.

The geometry of the PG deposits and hydraulic communication of groundwater with the Smith and Bybee Wetlands and Willamette and Columbia Rivers influences both regional and local patterns of groundwater flow in the PG. In general, the groundwater flows from the south to north at the St. Johns Landfill with some minor seasonal fluctuation in the flow direction in the CRS/PG (Sweet Edwards/EMCON, 1989; CH2M HILL, 2006f). During the wet season the groundwater flow direction is more to the northeast and during the dry season it flows more to the north. The horizontal hydraulic gradient in the CRS/PG wells is approximately 0.00012 ft/ft during the wet season and 0.000042 ft/ft during the dry season. Because of its substantially higher estimated hydraulic conductivity, groundwater in the CRS/PG aquifers flows approximately three orders of magnitude faster than in the OBS with horizontal velocities ranging from 5.2 ft/year to 14.9 ft/year (CH2M HILL, 2006f). Groundwater in the lower portions of the CRS /PG most likely discharges to the Willamette and Columbia Rivers where the river channels incise the CRS and PG units. Regionally, groundwater flows under confined conditions in the CRS/PG aquifer (Li and Lowry, 1995).

During the wet season, the vertical groundwater gradient is predominantly downward from the Upper OBS to the Lower OBS and downward from the Lower OBS to the CRS/PG unit. This would be the expected flow regime during a period of high precipitation (i.e., recharge through infiltration) in the shallow sediments. During the dry season an upward vertical gradient from the CRS/PG to the Lower OBS exists in the northern portion of the site while a downward vertical gradient occurs along the southern portion of the site (CH2M HILL, 2006f).

2.5 Surface Water Effects on Groundwater Levels

Surface water features bound the landfill on all sides and are hydraulically connected to the OBS, CRS, and PG (Sweet Edwards/EMCON, 1989; Li et al., 1995; CH2M HILL, 2006f). The OBS floodplain sediments are hydraulically connected to the Smith and Bybee Wetlands, the Blind Slough, and the Columbia Slough.

The CRS and PG units are hydraulically connected to the Willamette and Columbia Rivers. This connection is demonstrated by a close correlation between changes in river stage and groundwater response to the change in river stage (CH2M HILL, 2006f). Groundwater levels in CRS and PG monitoring wells have been observed to respond rapidly to fluctuations in surface water levels as a result of river and tidal influences in monitoring wells at the facility

(Sweet Edwards/EMCON, 1989). This rapid response is likely due to the confined nature of the aquifer, which efficiently transmits hydraulic pressure changes more rapidly than unconfined aquifers.

In 2003, a water level management program was initiated in Smith and Bybee wetlands using a water control structure to improve water quality in the wetlands and better mimic natural seasonal conditions of the wetlands. The control of the wetlands surface water elevation (at higher levels during early summer) would be expected to affect the groundwater levels in the OBS more than the CRS or PG.

3.0 Summary of Water Quality Monitoring Program

In the late 1980s, Metro assessed the effects of the St. Johns Landfill on surface and groundwater quality to develop options for long-term environmental management of the site (Sweet Edwards/EMCON, 1989). The assessment documented the geologic and hydrogeologic setting of the St. Johns Landfill area and indicated that leachate had limited effects on surface and groundwater quality. Additional groundwater and leachate monitoring wells were installed, consistent with recommendations of the 1989 assessment, and Metro implemented an improved comprehensive groundwater water quality monitoring program in 1993.

Groundwater monitoring wells and piezometers have been installed at the site to provide information for evaluating water quality and groundwater flow patterns within the OBS and CRS/PG beneath and near the St. Johns Landfill. Active groundwater quality monitoring points and water level measurement locations at the site are shown in Figure 2. Table 1 identifies existing wells and piezometers at the site. Water quality monitoring of the upper, middle, and lower portions of the OBS is currently performed at 22 monitoring wells, while three monitoring wells are screened in the CRS and five are screened in the PG.

3.1 Leachate Monitoring

Five H-series leachate wells are installed in the interior area of the site, and completed in landfill refuse to monitor landfill leachate. Each H-series well is centrally located in each of the five subareas of the landfill. A sixth well, K-5, is considered a leachate monitoring well for this evaluation because it is screened across buried refuse. The six leachate wells were intended to be monitored on a semiannual basis to measure the long-term effectiveness of the landfill cover, to provide further characterization of leachate composition, and to determine how seasonal changes in the water table affect leachate composition. Problems with casing blockages or sample volume limitations, however, sometimes prevent samples from being taken at some of the leachate wells. Data collected from leachate wells from 1993 to the present are used to characterize leachate in the St. Johns Landfill.

3.2 Groundwater Monitoring

Groundwater quality monitoring at the site is conducted on a semiannual basis (spring and fall sampling events) using a network of 30 monitoring wells. These wells include D-, G-, and K-series wells (with the exception of well K-5 noted above), and well F-1. Table 1 identifies the water quality sampling locations, frequency of sampling, and the sampling schedule as presented in the St. Johns Landfill Environmental Monitoring Plan (EMP)

(Metro, 2001). The wells are monitored for the following five constituent groups (groups 1A, 1B, 2A, 2B, and 3):

- Group 1A—Physical parameters such as pH, turbidity, and conductivity
- Group 1B—Laboratory properties such as alkalinity and chemical oxygen demand
- Group 2A—Anions and cations (metals, silica, phosphorus, nitrogen, and carbonate species)
- Group 2B—Trace metals (metals and metalloids of low relative abundance in nature such as arsenic, barium, and chromium)
- Group 3—Organic compounds such as hydrocarbons, chlorinated hydrocarbons, and aromatic hydrocarbons commonly referred to as volatile organic compounds (VOCs)
- Priority pollutants—Other organic compounds include polychlorinated biphenyls (PCBs), pesticides, herbicides, and semivolatile organic compounds (SVOCs)

The constituents included in each constituent group listed are identified on Table 2.

