B&L Woodwaste Site
Pierce County, Washington

Engineering Design Report (EDR) Addendum 1

Phase 1 Part 1 Remediation Design Report

Barrier Wall and Interceptor Trench

Appendix 1B
Groundwater Modeling Memorandum

FINAL

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Technical Memorandum

To: Dom Reale, Washington Department of Ecology

Copies: D. Silver, T. Floyd

From: C. Stringer, R. Wyckoff

Date: April 21, 2009

Project No: B&L RIM

Re: **Hydrogeologic Modeling for Assessment of Groundwater Mounding and Mitigation of Aquitard Gaps, B&L Woodwaste Site, Pierce County, Washington**

This memorandum presents results from hydrogeologic modeling conducted to assist the design of the subsurface barrier wall and groundwater interceptor trench system. The Consent Decree (Decree) and 2008 Cleanup Action Plan (2008 CAP) for the B&L Woodwaste Site (Site) specify that a subsurface barrier wall around the entire perimeter of the Landfill and a groundwater interceptor trench system be designed and constructed as part of the final Site remedy. The barrier wall is one component of the final remedy for the Site; a groundwater recovery system will be constructed within the contained area as described in the Engineering Design Report (EDR).

This memorandum addresses two different and distinct questions regarding the barrier wall and interceptor trench system. The first question address the potential for upgradient mounding. Specifically, the subsurface barrier wall, without the interceptor trench, could conceivably cause groundwater mounding on the upgradient side of the barrier wall. Therefore, the potential impact of the subsurface barrier wall on the water level in adjacent, upgradient areas was modeled to better understand the potential to create adverse conditions.

Second, and unrelated to the upgradient mounding issue, subsurface investigations conducted for design of the barrier wall have identified two gaps within the Lower Silt Aquitard beneath the Landfill (EDR Section 4.2). One gap, referred to as the southwest gap, is located beneath the southwest corner of the Landfill, while the other gap, referred to as the east gap, is along a portion of the eastern perimeter of the Landfill. The limit of the east gap toward the center of the Landfill has not been identified. The presence of the two gaps will likely increase the groundwater leakage into the Upper Sand Aquifer from the Lower Sand Aquifer during pumping to maintain an inward hydraulic gradient within the contained area, thereby affecting the necessary groundwater extraction rate. Therefore, potential approaches for mitigation of the aquitard gaps to reduce the groundwater extraction rate required to maintain an inward head differential across the barrier wall were evaluated. Possible mitigation approaches considered include exclusion of the gaps from the barrier wall containment area or deepening the barrier

wall at the gaps to lengthen the flowpath and reduce the flow of groundwater upward through the gaps.

Groundwater simulations were conducted to:

- evaluate potential upgradient mounding caused by the barrier wall; and design the groundwater interceptor trench system so that it would mitigate the potential mounding,
- evaluate mitigation measures for the aquitard gaps.

The steady-state groundwater flow model developed using the United States Geological Survey (USGS) Modular Three-Dimensional Finite Difference Groundwater Model (MODFLOW) was used to conduct the simulations. A complete discussion of model development and calibration is presented in Appendix C of the EDR.

2.0 UPGRADIENT GROUNDWATER MOUNDING

2.1 Historical Precipitation Data

The simulations were conducted under two hydrologic conditions that are different from that used for model calibration. The hydraulic condition in the numerical model was adjusted by changing recharge, boundary conditions, river stage, and drain stage to reflect reasonable worst-case conditions suitable for the design evaluation. Recharge was calculated by multiplying the reasonable worst-case precipitation intensity by the ratio of recharge to precipitation obtained from model calibration. Precipitation intensities for the two hydrologic conditions were developed from historical precipitation records.

Monthly total precipitation data between 1919 and 2008 were obtained for two weather stations in Tacoma, Washington: 1919 to 1981 data for station Tacoma #1 (COOP ID 458278) and 1982 to 2008 data for station Tacoma City Hall (COOP ID 458286). These two stations were selected because of their proximity to the Landfill. The data for the period of January 1919 through August 2008 were obtained from the National Climatic Data Center (NCDC)[1]. The data for September, October, November, and December 2008 were provided by the Western Regional Climate Center through e-mail communication[2]. These data were combined into a single dataset to calculate two precipitation intensities for the groundwater flow simulations, as described in the sections below.

