Horn Rapids Landfill
Remedial Investigation Work Plan

Prepared for
City of Richland Public Works Department

February 2017

Prepared by
Parametrix

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City of Richland Public Works Department

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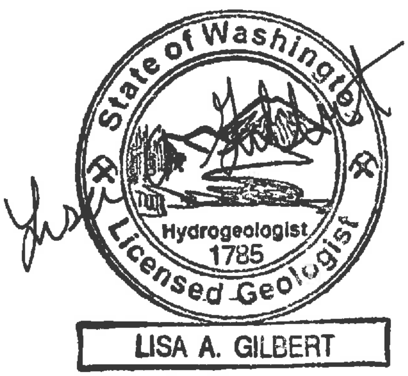
CERTIFICATION

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



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ACRONYMS AND ABBREVIATIONS

BFHD	Benton-Franklin Health District
COCs	Chemicals of Concern
City	City of Richland
City Facility	275-acre permitted waste facility, including Landfill
City Property	Contiguous property owned by the City of Richland, including the City Facility (approximately 2,306 total acres)
DCA	Dichloroethane
DCE	Dichloroethene
DO	dissolved oxygen
Ecology	Washington Department of Ecology
Expansion	proposed 104-acre expansion of the Horn Rapids Landfill located within the City Facility east of the Landfill
GWQSs	groundwater quality standards (Chapter 173-200 WAC)
Landfill	46-acre permitted area where MSW has been placed within the City Facility
LFG	landfill gas
MCL	maximum contaminant level (Chapter 246-290 WAC)
MSW	municipal solid waste
MTCA	Model Toxics Control Act (Chapter 173-340 WAC)
ORP	oxidation-reduction potential
ORV	off-road vehicle
PCE	Tetrachloroethene
QAPP	Quality Assurance Project Plan
RI/FS	remedial investigation and feasibility study
TCE	Trichloroethene
TDS	Total Dissolved Solids
VC	Vinyl Chloride
VOCs	volatile organic compounds

1. INTRODUCTION

1.1 Objectives

This work plan is intended to be an exhibit to the anticipated Agreed Order to be entered into between the City of Richland (City) and the Washington State Department of Ecology (Ecology). The objective of the work plan is to define the investigation activities necessary to supplement existing data, fill remaining data gaps identified by the City and Ecology, and define the nature and extent of contamination at the Horn Rapids Landfill in accordance with Chapter 173-340 WAC, the Model Toxics Control Act (MTCA). This Work Plan was prepared in accordance with MTCA and its implementing regulations.

For the purposes of this work plan, the following terminology related to the Horn Rapids Landfill has been developed, as further described in Sections 1.2 and 1.3:

- City Facility: 275-acre permitted waste facility, including Landfill
- Landfill: 46-acre permitted area where municipal solid waste (MSW) has been placed within the City Facility
- City Property: Contiguous property owned by the City of Richland, including the City Facility (approximately 2,306 total acres)
- Expansion: proposed 104-acre expansion of the Horn Rapids Landfill located within the City Facility east of the Landfill

1.2 Horn Rapids Landfill Setting

The Horn Rapids Landfill is owned and operated by the City Public Works Department. It is located northwest of and within the City limits of Richland, Washington in an area bounded by Twin Bridges Road on the west, Horn Rapids Road on the north, and State Route 240 on the south.

The Horn Rapids Landfill is located within the southwest quadrant of a larger 275-acre parcel of City-owned property (City Facility, see Figure 1) that includes the 46-acre existing landfill (Landfill) permitted for disposal of MSW, a support facility, a 9-acre composting facility, and a moderate-risk hazardous waste receiving facility, which was destroyed by a fire in 2010.

As shown on Figure 1, the City also owns contiguous property (City Property) to the west, south and east of the City Facility (a total of approximately 2,306 total acres), with the exception of several small privately owned parcels, two located along the southwest corner of the City Facility, and one within the northeast corner of the City Facility. East of the City Facility are circle-irrigated agricultural fields used to grow alfalfa hay, corn, and potatoes. Irrigation water for these fields is obtained from the Columbia River and not from a groundwater source. Irrigated fields are also located west of the City Facility across State Highway 240. These fields have been in use since 1987, with irrigation occurring between the months of April and October (Shaw Environmental Inc. 2003). The remaining City Property south and southeast of the Landfill is undeveloped.

As shown on the Site Vicinity Map (Figure 2), the City Property immediately west of the City Facility has been developed as an off-road vehicle (ORV) park, which includes a road racing track and a motocross track facility. A portion of the ORV Park is designated as public facilities with restrooms and picnic areas.

The Site Plan (Figure 3) shows the City Facility Boundary, the Landfill and other City Facility features, and monitoring locations including gas probes, groundwater monitoring wells, and lysimeters. The area within the City Facility east of the currently permitted 46 acres is the proposed Horn Rapids Landfill Expansion (Expansion).

1.3 Landfill Description

The Landfill began receiving MSW in 1974. The Landfill historically accepted only municipal wastes and was initially developed by placing waste into a series of north-south oriented trenches in the Phase 1 western portion of the Landfill. The waste depths in the trenches ranged from 12 to 30 ft.

The Landfill (refuse) boundary is shown on Figure 3. Phase 1 (the western portion of the permitted area) was closed in 2011, including installation of a landfill gas (LFG) collection system. From 2005 to 2010, the Landfill was filled and graded to the proposed closure grading plan. During the 2011 construction season, Phase 1 closure was installed over the western portion of the Landfill, which included the installation of the active LFG system.

MSW is currently being accepted in Phase 2 of the permitted area, and closure of Phase 2 is expected to occur in 2020. The proposed 104-acre, Horn Rapids Landfill Expansion is located east of the currently permitted 46-acres. Engineering plans for the proposed Expansion are presented in the Preliminary Conceptual Engineering Report (Parametrix 2016a).

The City has operated a compost facility at the City Facility since 2010. The Compost Facility is situated on 9 acres just north of the Landfill, approximately 500 ft south of Horn Rapids Road, and was permitted under WAC 173-350-220, WAC 173-350-710, and WAC 173-350-715. The compost facility receives and processes regional municipal and commercial green waste materials and produces compost from acceptable materials such as vegetative yard or agricultural waste, wood waste, lawn clippings, sawdust, straw, manure, Class A biosolids, and compostable winery waste.

1.4 Regulatory History and Interim Actions

The Horn Rapids Landfill was originally permitted under Chapter 173-301 WAC, and currently operates under the Criteria for Municipal Solid Waste Landfills, Chapter 173-351 WAC and the current Solid Waste Permit (Permit) issued by the Benton-Franklin Health District (BFHD).

Concentrations of volatile organic compounds (VOCs) above MTCA cleanup levels were detected in new groundwater monitoring wells MW-5 and MW-6 (Shannon and Wilson, Inc. 1998). An Early Notice letter was submitted in March 2000, and the City Facility was placed on Ecology's Known or Suspected Contaminated Site List based on notification by the City that groundwater results were statistically elevated compared to background. The City Facility has been in assessment monitoring since that notification. The primary VOCs of concern in groundwater are chlorinated ethenes and ethanes.