During fall sampling events, samples collected from leachate wells and nine selected groundwater monitoring wells are tested for the St. Johns Landfill priority pollutant parameters. This parameter group includes SVOCs, pesticides, herbicides, and PCBs. Table 2 lists the specific compounds and analytical methods. The criteria used to select wells for annual priority pollutant analysis include previous detection(s) of VOCs or priority pollutants.

3.3 Surface Water Monitoring

Surface water monitoring is not required under the landfill permit, although Metro has historically collected surface water data consisting of pH, oxidation reduction potential (ORP), dissolved oxygen (DO), specific conductance, and turbidity. At several locations, testing for metals and VOCs has also been conducted. Water quality samples from seeps discharging to the North and Columbia Slough were collected in 2005 during the spring and fall (CH2M HILL, 2006d).

4.0 Groundwater Data Quality Assurance Evaluation

The data quality assurance evaluation of existing groundwater quality data collected at the St. Johns Landfill is presented in Appendix A. The evaluation consisted of a review of the *Well Assessment Report St. Johns Landfill, Portland, Oregon* (Groundwater Solutions, Inc., 2003), a review of video logs of low-yielding monitoring wells, a description of current low flow sampling methods, and an evaluation of the proportion of purge water to casing volume generated during groundwater sampling. Evaluation results indicated that existing groundwater sampling data collected using the low flow sampling method are representative of aquifer conditions.

The results from the Groundwater Solutions report indicated only small short-term improvements in well yield resulting from well rehabilitation work. Evaluation of the proportion of purge water to well casing water during sampling indicates the majority of water generated during sampling activities comes from the water-bearing formation. Water associated with a reduction in well casing storage ranges between 0.6 and 9 percent.

On the basis of these evaluations, existing low flow sampling methods are considered appropriate and no changes are currently recommended. However, additional review of construction information on monitoring well F-1 should be conducted. The current construction diagram suggests that the well is not constructed properly, and could potentially be a conduit for transmitting surface constituents to the subsurface.

5.0 Nature and Extent of Landfill-Related Constituents in Groundwater

Determining the nature and extent of landfill-related constituents in the groundwater involves characterizing background groundwater quality, identifying potential sources of contamination, investigating the horizontal and vertical extent of landfill-related constituents, and evaluating whether constituents related to the landfill are expanding, stable or contracting in extent. This review uses available groundwater data to evaluate extent of landfill constituents in groundwater in the OBS, and evaluates the potential for landfill constituents to migrate from OBS to the CRS and PG.

The section is organized as follows:

- Potential Sources
- Constituent Screening
- Summary of Organic Compounds
- Evaluation of Leachate Constituent Impacts on Groundwater Quality
- Summary of Nature and Extent of Contamination in Groundwater

5.1 Potential Sources

Since 1996, Metro has installed several source controls to protect against degradation of the air, soil, and surface water in the vicinity of the site. These include the following:

- A final cover system consisting of a 6- to 12-inch-thick compacted silt layer overlying the refuse top and sloped sides, a 40-mil thick polyethylene geomembrane cap, 12 to 18 inches of sand on the top of the polyethylene cap, and 12 inches of topsoil and compost was placed over the entire landfill cover and the site was revegetated in the early 1990s.

- Subareas 4 and 5 (the youngest waste management areas of the landfill) have a leachate removal system that discharges to the City of Portland sanitary sewer system. Discharges volumes have been decreasing annually since implementation in 1997.

- An active landfill gas extraction system was installed to limit gas build-up under the final cover system. Landfill gas is captured and removed by a gas extraction system and flared or used as fuel at Ash Grove Cement.

- Surface runoff is controlled by a soil perimeter dike surrounding the 55-acre expansion area, silt levees, and a site-wide stormwater control system.

- Containment dikes of compressed bentonite clay along the perimeter of the landfill.
- A low permeability engineered dike installed along the eastern portion of the landfill to limit offsite flow to Smith wetlands.

In spite of these mitigation actions, the St. Johns Landfill waste cells remain a potential source of groundwater contamination. Offsite sources also have the potential to impact groundwater quality in the regional aquifer. Detailed information concerning potential sources is provided below.

5.1.1 St. Johns Landfill Sources

Landfill leachate is formed by decomposition of solid and liquid refuse in the waste cells and interaction with infiltration of precipitation and shallow groundwater interaction near the unlined bottoms of the landfill. Decomposition of liquid and solid inorganic and organic waste results in the release of energy in the form of heat, gases, and chemicals contained in the waste. The decomposition process consumes any available oxygen in the system, resulting in anaerobic (or reducing conditions) in the leachate.