2.2 Problem Definition

The modeling objective was to evaluate the potential impact of the subsurface barrier wall on groundwater elevations on the upgradient side (southeast) of the barrier wall. Additionally, the model was used to support design of the interceptor trench system by estimating likely flows to the groundwater interceptor trench that would control groundwater elevations in this area.

[1] National Climatic Data Center, http://www.ncdc.noaa.gov/oa/climate/climateinventories.html, accessed on January 12, 2009.
[2] E-mail communication with Michelle Breckner, Service Climatologist at the Western Regional Climate Center.

2.3 Hydrologic Condition Used

Groundwater simulations were conducted for a high-precipitation and high-water level condition, as represented by the total precipitation for the "wettest" 3 months with 10-year recurrence. This condition is used because it represents a reasonable worst-case scenario for groundwater mounding and corresponds to a conservative estimate of the flow capacity for the groundwater interceptor trench.

The historical monthly precipitation data indicate that the 3-month period of November, December, and the following January typically has the highest 3-month precipitation in a year (refer to Figure C.13 in Appendix C of the EDR). The 3-month total precipitation for this period with 10-year recurrence was found to be 23.3 inches from recurrence analysis. As this precipitation intensity is higher for this 3-month period than that used in model calibration (36.7 total inches per year), it was assumed that under this precipitation condition, the boundary flux rates for the model would be 25 percent higher than used for calibration, the river and surface drain stage elevations were assumed to be 1-foot higher, and the heads on the constant head boundaries would be 1-foot higher than used in the calibrated model. These conditions represent a reasonable worst case for evaluating groundwater mounding and estimating flow to the interceptor trench from groundwater.

Because the potential for mounding is related to seasonal groundwater elevations, it should be noted that this simulation is not designed to address the situation were a large rainfall event has resulted in flooding of the Hylebos Creek basin. When the basin is flooded, drainage from the basin is controlled by topographical and drainage system conveyance features completely unrelated to the Landfill and its remedy. These are discussed in more detail in Section 3.1 of the EDR and in the Washington State Department of Transportation (WSDOT) Environmental Impact Statement for the SR-167 extension[3] and associated hydraulic analyses.[4]

2.4 Simulations and Results

A total of three steady-state simulations were conducted. A simulation without the barrier wall was first run under the worst-case hydrologic condition described above to establish baseline hydrologic conditions. The area where groundwater elevation exceeds the ground surface (ponding area) was identified, and the average simulated surface elevation in the ponding area upgradient of the Landfill was calculated. With the planned barrier wall added to the model as a horizontal flow barrier (HFB) boundary condition along the perimeter of the Landfill, another simulation was run to identify changes to the ponding area caused by the barrier wall and to calculate the average surface elevation in the ponding area when the barrier wall is in place.

Results from these two simulations indicate that, without the interceptor trench in place, the predicted potential ponding area would be slightly larger with the barrier wall in place under this

[3] Washington State Department of Transportation (WSDOT). 2006. *SR 167 Puyallup to SR 509 Tier II Final Environmental Impact Statement and Section 4(f) Evaluation*. U.S. Department of Transportation Federal Highway Administration, Army Corps of Engineers, City of Fife. November.

[4] MSG Engineering Consultants, Inc., Montgomery Water Group, Inc., GeoEngineers, Kirsty Burt Geographic Information Services. 2004. *Analysis of the SR-167 Extension and Riparian Restoration Proposal in the Hylebos Watershed Hydrology, Hydraulics and Geomorphology.* Prepared for Washington State Department of Transportation. November.

high-precipitation/high-water level hydrologic condition than under the situation where there is no barrier wall. The predicted average groundwater elevation directly upgradient (southeast) of the Landfill would be 18.8 feet (ft) under these extreme conditions without the barrier wall or the interceptor trench. When the barrier wall is in place (without the interceptor trench), the groundwater elevation in the ponding area is predicted to rise to 19.4 ft. This is consistent with the expected hydraulic effect of a subsurface barrier wall on groundwater flow. In order to keep the predicted groundwater elevation at the same level as without the barrier wall, the groundwater interceptor trench will be required. Based on these simulation results, it was decided to include the interceptor trench in the design to mitigate the potential for upgradient ponding.