In 2004 and 2005, the City performed an independent two-phased remedial investigation and a pilot study/feasibility study (RI/FS, Shaw Environmental, Inc. 2003, 2004, 2005). The RI determined that LFG is the likely source of the VOCs impacting groundwater. A LFG extraction system was designed (Parametrix 2005) based on pilot study results that showed LFG extraction would effectively remove VOCs from the subsurface, and closure including a LFG extraction system is being implemented in two phases (Parametrix 2011, 2012a, 2012b).

Between 2005 and 2010, Phase 1 (the western portion of the permitted area) of the landfill was filled and graded to approved closure grading plans (EMCON 1999; Parametrix 2006, 2008, 2011), and was closed in 2011 (Parametrix 2011, 2012a, 2012b) as an independent remedial action in accordance with Chapter 173-340 WAC. The Phase 1 closure included a final cover and gas collection system consisting of in-refuse wells, collection manifold and laterals, a condensate manhole, and a flare station. Vertical gas collection wells were installed as part of the Phase 1 landfill closure. The wells are typically spaced at 150 ft apart around the perimeter and 200 ft apart in the interior of the landfill. The gas collection system was started up in September 2011 to prevent subsurface LFG migration beyond the landfill perimeter and to remove VOCs from groundwater beneath the landfill. The collection system has operated 24 hours a day since startup. The applied vacuum from the permanent blower/flare facility produces a pressure gradient within the MSW that causes LFG to flow into the collection field rather than migrate.

Phase 2 (the eastern portion of the permitted area) is currently being filled to grade and closure is expected to occur in 2020. Additionally, since the RI/FS, quarterly environmental monitoring has been conducted in accordance with Chapter 173-351 WAC, including Assessment Monitoring, and the current Permit. Periodic monitoring that has been performed at the Landfill is described in more detail in section 1.5.

1.5 History of Environmental Monitoring

Environmental monitoring at the City Facility has included LFG, leachate, and groundwater, at the locations shown on Figure 3. No surface water monitoring is conducted since any surface runoff is collected in perimeter ditches and routed to infiltration facilities discussed in the Permanent Stormwater Control Plan (Parametrix 2008).

1.5.1 Landfill Gas Monitoring

LFG probes (currently GP-1 through GP-4; GP-7 through GP-12) are used to monitor the potential for subsurface LFG migration adjacent to the waste and along the Landfill and City Facility Boundary (see locations on Figure 3). Results of quarterly LFG monitoring are described in Section 2.4.1.

Construction details for each gas probe, including the depth relationship of each screened interval to the adjacent waste, are presented in Table 1. All gas probes are completed in alluvium outside the Landfill, and each gas probe is screened at two subsurface intervals, with the exception of GP-12, which is screened at three separate intervals. Gas probes GP-5 and GP-6 were decommissioned in May 2010 because they were located within the construction footprint of the closure of the Phase 1 portion of the Landfill.

Table 1. Landfill Gas Probe Construction, Horn Rapids Landfill

Probe	Port	Ground Surface Elevation (ft)	Top of Screen Depth (ft bgs)	Bottom of Screen Depth (ft bgs)	Bottom Elevation of Probe (ft bgs)	Waste Depth (ft bgs)	Bottom Elevation of Waste (ft bgs)	Probe Depth Below Waste (ft bgs)	Probe Depth Above Groundwater (ft bgs)
GP-1	**1**	485.3	18.5	20.0	465.3	25	460.3	-5.0	79.3
	2	485.3	8.5	10.0	475.3	25	460.3	-15.0	89.3

Table 1. Landfill Gas Probe Construction, Horn Rapids Landfill (continued)

Probe	Port	Ground Surface Elevation (ft)	Top of Screen Depth (ft bgs)	Bottom of Screen Depth (ft bgs)	Bottom Elevation of Probe (ft bgs)	Waste Depth (ft bgs)	Bottom Elevation of Waste (ft bgs)	Probe Depth Below Waste (ft bgs)	Probe Depth Above Groundwater (ft bgs)
GP-2	**1**	489.1	36.5	38.0	451.1	30	459.1	8.0	65.1
	2	489.1	18.5	20.0	469.1	30	459.1	-10.0	83.1
GP-3	**1**	477.1	36.5	38.0	439.1	12	465.1	26.0	53.1
	2	477.1	18.5	20.0	457.1	12	465.1	8.0	71.1
GP-4	**1**	477.5	36.5	38.0	439.5	12	465.5	26.0	53.5
	2	477.5	18.5	20.0	457.5	12	465.5	8.0	71.5
GP-5 (former)	**1**	479.4	56.5	58.0	421.4	25	454.4	33.0	35.4
	2	479.4	36.5	38.0	441.4	25	454.4	13.0	55.4
	3	479.4	18.5	20.0	459.4	25	454.4	-5.0	73.4
GP-6 (former)	**1**	479.4	36.5	38.0	441.4	25	454.4	13.0	55.4
	2	479.4	18.5	20.0	459.4	25	454.4	-5.0	73.4
GP-7	**1**	479.4	24.0	28.0	451.4	12	467.4	16.0	65.4
	2	479.4	11.0	15.0	464.4	12	467.4	3.0	78.4
GP-8	**1**	478.8	26.0	30.0	448.8	12	466.8	18.0	62.8
	2	478.8	11.0	15.0	463.8	12	466.8	3.0	77.8
GP-9	**1**	489.3	26.0	30.0	459.3	25	464.3	5.0	73.3
	2	489.3	11.0	16.0	473.3	25	464.3	-9.0	87.3
GP-10	**1**	484.5	26.0	30.0	454.5	30	454.5	0.0	68.5
	2	484.5	11.0	15.0	469.5	30	454.5	-15.0	83.5
GP-11	**1**	486.0	36.0	39.0	447.0	30	456.0	9.0	61.0
	2	486.0	14.0	17.0	469.0	30	456.0	-13.0	83.0
GP-12	**1**	480.3	22.5	32.5	447.8	30	450.3	2.5	61.8
	2	480.3	49.5	59.5	420.8	30	450.3	29.5	34.8
	3	480.3	76.5	86.5	393.8	30	450.3	56.5	7.8

1.5.2 Leachate Monitoring

Leachate is collected in four lysimeters that monitor the vadose zone directly beneath the MSW in the northeast corner of the Landfill. Drains from each lysimeter are connected to a common sampling vault where discrete samples of leachate are collected from four sampling ports. The approximate location of the lysimeters and sampling vault are shown in Figure 3. The lysimeters were installed in 1993, and samples of leachate were collected and analyzed between 1994 and 2002 (Shaw Environmental 2004). Initially, the monitoring frequency was quarterly, but was decreased to semiannually in 1995 due to the declining volumes of leachate observed. No leachate was collected in the lysimeters between 2006 and

2014. In November 2014, June 2015, and June 2016, small quantities of leachate were observed in one of the lysimeter ports and samples were collected. Leachate quality is discussed in Section 2.4.2.