In general, in unlined landfills the leachate percolates downward and laterally away from the refuse source transporting inorganic and organic constituents which results in a plume of landfill affected groundwater. Inorganic constituent mobility in groundwater is governed by chemical speciation, dissolution/precipitation, oxidation/reduction, adsorption/ion exchange reactions, and colloidal transport. The mobility of organic constituents in groundwater is governed by solubility, volatility, degradation, sorption processes, and ionization. These geochemical reactions and processes result in changes in the geochemistry of the landfill affected groundwater as it migrates laterally and vertically in the subsurface. Concentrations of most inorganic geochemical species tend to decrease with increased travel time and distance from the landfill because of geochemical reactions. Organic compounds may decrease, increase or degrade to another organic compound not present in leachate as they migrate through the subsurface.

At the St. Johns Landfill, the most likely potential pathway for the migration of the leachate constituents into groundwater is downward vertical percolation of leachate through either the unlined bottom or lateral migration away from the landfill. Leachate elevations appear to be decreasing across the landfill, with the highest elevations of leachate mounding occurring at Subarea 4 and Subarea 5 (see Figure 2 and CH2M HILL 2006f). Leachate elevations are consistently higher than the groundwater elevations in the OBS, and surface water elevations in the Slough and Smith and Bybee Wetlands suggest a hydraulic head and a potential for leachate migration to the Slough and Wetlands via the OBS.

5.1.2 Potential Offsite Sources

Offsite sources exist that may also influence groundwater quality in wells, especially wells located near the upgradient portion (southeastern portion) of the landfill intended to provide background water quality data for groundwater flowing beneath the landfill footprint. Upgradient of the facility the land use historically has included light and heavy industry and manufacturing. DEQ has noted the presence of low concentrations of certain VOCs in deep groundwater (PG and deeper) regionally in North Portland. However, the source for these VOCs is not known (pers. comm., DEQ 2006; Radivojsa-Kininmonth, 2004).

A survey of potentially contaminated sites in the vicinity of St. Johns landfill identified several other sites with VOCs present in the CRS/PG (Radivojsa-Kininmonth, 2004). Most of the locations are upgradient of the St. Johns Landfill including Union Carbide, Bonneville Power Administration (BPA) substation, Larsen South, and Chemcentral (Figure 1). The presence of aliphatic hydrocarbons in the CRS/PG wells along the eastern and southern portion of the St. Johns Landfill is likely attributable to dissolved phase migration from upgradient sources identified in a recent unpublished DEQ study (Radivojsa-Kininmonth, 2004). Two of the upgradient locations with the highest observed concentrations of aliphatic chlorinated hydrocarbons are discussed in the paragraphs that follow.

Chemcentral, a distributor of both aromatic and chlorinated hydrocarbons, has had several high aliphatic hydrocarbon detections in multiple wells in the CRS/PG. Chlorinated hydrocarbons detected from 2002 to 2004 in the PG wells at the Chemcentral facility include the following: 1,1 DCA (310 parts per billion [ppb]), 1,1 DCE (260 ppb), 1,2 DCE (7900 ppb), PCE (720 ppb), 1,1,1 TCA (100 ppb), TCE (1300 ppb), 1,1,2 TCA (1.91 ppb), and vinyl chloride (1300 ppb).

The Larsen South site is located approximately 7,500 feet southeast of the landfill. Wells completed in the OBS silt at that location have detected TCE, 1,2 DCE, PCE, 1,1 DCA, and VC. TCE (10,200 ppb), trans 1,2 DCE (35,500 ppb) and cis- 1,2, DCE (28,900 ppb) were detected at concentrations greater than 1 percent of their solubility in water, indicating that free hydrocarbon product may be present in the subsurface near the Larsen South location.

Additionally, stormwater in the North Portland area is managed using drywells, most of which are installed in the area south-southeast of the landfill (RNSA, 1998). The drywells act as conduits for untreated stormwater to recharge directly into shallow groundwater and can contain nitrate, dissolved and total metals (such as zinc, copper and lead), SVOCs, and VOCs. While most of these contaminants are associated with particulate matter and are removed by settlement of the stormwater during infiltration, nitrogen and dissolved metals can be mobile in groundwater (Pitt, 1996).

5.2 Constituent Screening

An initial screening of leachate and groundwater constituents was conducted to obtain a preliminary understanding of potential landfill impacts to groundwater. Table 3 presents the maximum concentration for leachate constituents from 2004 through 2005. Detected leachate constituents include various general chemistry parameters, metals, PCBs, SVOCs, and VOCs.

Maximum detected results in groundwater from 2004 through 2005, compared with preliminary regulatory screening values for groundwater, are shown in Table 4. The screening values were selected based on the preliminary beneficial use determination for each hydrogeologic unit, presented in previous investigations (Hart Crowser, 1999 and CH2M HILL, 2006e) and summarized in Section 6 of this report. The following preliminary screening criteria were used to provide a relative interpretation of groundwater quality in the different hydrogeologic units based on their preliminary beneficial use:

- PG and CRS—U.S. Environmental Protection Agency (EPA) Primary and Secondary Drinking Water Standards (2006), and EPA Region 6 Primary Remediation Goals (PRGs), 2004

- OBS, PG, and CRS—Oregon DEQ Guidance for Ecological Risk Assessment Level II Screening Level Values

Screening values are by definition conservative, often by significant margins, and should not be perceived as indicators of actual or site-specific risk. Final screening values will reflect the results of the final beneficial water use determination and site-specific risk-based values will be determined during the risk assessment once potential exposure pathways and receptors have been assessed. Screening values are used here for initial evaluations and identification of landfill-affected groundwater.