A third simulation was conducted to estimate the flow rate to the interceptor trench necessary to maintain baseline conditions (i.e., conditions in the absence of the barrier wall). A drain boundary condition was added to the model immediately outside the upgradient section of the barrier wall to represent the interceptor trench. The drain elevation in the model was adjusted until the average predicted water elevation in the ponding area, with the barrier wall in place, was approximately 18.8 ft. The groundwater flux at this drain boundary was then taken as an estimate of the groundwater extraction rate in the interceptor trench. The estimated extraction rate for the interceptor trench was nine gallons per minute (gpm) under worst-case hydrologic conditions.

3.0 MITIGATION OF AQUITARD GAPS BY EXCLUSION OF THE SOUTHWEST GAP

Groundwater model simulations were also conducted to assess alternate approaches for mitigating the effect of the aquitard gaps on future pumping rates needed to establish hydraulic control for groundwater beneath the Landfill. The objective for the simulation discussed below is to evaluate the effects of excluding the southwest gap from barrier wall containment on future groundwater extraction rate beneath the Landfill. Under this scenario, the barrier wall alignment along the southwest corner of the Landfill would be moved toward the center of the Landfill so that it could be keyed into the aquitard. Waste above the aquitard gap would then be removed and relocated within the contained area. It was assumed that hydraulic containment would be achieved by maintaining a head difference of 6-inches across the barrier wall.

3.1 Hydrologic Condition Used

Groundwater flow simulations were conducted for an average hydrologic condition, as represented by an annual precipitation with 10-year recurrence. This condition was used because it is consistent with long-term operation of the groundwater extraction system. Based on the historical precipitation data, the annual total precipitation with a 10-year recurrence interval was approximately 44 inches per year. Since the annual rainfall with a 10-year recurrence interval (44 inches per year) is similar to the long-term average used in model calibration (36.7 inches per year), no adjustments to the model boundary conditions were made.

3.2 Simulation Scenarios

In the calibrated model, the southwest gap has an area of approximately 0.6 acre, while the east gap has an area of approximately 1.0 acre. Because the size of the east aquitard remains

undefined and the continuity of the aquitard beneath the approximately 13-acre Landfill is not known, the total area of the aquitard gap underneath the Landfill remains unknown. To account for this uncertainty, six steady-state simulations with different total aquitard gap sizes were performed to determine the optimal cumulative pumping rates in the Upper Sand Aquifer beneath the Landfill to maintain a 6-inch inward gradient across the entire barrier wall. The six scenarios are described below:

1. A continuous aquitard (aquitard gap size = 0 acres)
2. Assumed east aquitard gap only (aquitard gap size = 1.0 acre)
3. Assumed east and southwest aquitard gaps (aquitard gap size = 1.6 acres)
4. The east and southwest aquitard gaps plus an additional hypothetical 2.4 acres in the middle of the Landfill (aquitard gap size = 4.0 acres)
5. The east and southwest aquitard gaps plus an additional hypothetical 6.4 acres in the middle of the Landfill (aquitard gap size = 8.0 acres)
6. The east and southwest aquitard gaps plus an additional hypothetical 8.0 acres in the middle and northwest corner of the Landfill (aquitard gap size = 10 acres)

Vertical extraction wells were assumed for the modeling evaluation. Alternate well configurations may be used for the future groundwater extraction system. Pumping rates for the six simulations were optimized based on maintaining the target cross-wall gradient uniformly around the Landfill.

3.3 Evaluation Results

Figure 1B.1 provides the aquitard gap configuration, barrier wall alignment, and 16 Upper Sand Aquifer extraction well locations for each of the six scenarios listed above. The barrier wall alignment and extraction well locations were kept constant for the simulations used in this evaluation. The inverse modeling code PEST[5] was used to minimize the cumulative groundwater extraction rate required to maintain a 6-inch inward gradient across the barrier wall for each gap configuration. Figure 1.2 in Addendum 1 presents the optimal extraction rates as a function of the total size of the aquitard gap. The figure demonstrates that the required extraction rate increases rapidly with increasing gap size when the total gap size is below approximately 2 acres, and that the increase is much less when the total gap size is over 2 acres. In other words, reducing the aquitard gap size by 0.6 acre (i.e., by moving the barrier wall to exclude the southwest gap) would not result in substantial reduction in extraction rate if the size of aquitard gap underneath the Landfill is 2 acres or more.