Correspondence between the City and the Health District discussing the lysimeters indicates that the lowest elevation of waste is approximately 422 ft MSL, and the lysimeters are somewhere below that. Groundwater is present at an elevation of approximately 378 ft MSL.

1.5.3 Groundwater Monitoring

Groundwater monitoring has been performed at the landfill since 1987 and documented in quarterly and annual groundwater monitoring reports. Results of the groundwater monitoring are discussed in Section 2.4.3.

The initial groundwater monitoring network consisted of one upgradient well (MW-1) located on the western boundary of the City Facility, and three downgradient monitoring wells (MW-2, MW-3, and MW-4) located along the eastern boundary of the City Facility, approximately 1,400 ft east of the Landfill. Groundwater monitoring was conducted in accordance with a groundwater monitoring plan (SCS Engineers 1996). In 1998, two additional wells (MW-5 and MW-6) were installed less than 50 ft from the eastern edge of the Landfill, and VOCs were detected in these wells. Additional downgradient wells MW-7 through MW-10 were installed in 2001 (Shaw Environmental, Inc. 2003, 2004). A brief summary of each phase of the RI is presented in Section 2.1.

Groundwater monitoring well MW-7 was decommissioned in May 2010 because it was located within the construction footprint of the closure of the Phase 1 portion of the Landfill. Well MW-7, although in an upgradient position with respect to groundwater flow, had not been used to characterize upgradient groundwater quality because it showed Landfill impacts due to its close proximity to the MSW. Instead, MW-1, located west of the Landfill, has been used to characterize upgradient groundwater quality, although it also shows some water quality impacts, including those seen area-wide.

An additional upgradient well MW-11 was installed in May 2010 at the location shown on Figure 3. Groundwater flow is toward the southeast and this location was selected to be upgradient of the Landfill and the proposed Expansion. The City Facility extends approximate 2,800 ft to the north of the Landfill and is vacant except for the shooting range just northwest of the Landfill.

Monitoring well construction details are shown on Table 2. Wells MW-7 through MW-11 are constructed with screened intervals across the water table, and the other wells are constructed with the top of their screen between 8 to 16 ft below the top of the water table.

1.6 Hydrogeologic Setting

The hydrogeologic setting in the vicinity of the Landfill is described below, including a description of the hydrogeologic units, groundwater flow, and groundwater flow direction and gradient.

1.6.1 Hydrogeologic Units

The local and regional geology and hydrogeology in the vicinity of the Landfill is detailed in reports documenting previous investigations (Hong West 1991; Shannon & Wilson 1998; Shaw Environmental Inc. 2003; Parametrix 2016c) and summarized in the following paragraphs.

Table 2. Groundwater Monitoring Well Construction Information, Horn Rapids Landfill

Monitoring Well	Northing	Easting	Elevation of TOC (ft NAVD88)	Screen Length (ft)	Screened Interval (ft below top of well seal[a])	Depth to Groundwater December 2015 (ft)	Groundwater Elevation December 2015 (ft NAVD88)	Water level and top of screen [negative is below top of screen] ft
MW-1	371,572.00	2,291,691.97	489.68	25	114-139	103.04	386.64	-10.96
MW-2	372,460.09	2,294,368.28	469.73	25	98-123	83.91	385.82	-14.09
MW-3	371,529.10	2,294,408.23	481.28	25	111-136	95.44	385.84	-15.56
MW-4	370,722.92	2,294,379.43	462.52	25	90-115	76.78	385.74	-13.22
MW-5	371,784.64	2,293,120.19	469.94	10	91-101	83.90	386.04	-7.1
MW-6	370,965.00	2,293,109.43	484.54	10	106-116	98.71	385.83	-7.29
MW-7 (former)	NA	NA	479.03	21.5	86.5-108	91[b]		
MW-8	370,228.88	2,293,869.87	476.47	15	87.5-102.5	90.92	385.55	3.42
MW-9	370,175.53	2,293,150.76	490.75	15	100.5-115.5	105.02	385.73	4.52
MW-10	372,265.23	2,293,111.61	460.85	15	72.5-87.5	74.72	386.13	2.22
MW-11	373,725.48	2,291,860.98	481.16	15	90-105	94.27	386.89	4.27

Notes: All wells are constructed of 2-inch-diameter PVC casing and slotted well screen.

TOC - Top of PVC casing.

[a] Assumes 3 ft of stickup above ground surface

[b] Typical historical value (well decommissioned)

Groundwater in the uppermost aquifer occurs under water table conditions in the sand, silt and gravel sediments of the middle Ringold Formation. The water table beneath the Landfill occurs at depths of approximately 75 to 105 ft bgs and elevations of approximately 385 to 388 ft NAVD88, and typically fluctuates less than a foot throughout the year. Based on the geologic logs of the on-site water well and the adjacent ORV-2 well, the aquifer thickness is approximately 80 to 110 ft.

Geologic cross sections (A-A' through E-E') are presented in Appendix A. Geologic cross section B-B' extends through the off-site wells illustrating deeper subsurface units. Geologic information is available from the following subsurface explorations:

- Eleven on-site groundwater monitoring wells and one deep gas probe drilled to total depths of 102 to 139 ft (see well locations on Figure 3).
- Water supply well (nonpotable use) drilled to a depth of 312 ft, located in the southwest corner of the City Facility.
- Two water supply wells (nonpotable use) constructed for the ORV Park west of the City Facility, ORV-1 drilled to a depth of 386 ft, and ORV-2 drilled to a depth of 485 ft.

The uppermost geologic unit consists of sand, varying from fine to coarse-grained with some silt, to depths varying from 68 to 101 ft below ground surface. The sand unit is underlain by a deposit consisting of gravel with varying proportions of sand and some silt to the total depths of the monitoring wells. The geologic logs for monitoring wells MW-4, MW-8, and MW-9, located closest to the area of investigation, indicate soils within the water bearing zone are expected to be gravel with approximately 10 to 15 percent silt.

The City Facility water supply well encountered sand to a depth of 86 ft, underlain by water-bearing gravel to a depth of 171 ft. Below the gravel is broken basalt and clay to a depth of 202 ft, underlain by clay to a depth of 248 ft, followed by basalt.

1.6.2 Groundwater Flow Gradient and Direction

Regionally, groundwater flow has been documented to be eastward toward the Columbia River (Shaw 2003, Liikala 1994). However, historical groundwater measurements have indicated the flow direction at the Landfill to be locally influenced by groundwater mounding from irrigated crop circles on the City Facility's eastern boundary, deflecting the flow in the eastern portion of the City Facility seasonally toward the southeast. The general directions of regional groundwater flow and flow observed at and in the vicinity of the City Facility are shown on Figure 1. Crop circles have been used to grow alfalfa hay, corn and potatoes since 1987. The source of the irrigation water is from the Columbia River and irrigation occurs seasonally between the months of April and October. Irrigated fields are also located west of the City Facility across State Route 240.