As shown in Table 4, several of the organic and inorganic constituents monitored in groundwater as part of the St. Johns Landfill EMP have maximum concentrations that exceed the Oregon DEQ Level II Ecological Screening Values for surface water for aquatic life, or EPA's Region 6 PRGs. Screening level exceedances include general chemistry constituents nitrate and nitrite; 14 out of 21 metals; SVOC constituent bis-(2-ethylhexyl) phthalate; and VOC constituents 1,4-dichlorobenzene, m,p-xylene, tetrachloroethene, and trichlorethylene.

Exceedances of screening level values do not necessarily indicate landfill impacts to groundwater. Elevated levels of some constituents exist in background wells and suggest potential upgradient and offsite sources, and naturally occurring constituents in groundwater. The subsections that follow provide a detailed evaluation of selected groundwater constituent concentration data and indications of landfill impacts to groundwater. Section 5.3 focuses on the potential impacts of organic compounds, and Section 5.4 looks at selected leachate constituents to evaluate landfill impacts to groundwater quality.

5.3 Summary of Organic Compounds

Data for VOCs in leachate and groundwater geologic units from 1993 through 2005 are provided in Appendix B. Tables 5 and 6 were developed from Appendix B tables to summarize VOC impacts to groundwater. Electronic versions of Appendix B tables include a functional autofilter to allow easier review of the VOC analytical data.

Two different types of VOCs are detected in the St. Johns Landfill monitoring wells: aromatic compounds, which have an aromatic ring (such as benzene), and aliphatic compounds, which have a single or double bond structure. The most commonly detected organic compounds during the 2001 through 2005 sampling period are listed in Table 5. These consist mainly of aromatic compounds; cis-1,2 dichloroethene is the only aliphatic compound detected. Table 5 provides potential indicators of impacts to groundwater, including whether the constituent has been detected in groundwater and the lowest sedimentary horizon at which the constituent has been detected. Table 6 shows the distribution of VOCs among geologic units during the 2004/2005 sampling period. Aromatic compounds were detected mainly in the Upper OBS, whereas aliphatic compounds were detected in the CRS/PG wells.

The subsections below summarize VOC water quality conditions by geologic unit, including the Upper OBS, Mid OBS, Lower OBS, and CRS/PG aquifers. These subsections focus separately on aromatic and aliphatic compounds. For aromatic compounds, 1,4 dichlorobenzene, chlorobenzene, and carbon disulfide are used as indicator constituents. Carbon disulfide was selected as an indicator constituent because it is a common industrial chemical that was historically detected in many monitoring wells at the St. Johns Landfill. Cis-1,2 dichloroethene is the indicator constituent for aliphatic compounds because it is the only aliphatic compound detected in leachate also detected in groundwater.

5.3.1 Upper OBS Water Quality

The Upper OBS is monitored by 12 shallow monitoring wells (D-1A, D-2A, D-3A, D-4A, D-6A, G-4A, G5-A, K-1, K-2, K-3, K-4, and K6-A) as shown in Figure 2. Of the aromatic indicator constituents, chlorobenzene is the most prevalent in the Upper OBS. From 2004 through April 2006 chlorobenzene was detected in 7 of the 12 Upper OBS monitoring wells (D-1A, D-2A, D-3A, D-4A, K-2, K-3, and K6-A). 1,4 dichlorobenzene was detected in three Upper OBS monitoring wells (D-2a, K-2, and K6-A). Carbon disulfide was not detected in any of the Upper OBS monitoring wells, and has not been detected in the Upper OBS since the 1990s, when detections occurred in 9 of the 12 Upper OBS monitoring wells (D-1A, D-2A, D-3A, D-4A, D-6A, G-5A, K-1, K-2, and K-4). Aliphatic compounds were not detected in the Upper OBS wells during 2004 and 2005. Historically (1994 and 1995), cis-1,2 dichloroethene was detected in Upper OBS monitoring well K-4.

5.3.2 Middle OBS Water Quality

The Middle (Mid) OBS is monitored by four wells (D-1B, D-3B, G-2, and F-1). From 2004 through April 2006 no aromatic compounds were detected in Middle OBS monitoring wells. Historically chlorobenzene has been detected at wells D-1B and D-3B, and carbon disulfide has been detected at wells D-1B, D-3B, and G-2.

Aliphatic compounds were not detected in Mid OBS wells in 2004 and 2005. Cis-1,2 dichloroethene has never been detected in any Mid OBS monitoring well.

5.3.3 Lower OBS Water Quality

The Lower OBS is currently monitored by six wells (D-1C, D-4B, D-6B, G-1, G-3R, and G-8A). Well G-3 was abandoned and replaced with G-3R; however, historical data are presented here for additional information. From 2004 through April 2006, chlorobenzene was detected in well D-1C, with no detections for 1,4 dichlorobenzene and carbon disulfide. During the late 1990s, 1,4 dichlorobenzene was detected in well D-1C. In the mid to early 1990s, carbon disulfide was detected in wells D-4B, G-1, G-3, and G-3R.