4.0 MITIGATION OF AQUITARD GAPS BY DEEPENING OF BARRIER WALL

Groundwater model simulations were performed to investigate the relationship between barrier wall depth at the aquitard gaps and the total pumping rate required to establish hydraulic control for groundwater beneath the Landfill. The relationship of barrier wall depth and groundwater pumping rate was then used to assess the cost savings from reduced extraction rates and the

[5] Watermark Numerical Computing, PEST: Model-Independent Parameter Estimation, User Manual 5th Edition and Addendum, February 2008

additional costs associated with deepening the barrier wall. The cost savings considered include reduced capital costs for construction of the groundwater treatment system and costs for treatment system operations (including sludge disposal).

4.1 Hydrologic Condition Used

Groundwater flow simulations were performed using an annual precipitation with a 10-year recurrence, as described in Section 3.1

4.2 Simulation Scenarios

Steady-state simulations were performed to assess the reduction in groundwater extraction rate by increasing the depth of the barrier wall at the east and southwest aquitard gaps. Increasing the barrier wall depth would not prevent upward leakage from the Lower Sand Aquifer to the Upper Sand Aquifer inside the barrier wall. A deeper wall in the location of the discontinuities, however, may reduce the groundwater extraction rate required to establish hydraulic control by: (1) increasing groundwater flow paths and (2) increasing the resistance to vertical groundwater flow.

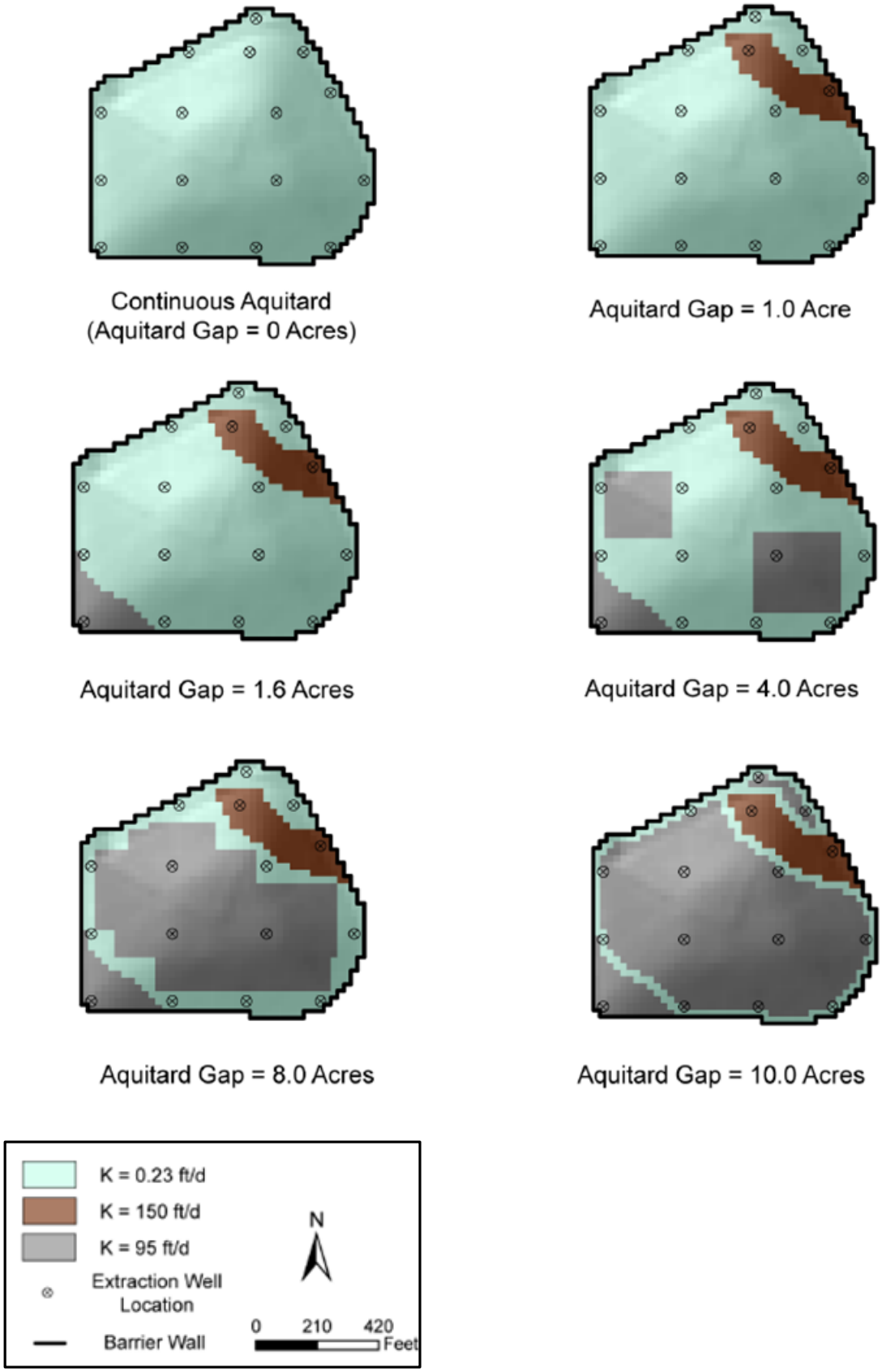
For the modeling scenarios used in this evaluation, an area of 0.6 acre was used for the southwest gap and an assumed area of 1 acre was used for the east gap (refer to Section 3.2). Three barrier wall depths (20-ft below ground surface [bgs], 35-ft bgs, and 50-ft bgs) along the east and southwest gaps were modeled for this evaluation. To assess the effects of different barrier wall depths, a 70-ft thick layer was added to the bottom of the model domain, resulting in an assumed 100-ft thick Lower Sand Aquifer with uniform hydraulic properties. Because of this adjustment, model geometry and calibration may not accurately represent local hydrogeology. The purpose of the simulations, however, is to estimate the variation in groundwater extraction with different barrier wall depths rather than to accurately predict actual groundwater pumping rates under the different conditions. Consequently the modified model is considered appropriate and was used for this evaluation without further calibration.