Groundwater is recharged by depletion of the Yakima River west and southwest of the Landfill, irrigation, and by precipitation. However actual recharge to the sediments from precipitation is significantly less due to the high rate of evapotranspiration. Precipitation in the Richland area from May 1944 to March 2013 indicate an average annual precipitation of 7.15 inches and an average total annual snowfall of 7.1 inches (Western Regional Climate Center 2013).

Groundwater discharge is to the Columbia River about 3 miles east of the Landfill. Insufficient data are available to determine the hydraulic relationship between the uppermost aquifer and the deeper basalt aquifers. However, Liikala (1994) described the aquitard underlying the uppermost aquifer as being regionally present, and calculated an overall upward vertical gradient in the vicinity of the Landfill based on a measured hydraulic head in the upper confined aquifer that was higher than in the uppermost unconfined aquifer. The uppermost aquifer thins toward the east.

Hydrographs presented in the Phase 1 RI (Shaw 2003) indicate a steady rise in water-level elevations from 1986 through 2002 with observed increases of approximately 5 to 7 ft. These changes were attributed to influences from irrigated crop circles on the City Facility's eastern boundary. Historical water elevation maps (presented in Appendix B) also show that the flow direction and gradient have changed in response to these increasing water levels. In 1987, the flow direction was eastward with a gradient of approximately 0.001 ft/ft, consistent with the regional groundwater flow direction. In 1995, the flow direction changed to southeasterly, with a gradient of 0.0004 ft/ft. The additional wells installed in 2002 allowed further refinement of the flow direction and gradient, and the data showed easterly flow in the western portion of the City Facility, changing to southeasterly flow in the central portion of the City Facility, a pattern that continues to be observed.

Historical influences at the ORV park west of the City Facility may have also temporarily altered local flow direction by periodically flooding shallow unlined waterways for boat racing, and allowing the water to seep out after each race. The ponds were constructed in 1999 and racing was discontinued in the mid 2000's. Other sources of artificial recharge include four septic systems at the ORV park, one recently installed for a new bathroom/shower facility designed for 4,000 uses per day.

2015 groundwater flow contours are provided in Appendix B for the wet (First Quarter) and dry (Third Quarter) seasons. Although groundwater flow across the City Facility is generally toward the southeast, during the dry season groundwater flow in the eastern portion of the City Facility shifts slightly more toward the south-southeast due to the mounding effect of the crop circles on the eastern edge of the City Facility.

The overall groundwater gradient at the City Facility is low, approximately 0.0005 ft/ft over the past few years, and the calculated rate of groundwater flow is less than 20 ft per year.

1.7 Beneficial Water Use

Logs for water wells and water rights within 2,000 ft of the Landfill were researched on the Ecology website and are presented in the Hydrogeologic Report (Parametrix 2016c). There are no drinking water wells within over a mile from the Landfill. The only wells within a mile of the Landfill are the two wells in the ORV park west of the Landfill in an upgradient direction, and the on-site water well, and these three wells are not used for drinking. The closest water well identified in a downgradient direction in the Ecology database is located approximately 2 miles from the Landfill, and it is also believed to be used for non-potable purposes.

No on-site water features were identified on the USGS map and the nearest adjacent surface water features are the Yakima River located approximately 1.3 miles to the south and the Columbia River approximately 3 miles to the east. According to US Department of Interior National Wetland Inventory maps, no wetlands are located in the vicinity of the Landfill and it is assumed that all water on the Landfill infiltrates based on the NRCS Soil Survey Drainage Class Rating (excessively drained).

2. BASIS FOR SUPPLEMENTAL REMEDIAL INVESTIGATION SCOPE

In addition to routine quarterly environmental monitoring conducted in accordance with Chapter 173-351 WAC, independent cleanup actions have been conducted at the Landfill including a remedial investigation conducted in two phases, a pilot study/feasibility study, and completion of interim actions including landfill closure and LFG collection. In addition, assessment monitoring activities have been conducted in accordance with Chapter 173-351 WAC. The findings of these previous studies and a summary of the current status of the environmental monitoring data are described below.

2.1 Remedial Investigation

In 1998, the City installed two additional groundwater monitoring wells (MW-05 and MW-06) (Shannon and Wilson, Inc. 1998). VOCs were detected above applicable MTCA cleanup levels, and in 2000, the Landfill was listed by Ecology on the Confirmed or Suspected Sites List. The City subsequently implemented an independent cleanup action beginning with a phased RI/FS (Shaw Environmental, Inc. 2003, 2004) over the next approximately five years.

Phase 1 of the RI (Shaw Environmental, Inc. 2003) included installing and sampling four additional groundwater monitoring wells to delineate the extent of VOC-impacted groundwater. The new wells were MW-7 upgradient of the Landfill's waste cells to refine the upgradient groundwater flow direction, MW-8 and MW-9 along the southern City Facility Boundary to determine whether VOCs had migrated off the City Facility, and MW-10 north of wells MW-5 and MW-6 to further evaluate the extent of groundwater impacts.

Phase 2 of the RI (Shaw Environmental Inc. 2004) included an assessment of whether leachate and/or LFG were the source of VOCs impacting groundwater. Activities included installing multilevel deep gas probe GP-12, measuring LFG concentrations in gas probes, collecting and analyzing discrete gas samples, and evaluating historical leachate data collected from lysimeters. In addition, a potential undocumented upgradient waste disposal site located approximately 1,200 ft northwest of the northwest corner of the Landfill was evaluated. The undocumented disposal site was found to be limited in extent, with an estimated MSW volume of 4,800 cubic yards, and it was concluded that the undocumented waste site was likely not the source of the VOCs impacting groundwater.

The RI concluded that LFG is the likely source of the VOCs impacting groundwater via vertical migration of LFG through the unsaturated soil to the capillary fringe zone. This conclusion was based on the presence of the same suite of VOCs detected in groundwater in hydraulically upgradient wells and in the vapor phase in the vadose zone including the deep screened zone of GP-12 immediately above the water table. The findings of the RI are summarized as follows:

- Significant concentrations of LFG, as measured in GP-12, occur in the shallow unsaturated subsurface to a depth of at least 90 ft bgs in the MW-6 area and high concentrations of LFG were detected in the casings of MW-5, MW-6, and MW-7, even though MW-7 is located hydraulically upgradient from the waste cells.
- The same suite of VOCs detected in groundwater samples were also detected in headspace gas samples from the monitoring wells and gas probe GP-12.
- Dissolved methane was present in groundwater samples.

- A subset of VOCs frequently detected in the lysimeters representative of Landfill leachate at high concentrations were either not detected in any of the groundwater samples, or detected infrequently at low concentrations.
- Geochemistry of the groundwater samples has a different chemical composition than the leachate. The observed decreases in pH and increases in alkalinity and calcium are indicative of the interaction of LFG and groundwater.