Aliphatic compounds were not detected in Lower OBS wells in 2004 and 2005. Cis-1,2 dichloroethene has never been detected in any Lower OBS monitoring well.

5.3.4 CRS/PG Water Quality

Eight monitoring wells (D-6C, G-4B, G-5B, G-6, G-7, G-8B, G-8C, and K-6B) are completed in the CRS/PG hydrogeologic unit. During the 2004 through 2005 sampling period, no aromatic compounds have been detected in CRS/PG monitoring wells. Historically chlorobenzene has been detected in well K-6B, and carbon disulfide has been detected in well G-7.

Aliphatic compounds detected during the 2004 through 2005 sampling period include the following chlorinated hydrocarbons:

- Tetrachloroethene at G-5B, D-6C, G-8B, and G-8C

- Trichloroethene at G-5B, D-6C, G-8B, and G-8C
- 1,1-dichloroethene at D-6C and G-8C
- Cis-1,2 dichloroethene at G-4B, G-5B, D-6C, G-8B, and G-8C
- Trans-1,2 dichloroethene at D-6C and G-8C
- 1,1,1-trichloroethane at wells D-6C and G-8C
- 1,1-dichloroethane at G-4B, G-5B, D-6C, G-8B, and G-8C

All of the wells with detections of aliphatic hydrocarbons are located on the eastern side of the landfill. Recent water level contour maps have indicated that predominate groundwater flow direction in the CRS/PG aquifer varies seasonally to the north and northwest of the facility (CH2M HILL, 2006f), indicating that the eastern side of the landfill in the PRG/CRS aquifer is upgradient of potential landfill impacts. This line of evidence, coupled with the absence of detected aliphatic hydrocarbons in the Mid and Lower OBS, indicates that detections of chlorinated hydrocarbons in the CRS/PG are not associated with the landfill and are likely associated with the offsite sources described in Section 5.1.

5.4 Evaluation of Leachate Constituent Impacts on Groundwater Quality

This section provides a detailed evaluation of leachate constituent impacts on groundwater quality in the vicinity of the St. Johns Landfill, including a description of characterization methods, and a summary of leachate impacts to groundwater by geologic unit.

5.4.1 Description of Characterization Methods

For determination of the influence of leachate on groundwater this report focuses on total dissolved solids (TDS), chloride, ammonia, alkalinity, and chemical oxygen demand (COD). These constituents are typical indicators of leachate influence in landfill settings. Sulfate, also a common indicator of leachate affects, was not included in this evaluation because it occurs in leachate at concentrations higher than groundwater in only one leachate well (H-3).

Statistical box plots representing the leachate indicator constituents were used as the primary tool to evaluate leachate impacts on the St. Johns landfill monitoring wells. Box plots (also known as box and whisker plots) are a graphic presentation of the median, upper quartile and lower quartile of data. Box plots can illustrate the following information:

- The difference between leachate water quality and groundwater quality
- Median background values and ranges for chemical constituents for each screening horizon
- Identifying wells influenced by leachate within each screening horizon
- Median values greater than 2 times background (or other wells screened in the same zone) concentrations for leachate indicators to identify groundwater that has been affected by leachate (EPA, 1998)

Leachate indicator constituent box plots are presented in Appendix C. Table 7 presents a summary of median values for the leachate indicator constituents. For interpretation purposes, the background concentrations for each constituent were selected from G-4A and G-5A Upper OBS monitoring wells. These wells are located across the North Slough from the landfill, and have consistently shown lower concentrations than the other Upper OBS wells. The greatest concentration for each constituent at G-4A and G-5A was selected as the background concentration. The median concentrations were then flagged to correspond with 1.5 times background, 2 times background, and 10 times background.

5.4.2 Evaluation of Leachate Constituents on Groundwater Quality by Geologic Unit

An evaluation of leachate constituents on groundwater quality by geologic unit was conducted using the tools described above. For this evaluation, median values of leachate constituents at levels two times background concentrations indicate leachate impacts to groundwater. Wells with leachate concentrations less than 2 times background were considered "not affected."

Upper OBS Water Quality. The Upper OBS is monitored by 12 shallow monitoring wells (D-1A, D-2A, D-3A, D-4A, D-6A, G-4A, G5-A, K-1, K-2, K-3, K-4, and K6-A), with G-4A and G-5A serving as background wells. Observations concerning leachate indicator constituents in the Upper OBS are as follows:

- Excluding the two background monitoring wells, TDS was two or more times background concentrations at six of ten wells, indicating leachate impacts. Three of the four wells not affected showed concentrations at 1.5 times background.
- Chloride was two or more times background concentrations at all ten wells, indicating leachate impacts. Median concentrations for six of the ten wells exceeded 10 times background.
- Ammonia was two or more times background concentrations at seven of ten wells, indicating leachate impacts. Median concentrations for four of the 10 wells exceeded 10 times background. One of the three wells not affected had a concentration at 1.5 times background.
- Alkalinity was two or more times background concentrations at nine of ten wells, indicating leachate impacts.
- COD was two or more times background concentrations at eight of ten wells, indicating leachate impacts. Both of the two wells not affected showed concentrations at 1.5 times background.