In the groundwater model, 12 groundwater extraction wells were placed beneath the Landfill in the Upper Sand Aquifer (Figure 1B.2). Well locations were kept constant for all modeling scenarios. For each scenario, the inverse modeling code PEST (Watermark Numerical Computing 2008) was used to optimize the total extraction rate required for maintaining a 6-inch inward head differential across the barrier wall. The predicted reduction in extraction rates achieved by deepening the barrier wall were then used to estimate treatment costs (capital and operations costs) and for comparison to the additional capital costs for barrier wall construction.

4.3 Evaluation Results

Table 1.2 in Addendum 1 provides the optimized total extraction rates for each combination of inward gradient and barrier wall depth. These results indicate that if the wall is extended at the location of the gaps to 35 ft, then the treatment system size can be reduced by about 10 percent and the average flow rate by about 5 percent. Extending the barrier the additional 15 ft at the gaps to a total depth of 50 ft, would again result in about a 5 percent further decrease in average flow rate but would not change the design treatment capacity because the wet season extraction rate would not be decreased.

Table 1.2 in Addendum 1 also compares the estimated cost savings from reduced extraction rates and the additional costs for deepening the barrier wall. This comparison suggests that deepening the barrier wall to the depth of 35 ft at the aquitard gaps would provide an appropriate balance of additional capital cost for the barrier wall versus reduced long-term operational cost.



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Addendum 1
B&L Woodwaste Site
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Figure 1B.1
Aquitard Gap Hydraulic Conductivity and Extraction Well Locations

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● Extraction Well Locations[1]

N

0 210 420 Feet

Notes: 1.) Pumping wells shown in their horizontal locations.
Wells screened in the Upper Sand Aquifer (Layer 2)
for all simulations.

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Addendum 1
B&L Woodwaste Site
Pierce County, Washington

Figure 1B.2
Barrier Wall Sensitivity Analysis – Extraction Well Locations

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