2.2 Pilot Study/Feasibility Study

A pilot-scale LFG extraction test was performed to assess the feasibility of implementing an active LFG collection system as a method for mitigating the LFG source of vapor-phase VOCs (Shaw EMCON/OWT, Inc. 2005). One LFG extraction well and three LFG observation wells and temporary probes were installed. The results of the extraction test indicated that LFG collection would be effective as a remedy to remove vapor phase VOCs within the waste before they migrate vertically through the underlying subsurface soil and partition into groundwater.

2.3 Assessment Monitoring Program

In 2013, Ecology requested that additional activities be conducted to comply with the assessment monitoring requirements of WAC 173-351, and the following activities were completed:

- In March 2014, a groundwater sample was collected from monitoring well W-1 on the east side of the Weidle neighborhood and analyzed for the Landfill analyte parameters. This well was installed in 1993 as part of the Triangle Development located approximately one mile south of the Landfill and previously sampled by the Health District. These data indicate that the Landfill has not impacted drinking water wells in the Weidle neighborhood.
- Testing for Appendix III parameters was conducted annually in phases, including one well near the active cell and one well at the City Facility Boundary each year. The tested wells were wells MW-6 and MW-9 (June 2014), MW-5 and MW-8 (June 2015), and MW-4 and MW-10 (June 2016). No Appendix III parameters were detected in any of the wells with the exception of cyanide, detected in well MW-9 at a concentration slightly above the reporting limit and below the MCL. No cyanide was detected in MW-9 during the retesting in September 2014.

Appendix III monitoring parameter testing has not detected any compounds other than the VOCs identified during the RI. Therefore it is recommended that testing for the additional Appendix III parameters be continued annually on a rotating schedule at one of the three wells located closest to the Landfill (MW-5, MW-6, and MW-10), or at well MW-9 located at the City Facility Boundary. If Appendix III data for leachate becomes available in the future, the City will apply for an alternative monitoring program under WAC 173-351-450 to eliminate or reduce the subset of Appendix III parameters to be tested in the assessment monitoring wells.

2.4 Environmental Monitoring Data Summary

A summary of recent LFG, leachate, and groundwater data is presented in the Calendar Year 2015 Environmental Monitoring Report (Parametrix 2016d). Data presented in this report are summarized in the sections below by media.

2.4.1 Landfill Gas

Historical LFG data and a cross section showing the typical configuration of the LFG probes and extraction wells with respect to the waste are presented in Appendix C. The extent of LFG migration remains within close proximity of the MSW and concentrations have not exceeded the 5 percent by volume regulatory action limit at the City Facility Boundary. No LFG has ever been detected in any of the on-site buildings.

Methane has been detected in gas probes GP-2, GP-9, and GP-12, all located in close proximity to the MSW. Since 2015, all concentrations in these probes have been less than 5 percent by volume except for GP-2-1 and GP-2-2 where concentrations of over 25 percent by volume continue to be periodically observed.

Trends in probes where methane has historically been observed (GP-2, GP-9, and GP-12) are shown on the time-series plot in Appendix C. The data indicate that despite limited spikes, overall substantial decreases have been observed since the closure activities started in 2011 that included installation and operation of an active LFG collection system. For example, methane concentrations in GP-12 decreased from over 30 percent by volume prior to the 2011 Phase 1 Closure, to 5 percent or less during 2015. The LFG source is expected to be further reduced upon full closure of the Landfill that is anticipated in 2020 which will include an expanded LFG extraction system, thus reducing or eliminating future VOC impacts to groundwater.

2.4.2 Leachate

Leachate quality data and correspondence related to leachate quantities observed during the first years following lysimeter installation were presented in the Phase 2 RI Report. No leachate was observed in the leachate ports between 2006 and 2014. The most likely scenario for the observed lack of leachate in the lysimeters during the period beginning in 2006 is as follows: Leachate was initially generated due to infiltrating precipitation while the waste was thin, and as additional waste was placed the increasing thickness of waste became adequate to absorb the small amount of infiltrating precipitation. This eventually resulted in leachate not reaching the lysimeters. The correspondence documents the gradual difficulty in getting samples and indicates that the volume of leachate diminished as the waste depth increased over the lysimeters. It was likely a coincidence that the measurable leachate ceased at the same time as the ports were moved.

Phase 2 of the RI included a comparison of leachate data collected between 1993 and 2002 to groundwater data. Geochemistry of the leachate was determined to be different than typical groundwater samples as shown on the geochemical plots presented in Appendix D.

In the fourth quarter of 2014, liquid was observed in one of the ports, designated Port 3, and samples of the liquid were collected and analyzed for Appendix I and II parameters. The volume of the liquid drained was approximately 2 liters. The geochemical plot for this sample, presented in Appendix D, indicated the geochemistry of the leachate was different than typical groundwater samples. Some parameter concentrations in the leachate sample were higher than in the groundwater samples, notably ammonia, chloride, and TOC, and the total metals barium, iron, manganese, and zinc. Concentrations of nitrate and sulfate were lower than in the groundwater samples.

The ports were rechecked semiannually, and only small quantities of liquid (less than a liter) were present in the second quarters of 2015 and 2016. Samples were collected and tested for VOCs.

The 2014 through 2016 Port 3 leachate data were compared to groundwater quality data as shown on the selected time-series plots in Appendix D. Concentrations of some VOCs in the leachate were comparable to those in groundwater samples from wells near the active landfill (including 1,1-DCA, 1,2-DCA, cis 1,2-DCE, and VC). However, relative to groundwater, the leachate had lower concentrations of TCE and PCE, and higher concentrations of BTEX (benzene, ethylbenzene, toluene, total xylenes), and ketones (acetone and 4-methyl-2-pentanone).

The minimal quantity of leachate currently produced indicates that leachate is not a significant ongoing source of contaminants to groundwater.

2.4.3 Groundwater

The results of ongoing groundwater monitoring have documented that concentrations of inorganics and VOCs in both upgradient and downgradient wells exceed state groundwater quality standards (GWQSs, WAC 173-200) and state drinking water standards (MCLs, WAC 246-290). However, inorganic compound concentrations reflect an elevated area-wide background, as described in Section 2.4.3.1.

The 2015 groundwater quality data and isoconcentration maps are presented in Appendix E. The maximum concentrations of chemicals detected during 2015 above GWQSs and MCLs in upgradient/cross-gradient and downgradient wells are shown in Table 3 below.

2.4.3.1 Area-Wide Background Groundwater Contamination

Groundwater quality data collected from wells in the northern portion of the Landfill, in particular upgradient well MW-11, former upgradient well MW-7 (decommissioned due to Phase 1 closure construction), and cross gradient well MW-2, indicate that sources upgradient of the Landfill are contributing to an area-wide background of elevated concentrations of inorganic compounds, including total dissolved solids (TDS), chloride, nitrate, and cations.