Middle OBS Water Quality. The Mid OBS is monitored by 4 wells (G-2, D-3B, F-1, and D-1B). Observations concerning the leachate indicator constituents in the Mid OBS are as follows:

- There are no wells affected by TDS in the Mid OBS.
- Chloride was ten or more times background at well D-3B.
- Ammonia was two or more times background at D-1B.
- There are no wells affected by alkalinity in the Mid OBS, although three of the four wells show median concentrations at 1.5 times background.
- COD was two or more times background at D-3B.

Lower OBS Water Quality. The Lower OBS is monitored by six wells (G-1, G-8A, G-3R (replacement for G-3), D4-B, D-6B, D-1C). Observations concerning leachate indicator constituents in the Lower OBS are as follows:

- There are no wells affected by TDS in the Lower OBS.
- Chloride was two or more times background at well D-1C.
- Ammonia was two or more times background at wells D-1C and G-1.
- Alkalinity was two or more times background at well G-1.
- There are no wells affected by COD in the Lower OBS.

CRS/PG Water Quality. Eight monitoring wells (G-4B, G-5B, G-7, K-6B, D-6C, G-6, G-8B, and G-8C) are completed in the CRS/PG hydrogeologic unit.

- TDS was two or more times background at well K-6B. The median concentration at G-7 was greater than 1.5 times background.
- Chloride was ten or more times background at well G-7 and two or more times background at K-6B.
- Ammonia was two or more times background at wells G-7 and K-6B.
- Alkalinity was two or more times background at well G-7. At well K-6B the median concentration was greater than 1.5 times background.
- COD was two or more times background at well G-7.

5.5 Summary of Nature and Extent of Contamination in Groundwater

As described in Section 2 and in the *Draft Groundwater Elevation Data Set Evaluation Memo* (CH2M HILL, 2006f), interpreted groundwater mounding occurs in the Upper OBS associated with leachate, with lateral flow to the North and Columbia Slough and vertical flow downward to the Lower OBS unit. In the Lower OBS, groundwater flows laterally to the northeast during the dry season and to the northwest during the wet season, and vertically downward to the CRS/PG unit. In the CRS/PG unit, groundwater flows from south to north with some minor seasonal fluctuation.

In the science of hydrogeology and contaminant transport, groundwater hydraulics (directions and gradients) dictate the likely contaminant transport pathway. Assuming no attenuation, it is expected that potential contaminants would move vertically downward through the OBS into the CRS/PG unit then north toward the Columbia. This conceptual model is supported by the St. Johns Landfill monitoring well network water quality results.

5.5.1 Impacts of Landfill Associated VOCs

Based on the detailed evaluation presented in Section 5.3, Upper OBS wells D-1A, D-2A, D-3A, D-4A, K-2, K-3, and K6-A show current impacts from landfill VOC constituents (chlorobenzene and 1,4 dichlorobenzene). No landfill associated VOCs are detected in deeper geologic units.

Historically, carbon disulfide was detected in various monitoring wells including:

- Upper OBS Wells D-1A, D-2A, D-3A, D-4A, D-6A, G-5A, K-1, K-2, K-4, and K5

- Mid OBS—Well D-1B, D-3B and G-2
- Lower OBS—Wells D-4B, G-1, G-3, and G-3R
- CRS/PG—Well G-7

Carbon disulfide has not been detected in any landfill monitoring wells since August 1996. It has never been detected in any leachate wells, since sampling of these wells was initiated in November 2001. The historical versus current carbon disulfide data suggest that leachate impacts to groundwater are attenuating. Although carbon disulfide is no longer present at detectable levels, the historical distribution of the constituent could prove useful in evaluating the likely pathway of potential future VOC contaminant plumes. Given the historical carbon disulfide detections noted above, potential future VOC contaminant migration off site may be monitored via well G-7.

5.5.2 Landfill Leachate Impacts

The evaluation presented in Section 5.4 indicates that St. Johns Landfill monitoring wells with median values of constituents showing impacts are as follows:

- Upper OBS Wells D-1a, D-2A, D-3A, D-4A, D-6A, K-1, K-2, K-3, K-4, and K-6A. This list includes all Upper OBS wells except for background wells G-4A and G-5A.
- Mid OBS—Wells D-1B and D-3B
- Lower OBS—Wells D-1C and G-1
- CRS/PG—Wells G-7 and K-6B

Figures 4 through 7 display locations of leachate affected monitoring wells for the four geologic units. The most downgradient leachate affected well in the Lower OBS is monitoring well D-1C , and in the CRS/PG monitoring well G-7 is the most downgradient well with leachate impacts.

6.0 Locality of Facility Determination

OAR 340-122-080(3) requires a facility characterization to identify current and reasonably likely future beneficial water uses in the locality of the facility (LOF). The LOF is defined in the OAR 340-122-115(34) as any point where a human or an ecological receptor contacts, or is reasonably likely to come into contact with, facility-related hazardous substances.

Relevant considerations for defining the LOF include:

- The chemical and physical characteristics of the hazardous substances
- Physical, meteorological, hydrogeological and ecological characteristics that govern the tendency for hazardous substances to migrate through environmental media or to move and accumulate through food webs AND any biological or human activities that govern the tendency to move into and through environmental media or to move and accumulate through food webs
- The time required for contaminant migration to occur based on the above factors

As a result of the different hydraulic properties, beneficial uses, and potential discharge areas, it is reasonable to identify a separate LOF for each of two hydrogeologic unit groupings based site conditions and potential receptors of contaminant migration.

The preliminary LOF for the Upper and Mid OBS is limited to the adjoining surface water features and shallow groundwater surrounding the landfill. Groundwater quality data suggest that the Upper and Mid OBS are hydraulically connected to the nearby surface water features and has the potential to impact ambient surface water quality of the Columbia Slough.

The second LOF includes the Lower OBS and CRS/PG sediments below and downgradient of the landfill. Based on the current understanding of the groundwater flow system, the LOF would consist of the area north and west of the site, in the main beneficial use aquifer in the area. Lower OBS, CRS and PG wells along the eastern and southern border of the landfill have not shown impacts from leachate. Lower OBS Wells and PG wells along the southern (D4-B), northern (G-7) and western perimeter (D1-C and G-6) have historical VOC detections. Currently, not enough information is available regarding offsite migration of leachate in this portion of the facility to propose a final LOF in the Lower OBS, CRS and PG. Conservative identification of the potential receptors would include human receptors from water wells used for domestic drinking water (though such theoretical wells were not identified during the beneficial use survey) and ecological receptors where groundwater discharges to the Willamette and Columbia Rivers.

7.0 Summary of Beneficial Land and Water Use

This section summarizes the preliminary beneficial use determination for a 1-mile radius surrounding the St. Johns Landfill.

7.1 Land Use

The Metro St. Johns Landfill site is located in an industrial area of North Portland. The site historically was an unnamed wetland and seasonal lake that was part of an extensive inter-connected network of lakes, marshes, wetlands, and sloughs. The site is situated within the boundary of the Smith and Bybee Wetlands Natural Area. As such, current and future land use at the landfill is subject to the Natural Resources Management Plan for Smith and Bybee.

The landfill area is zoned as Heavy Industrial and Parks and Open Spaces by the February 2006 Metro zoning map. Surrounding area zoning includes Light Industrial to the southeast, Parks and Open Spaces to the north, east, and northeast, Heavy Industrial to the north, west, and northwest, and Residential to the east and southeast. As a result of the shortage of industrial land in the Portland area, land use changes are unlikely for areas currently zoned as industrial.

7.2 Beneficial Water Use

Water well records indicate that the majority of the 40 recorded wells in the vicinity of the site were installed before 1980. Well water was used primarily for industrial, irrigation, and possibly drinking water purposes. A Port of Portland property survey in the vicinity (Hart

Crowser, 1999) indicated that the majority of the area properties were supplied by water wells until the City of Portland's public water supply became available in the early 1900s. Original well logs obtained from the OWRD indicate that the wells were used for industrial, domestic, irrigation, and municipal supply (CH2M HILL, 2006). The City of Portland municipal water system currently is the main source of drinking and other water uses in the site area.

7.3 Current and Future Beneficial Water Use

Based on preliminary beneficial water use surveys, current and reasonably likely future beneficial uses of the groundwater have been identified within 1 mile of the landfill site (CH2M HILL, 2006e; Sweet Edwards/EMCON, 1989). This radius assumes that the final LOF will lie within a 1-mile boundary, while allowing a comprehensive review of more distant wells in the area. Preliminary beneficial uses are outlined in sections 7.3.1 and 7.3.2.

7.3.1 Shallow Groundwater

- Recharge to surface water (Columbia Slough, Smith and Bybee Wetlands, and Willamette and Columbia Rivers)
- Recharge to deeper groundwater (i.e., the CRS/PG aquifer)

7.3.2 Deeper Groundwater

- Recharge to surface water
- Irrigation and industrial uses

8.0 Conclusions and Recommendations

The groundwater quality data evaluation presented in this document indicates the following:

- VOCs associated with landfill impacts currently are detected only in Upper OBS monitoring wells.
- The chlorinated hydrocarbons detected in CRS/PG monitoring wells are likely associated with offsite sources to the southwest.
- As demonstrated through landfill leachate indicator constituents (TDS, chloride, ammonia, alkalinity, and COD), landfill leachate has affected all Upper OBS monitoring wells located within the landfill footprint.
- In the Lower OBS, D-1C is the most downgradient monitoring well to exhibit leachate impacts.
- In the CRS/PG, G-7 is the most downgradient monitoring well to exhibit leachate impacts.

Based on documented groundwater flow directions and water quality evaluation results, and likely sources and source controls, five additional monitoring wells are recommended to assess the nature and extent of groundwater contamination associated with the St. Johns Landfill. The proposed wells would be located along the western and northern portion of the landfill in the Lower OBS, CRS, and PG, as shown in Figure 8. Details of the recommended wells are as follows:

- The installation of a cluster of downgradient wells north to northeast of the D-1 cluster in the area across the North Slough is recommended. Based on historical and recent groundwater gradients in the CRS/PG, and observed water quality data at G-7, the potential exists for offsite migration of leachate in this area. An OBS and CRS/PG well pair similar in construction to the G-4 and G-5 well clusters is recommended. An additional well may be required at this location if the OBS is unexpectedly thick and a supplemental well is needed to provide greater resolution in the OBS. Wells G-4 and G-5 will still function as downgradient wells for the CRS/PG.
- An additional Lower OBS well is recommended near the G-6 (PG) location because the well location is generally cross-gradient or downgradient to groundwater flow in the Lower OBS. There are no Lower OBS wells located in the southwest portion of the landfill. Additionally, a well located here would improve the accuracy of water level contour determinations.
- An additional Lower OBS well and CRS/PG well are recommended near the south-western extent of the landfill by the location of the D-3 well cluster (Upper and Mid OBS). The wells would better define the vertical extent of the leachate migration along the western border of the oldest portion of the facility, improve water level contouring, and help determine if any contaminants are potentially migrating toward the site from upgradient offsite sources.