Data spikes observed in these wells (such as nitrate in 2003 in MW-7, and in MW-2 in 2008) suggest that more than one source may have contributed pulses of contaminants over time. Likely potential upgradient sources are those that involve application of water, such as the agricultural irrigation at the crop circles, and septic systems in the adjacent ORV park. Ongoing groundwater monitoring related to the Hanford Reservation has documented occurrences of nitrate plumes with concentrations of greater than the GWQS and MCL (10 mg/L nitrate as N) in the Richland area, with sources attributed to agricultural applications of fertilizer to irrigated fields (CH2M 2015). Biosolids applications in the northern portion of the City Facility have also been considered as a source, but are not presently believed to have had substantial impacts since precipitation at the City Facility is low, and the biosolids are dry and applied in thin layers and have largely already been scraped off for other City Facility uses.

2.4.3.2 VOCs

Due to the area-wide background concentrations of inorganic indicator parameters, VOCs are the only chemicals that clearly reflect Landfill impacts. The groundwater monitoring wells located in close proximity to the MSW along the eastern edge of the Landfill (MW-5, MW-6, and MW-10) show the highest number and concentrations of VOCs. Further downgradient well MW-9, located along the southern City Facility Boundary approximately 500 ft from the waste, has also been impacted by the same suite of VOCs in lower concentrations. The other three further downgradient monitoring wells along the City Facility Boundary, MW-3, MW-4, and MW-8, each show slightly different distributions of VOCs and in generally lower concentrations.

Table 3. Maximum Concentrations of Parameters above Groundwater Quality Criteria during 2015, Horn Rapids Landfill

Parameter	Units	GWQS	MCL	Highest 2015 Observed Concentration Above Criteria					
				Upgradient or Cross Gradient (MW-1, -2, -11)		Downgradient			
						Adjacent to Active Cell (MW-5, -6, -10)		Facility Boundary (MW-3, -4, -8, -9)	
				Concentration	Well	Concentration	Well	Concentration	Well
FIELD PARAMETERS									
Conductivity	umhos/cm	NA	700	1680	MW-11	1384	MW-5	1032	MW-9
pH		6.5-8.5	NA			6.46	MW-10		
INORGANICS									
Arsenic	mg/l	0.00005	0.01	0.0068	MW-11	0.0043	MW-5	0.0086	MW-8
Selenium	mg/L	0.01	0.05	0.011	MW-11				
Nitrate	mg/L	10	10	38	MW-11	35	MW-5	17	MW-8
Sulfate	mg/L	250	250	270	MW-11				
Total Dissolved Solids (TDS)	mg/L	500	500	1,300	MW-11	870	MW-5	650	MW-9
VOCS									
Bromodichloromethane	ug/L	0.3	80					0.78	MW-8
Chloroform	ug/L	7	80					9.8	MW-8
1,1-Dichloroethane (1,1-DCA)	ug/L	1	NA			9.6	MW-10	4.0	MW-4
1,2-Dichloroethane (1,2-DCA)	ug/L	0.5	5			1.1	MW-5		
Tetrachloroethene (PCE)	ug/L	0.8	5	4.9	MW-1	40	MW-6	13	MW-9
Trichloroethene (TCE)	ug/L	3	5			20	MW-6	6.8	MW-9
Vinyl Chloride (VC)	ug/L	0.02	2			7.8	MW-5	0.069	MW-4

MW-1 and MW-11 are upgradient from the landfill; MW-2 is cross-gradient from the landfill

GWQS = Water quality standards for groundwaters of the State of Washington (WAC 173-200).

MCL = Maximum Contaminant Level (WAC 246-290)

Isoconcentration maps of detected VOCs (1,1-DCA, PCE, TCE, cis 1,2-DCE, and VC) were previously presented in the RI (Shaw 2003) using data from 2002. These maps have been updated using maximum detected concentrations at each well during 2015. Both sets of isoconcentration maps are presented in Appendix E.

The areas impacted by VOCs extend to the south-southeast in a direction generally consistent with the direction of flow indicated by recent groundwater flow contours. Although concentrations of some VOCs (especially 1,1-DCA in wells MW-5, MW-6, and MW-10, and PCE, TCE, and VC at MW-6) in the central portion of the impacted area have decreased since 2002, 1,1-DCA, PCE, TCE, and VC concentrations above the GWQS extend beyond the City Facility's southern boundary. Compared to 2002, the concentration of PCE at well MW-9 has increased, TCE and cis 1,2-DCE are present at wells MW-9, MW-3 and MW-4, and VC is present intermittently in low concentrations at wells MW-9 and MW-4. The 2015 concentrations of 1,1-DCA at wells MW-9 and MW-4 are similar to those measured in 2002, but 1,1-DCA is also present at well MW-3.

The estimated extent of VOCs exceeding GWQSs beyond the City Facility Boundary for 1,1-DCA, PCE, TCE, and VC are shown on the 2015 isoconcentration maps. Except for 1,1-DCA, the estimated extent is limited to a distance of less than 400 ft from the City Facility Boundary.

Trend analyses indicate that VOC concentrations have shown significant decreases in some downgradient wells during the 5 years since Phase 1 Landfill closure, including 1,1-DCA in wells MW-3, MW-6, and MW-10, and chlorinated ethenes (TCE, trans 1,2-DCE, and VC) in well MW-6. Well MW-6 is located near the older portion of the Landfill that has completed Phase 1 closure. However, upward trends of cis 1,2-DCE, PCE and VC have been observed in well MW-10 located closest to the area of active filling, and PCE in well MW-9 located at the southern City Facility Boundary.

Additional parameters are being monitored to assess whether natural attenuation is occurring, including methane, ethene, and ethane, and dissolved oxygen (DO) and oxidation-reduction potential (ORP). DO and ORP measurements continue to indicate that conditions in groundwater near the Landfill source are consistent and favorable for biodegradation of chlorinated hydrocarbons. However, analysis of other evidence is inconclusive. The continuing presence of methane in groundwater could indicate biodegradation of organic carbon is occurring via methanogenesis; however natural attenuation via methanogenesis would be expected to result in production of ethene and ethane and these compounds have not been detected, and methane is also contributed directly by LFG. Trends in other parameters that might indicate that biodegradation is occurring, such as increases in chloride or alkalinity, or decreases in nitrate and sulfate, are somewhat ambiguous because concentrations of these parameters have been affected by influences from upgradient sources.

3. PRELIMINARY CONCEPTUAL SITE MODEL

The conceptual site (CSM) is presented for each media describes potential suspected sources, types, and concentrations of hazardous substances, and exposure pathways and receptors. The CSM provides a tool to identify data gaps and work to be conducted.