9.0 References

CH2M HILL. 2006a. *St. Johns Landfill Monitoring Wells.* Prepared for Metro, St. Johns Landfill.

CH2M HILL. 2006b. *Transducer System Integrity Assessment.* Prepared for Metro, St. Johns Landfill.

CH2M HILL. 2006c. *Shallow Groundwater Flux Measurement Methods and Results.* Prepared for Metro, St. Johns Landfill.

CH2M HILL. 2006d. *Shallow Groundwater (Pore Water) Sampling Methods and Results, St. Johns Landfill*. Prepared for Metro, St. Johns Landfill.

CH2M HILL. 2006e. *Preliminary Beneficial Land and Water Use Survey St. Johns Landfill Remedial Investigation/Feasibility Study.* Prepared for Metro, St. Johns Landfill.

CH2M HILL. 2006f. *St. Johns Landfill Groundwater Elevation Data Set Evaluation*. Prepared for Metro, St. Johns Landfill.

EMCON. 1997. *Assessment of PSU Groundwater Flow Model of St. Johns Landfill, Portland, Oregon*. Prepared for Metro.

Fishman Environmental Services. 1987. *Smith and Bybee Lakes Environmental Studies Summary Report*.

Groundwater Solutions, Inc. (GSI). 2003. *Well Assessment Report, St. Johns Landfill, Portland, Oregon*. Prepared for Metro. Project Number 159-001. September 2003.

Hart Crowser, Inc. 1999. *Remedial Investigation Report: Port of Portland, Terminal 4, Slip 3. Portland, Oregon*. March 2, 1999.

Hart Crowser, Inc. 2005. *Remedial Investigation Work Plan St. Johns Landfill, Portland, Oregon*. Prepared for Metro.

http://arcweb.sos.state.or.us/rules/OARs_300/OAR_340/340_040.html. Updated January 15, 2004, and accessed February 19, 2004.

Li, S., T. Lowry, and M. Chen. 1995. *St. Johns Landfill Groundwater Modeling System: Predicting Leachate Mounding, Fluxes and Offsite Migration*. Technical Report EWR-9-95. Prepared for Metro by Portland State University Department of Civil Engineering. December 1995.

Li, S., T. Lowry, Q. Huang, and W. Xu. 1997. *St. Johns Landfill Modeling System: Sensitivity Simulations and Response to Emcon Review Comments*.

Mcfarland, William D. and Susan V. Hartford. 1989. *Lithology, Thickness and Extent of Hydrogeologic Units Underlying the East Portland Area*. USGS Water Resources Investigation Report 88-4110.

Metro. 1992. St. Johns Landfill Groundwater Monitoring Well Improvement and Piezometer Installation, Request for Bids #92B-13-SW.

Metro. 1995. *Controlling Seepage from St. Johns Landfill to Surrounding Surface Water*.

Metro. 2001. *Environmental Monitoring Plan for the St. Johns Landfill*.

National Weather Service (NWS). 2004. NWS Portland: Past Weather & Climate at URL http://www.wrh.noaa.gov/Portland/climate/. Updated January 10, 2005, and accessed July 13, 2005.

Oregon Department of Environmental Quality (DEQ). 2001. Order on Consent: RI/FS Cleanup Agreement (Document No. LQSW-NWR-02-14).

Oregon Department of Environmental Quality (DEQ). Personal communication between Ivona Radivojsa-Kininmonth and Rob Healy of CH2M HILL on March 14, 2006.

Oregon Administrative Rules (OAR). 2004. OAR 340-040-0020. Department of Environmental Quality, Division 40—Groundwater Protection, General Policies at URL.

Pitt, Robert. 1996. *Groundwater Contamination from Stormwater Infiltration*. Ann Arbor Press, Inc.

Radivojsa-Kininmonth, Ivona. 2004. *Potential Volatile Organic Contamination Sites in the Vicinity of St. Johns Landfill, Portland, Oregon*. Prepared for DEQ.

Roger N. Smith Associates, Inc. 1997. *Groundwater Well Monitoring Network Design Report for: CSO/Columbia Slough Watershed Sump Study, Portland, Oregon*. Prepared for the City of Portland.

Swanson, R.D., Mcfarland, W.D. Gonthier, J.B., and Wilkonson, J.M. 1993. *A Description of the Hydrogeologic Units in the Portland Basin, Oregon and Washington.* USGS Water Resources Investigations Report 90-4196.

Sweet Edwards/EMCON. 1989. *St. Johns Landfill Water Quality Impact Investigation and Environmental Management Options*. Volumes 1-4. Prepared for Metro.

U.S. Environmental Protection Agency (EPA). 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. EPA/600/R-98/128.

Tables

Figures

APPENDIX A
Groundwater Data Quality Assurance Evaluation

APPENDIX B

VOC Constituent Detection Tables

APPENDIX C

Box Plots of Groundwater and Leachate Quality