3.1 Landfill Gas

LFG probe data are available since 1998. LFG in the vadose zone has historically been present only in gas probes GP-2, GP-5 (now decommissioned), GP-9, and GP-12. These probes are all within close proximity (within about 100 ft) of the Phase 2 Landfill refuse boundary. No LFG has been detected in probes along the Phase 1 Landfill perimeter (GP-1, GP-3, GP-4, GP-6, and GP-7); these probes are about 150 ft from the refuse boundary. No LFG has been detected in probes further from the Landfill (about 300 to 500 ft) along the City Facility Boundary (GP-8, GP-10, or GP-11). These data support the conceptual model that LFG does not migrate in the subsurface for large distances from the waste.

Most of the LFG probes have one screened interval near the center of the waste thickness and one at the approximate elevation of the bottom of the waste. Comparing methane levels between multi-screened probes suggests that LFG is present in the entire zone between the base of the MSW to the surface of the groundwater, although the highest concentrations are typically observed in the zone near the bottom of the MSW. Phase 2 of the RI found LFG present within the screened interval of MW-7 (83.5 to 105 ft bgs) and GP-12-3 (73.5 to 83.5 ft bgs).

These data indicate that LFG and groundwater have historically interacted only in a limited area immediately beneath the waste and in a limited zone surrounding the waste. LFG is expected to migrate laterally and upward through the sandy unsaturated soils due to pressure and concentration gradients and discharge to the atmosphere.

Since its startup in 2011, the Phase 1 LFG extraction system and cover are effectively removing the LFG within close proximity of the bottom of the MSW and the Landfill's downgradient lateral perimeter as demonstrated by the sharp decreases in methane concentrations observed at multilevel gas probes GP-2 and GP-12, including deep probe GP-12-3, screened immediately above the water table. Methane concentrations in GP-12 have decreased from over 30 percent by volume prior to closure to five percent or less during 2015. The LFG source is expected to be further reduced upon full closure of the Landfill that is anticipated in 2020 which will include an expanded LFG extraction system, thus reducing or eliminating future VOC impacts to groundwater.

3.2 Leachate

Leachate is believed to be a minor overall contributor to historical groundwater impacts. Due to the arid environment, only minimal quantities of leachate were produced in the lysimeters in the early stages of landfilling when the waste was thin, and since then any leachate generated is being absorbed by the waste. The small quantities of leachate generated historically have contained a similar suite of VOCs at concentrations similar to those observed in groundwater. However, the geochemical signatures are slightly different than sampled groundwater, and some additional VOCs have been detected in leachate that are not present in groundwater.

3.3 Groundwater

Groundwater that has already been impacted by LFG containing VOCs will continue to move downgradient and will be naturally attenuated through processes such as advection, dispersion, sorption, and biodegradation. However, due to the relatively low flow rate and low rainfall, dilution is not expected to be significant, and sorption is likely to be low due to the low organic carbon in soils (typical total organic carbon concentrations are less than 5 mg/L). The primary VOCs of concern in groundwater at the Landfill are chlorinated ethenes (PCE, TCE, DCEs, and VC) and ethanes (1,1-DCA). An important potential mechanism for biodegradation of these compounds is reductive dechlorination whereby the more highly chlorinated compounds are reduced to less chlorinated compounds (EPA 1998, Jurgens et al 2009). Evaluation of natural attenuation parameters including reduced DO and ORP indicates degradation of chlorinated hydrocarbons is occurring at least near the Landfill source, although analysis of other indicator parameters is inconclusive.

Over the past 13 years, concentrations of some VOCs close to the Landfill have decreased, but the impacted area has expanded in the downgradient groundwater flow direction. The observed changes in impacted area dimensions are consistent with the measured flow direction, and the downgradient extent of impacts are consistent with the calculated groundwater flow rate of approximately 20 ft per year, or about 250 ft over the last 13 years. Monitoring data show that VOC impacts are limited to the hydraulically downgradient area in close proximity to the City Facility Boundary, consistent with the low rate of groundwater flow.

There are no downgradient users of groundwater or occurrences of surface water within over a mile downgradient of the Landfill. As shown on Figure 1, the City owns the property southeast of and hydraulically downgradient from the Landfill extending a distance of over 1,500 ft. It is expected that the movement of impacted groundwater will be restricted to an area within the City Property beyond the City Facility Boundary for many years, enhancing the potential for natural attenuation. Regional groundwater vertical gradients in the uppermost aquifer are believed to be upward, restricting the downward movement of contaminants to lower aquifers.

3.4 Conceptual Site Model Summary

The RI concluded that LFG was the primary source of the contaminants observed in groundwater. LFG interacts with moisture in the vadose zone and with groundwater in the capillary zone of the water table, where it becomes dissolved in and transported with groundwater flow. The concentrations of VOCs measured in LFG during the RI were high enough to comprise the primary source of VOCs in groundwater. Although it is possible that some leachate may also be produced within the waste, the on-site lysimeters have demonstrated that little to no leachate is being accumulated below the waste, due to the arid conditions and the ability of the waste to store the moisture that is generated.

Groundwater with concentrations above GWQSs has moved beyond the City Facility Boundary onto additional City Property, and natural attenuation is expected to occur prior to movement off City Property due to low groundwater flow rate. There are no current or anticipated risks to human health or the environment based on the data obtained to date. The presumptive remedy is to continue removing LFG and leachate sources through the system already in progress and to enhance removal through the second phase of landfill closure.

3.5 Preliminary Chemicals of Concern

Based on the measured concentrations at the Facility Boundary, the following VOCs are present in concentrations greater than GWQSs and are considered to be the preliminary chemicals of concern (COCs) for the Landfill.

Table 4. Preliminary Chemicals of Concern, Horn Rapids Landfill

Parameter	Units	GWQS	MCL	Highest 2015 Concentration Observed at Facility Boundary	Monitoring Well
Bromodichloromethane	ug/L	0.3	80	0.78	MW-8
Chloroform	ug/L	7	80	9.8	MW-8
1,1-Dichloroethane (1,1-DCA)	ug/L	1	NA	4.0	MW-4
Tetrachloroethene (PCE)	ug/L	0.8	5	13	MW-9
Trichloroethene (TCE)	ug/L	3	5	6.8	MW-9
Vinyl Chloride (VC)	ug/L	0.02	2	0.069	MW-4

3.6 Receptors/Exposure Pathways by Media

A summary of the receptors and exposure pathways by media is provided below, based on the conceptual site model.

LFG – The presence of LFG in the vadose zone is limited vertically to the area between the bottom of the MSW and the water table, and laterally, to a limited zone surrounding the MSW. LFG has not migrated beyond the City Facility Boundary. LFG has not been detected in on-site buildings. Therefore, there are no direct exposure pathways to human receptors.

Leachate - There is minimal leachate generation from the Landfill as shown by the lack of leachate collected in the lysimeters, and therefore there are no exposure pathways.

Groundwater - Possible receptors for VOC contaminated groundwater would be downgradient domestic well users, either via drinking water or inhalation of VOCs. However, since the closest domestic water well in a downgradient direction is located more than 2 miles from the City Facility, there are no completed exposure pathways. In addition, natural attenuation is expected to occur prior to movement of groundwater off City Property due to the low flow rate.

Surface Water – There is no off-site runoff, and the closest surface water to the City Facility is the Yakima River, over 1 mile from the City Facility, and the Columbia River, over 3 miles from the City Facility. Therefore there are no exposure pathways.

Soil – There is no known soil contamination at the City Facility. A risk assessment to assess potential impacts to terrestrial plants and animals in accordance with Chapter 173-340-7491 WAC is not expected to be required, since there are no hazardous substances expected to be present in soils. Any potential soil contamination associated with contaminated groundwater would be located at a depth below the point of compliance of 15 ft bgs.

4. WORK PLAN APPROACH

This section provides a summary of the data gaps identified by the conceptual site model, and objectives and approach for the field investigation.

4.1 Data Gaps

A substantial amount of data has been collected at the City Facility for approximately the past 30 years. However, the following data gaps have been identified based on the information presented in previous sections.

- The downgradient extent of VOCs in groundwater on City Property beyond the City Facility Boundary needs to be determined.
- The groundwater flow gradient downgradient of the City Facility needs to be refined and confirmed.

4.2 Work Plan Objectives

The work outlined in this section of the work plan has the following objectives:

- Define the downgradient extent of contaminants in groundwater originating from the Landfill, and refine the groundwater flow direction.
- Locate and install an additional downgradient monitoring well to confirm that natural attenuation of VOCs in groundwater is occurring, and to monitor for future potential impacts from the existing Landfill and proposed Expansion.

In addition to the activities outlined in this work plan, the following ongoing activities will be conducted.

- Continue monitoring VOC trends in existing groundwater wells included in the monitoring network. Analysis should use methodology that achieves reporting limits below GWQSs.
- Continue operating LFG collection system and monitoring methane trends in gas probes.
- Due to the area-wide background concentrations of several analytes, focus future testing on COCs and reduce the frequency of testing for parameters other than COCs.

4.3 Investigation Phasing

A phased investigation approach will attempt to use direct push probes to collect groundwater samples, and use the concentrations of VOCs measured in the samples to select a location for an additional downgradient monitoring well to be installed during a second phase of work. The objective of the Phase 1 push probe sampling will be to locate the furthest extent of the contamination directly downgradient from the central portion of the contaminant plume so that a permanent groundwater monitoring well can be installed during Phase 2 at a location that has not been impacted. This well will be used as a sentinel well for the assessment monitoring program.

If the push probe procedure is not effective, one monitoring well will instead be installed at a pre-selected location during the first phase of work.

4.4 Phase 1 - Direct Push Probes

The City will contract with Atkins (formerly EnergySolutions, Inc.) to collect groundwater samples using direct push technology (EPA 2005) at up to six locations on City Property downgradient of the Landfill. Atkins has devised a sampling system that has been used successfully to sample soils and groundwater at the nearby Hanford Reservation to depths of over 200 ft. Atkins believes their direct push system can be used to sample groundwater downgradient and in the vicinity of the Landfill.

The planned Phase 1 investigation will consist of the following sequence of activities:

- Six push probe installations will be conducted until groundwater is encountered to approximate depths of 100 ft, and groundwater samples will be collected from each probe at the total depth. No soil samples will be collected for chemical analysis.
- A trial push probe installation will be conducted to test whether the technology will be successful. If the push probe technology is successful, five additional probes will be installed.
- If the push probe trial is not successful, a driller will be contracted and a new downgradient monitoring well will be installed at the location shown on Figure 4.
- Groundwater samples will be collected from each push probe using a portable bladder pump.
- The groundwater samples will be hand delivered to a local analytical laboratory, Energy Northwest Environmental Lab, in Richland, WA, and tested for VOCs.

4.4.1 Push Probe Locations

The isoconcentration maps for 2015, shown in Appendix E, illustrate that the area impacted by COCs extends to the south of well MW-9, but also to the southeast of well MW-4. Since the groundwater flow direction is toward the southeast, and varies seasonally to south-southeast, the impacted area downgradient from the existing MSW is expected to be wedge shaped and extend from due south of MW-9 to east-southeast of MW-3 and MW-4. Except for 1,1-DCA, the contaminant distribution indicates that concentrations exceeding GWQSs are limited to an estimated distance of less than 400 ft from the City Facility Boundary.

Gas probe data indicates that LFG is only present in close proximity to the Landfill (less than about 100 ft), and only in gas probes GP-2, GP-9, and GP-12. Groundwater impacted by LFG in this area would generally flow toward existing wells MW-8 and MW-9. However due to groundwater impacts observed in MW-1, and lack of deeper screened gas probes in the southwestern portion of the City Facility, the push probe investigation has been planned to confirm the absence of LFG impacts to groundwater in the area downgradient from the southwesternmost portion of the Landfill.

Figure 4 shows the proposed locations of the first three push probes (PP-1 through PP-3), and possible locations for three additional probes (PP-4 through PP-6) to be installed only if VOCs are detected at the first three push probes. The rationale for selecting the first three push probe locations is outlined in Table 4-1. Probe numbers reflect the tentative order of installation. Decisions on subsequent probe locations will be based on VOC results that are expected to be available by the close of business of the following day. The schedule assumes one probe will be sampled each day.

It is important to note that the positions of the probes are tentative and provided for discussion purposes only, and the actual locations will be adjusted in the field based on ongoing results of VOC analyses. Probe locations may be adjusted based on the VOC results observed in previous probes, and all decisions will be agreed upon by consultation between representatives of Ecology, the City, and Parametrix.

Table 5. Data Quality Objectives for Initial Push Probe Locations

Probe Name	Location	Selection Criteria Notes	Data Quality Objective
PP-1	Near City Facility boundary between GP-10 and GP-11	Exact location to be determined in field based on logistics	Evaluate potential impacts to groundwater along City Facility Boundary due to LFG near the southern Landfill Refuse Boundary
PP-2	Downgradient from MW-9 (well with highest PCE concentrations at Facility Boundary)	Beyond projected extent of PCE concentrations above GWQSs	Evaluate extent of VOCs beyond City Facility Boundary
PP-3	Downgradient from MW-6 and MW-8	Beyond projected extent of VOC concentrations above GWQS	Evaluate extent of VOCs beyond City Facility Boundary

4.4.2 Push Probe Installation Procedures

Atkins will employ a hydraulic hammer probe driving unit that has the following features (see photographs of their equipment and specifications presented in Appendix F):

- Tractor unit mounted on Caterpillar 416C back-hoe tractor (small turning radius [19 ft] and have very low overall weights [less than 20,000 lbs])
- Mast with 6’ 9” travel allowing for utilization of 4 foot length rods
- Eurodrill hydraulic driven hammer with 450 ft/lb striking force per blow, cycling between 500 and 2000 blows per minute, rotating head with swivel and 10,000 ft/lbs of torque for use to make up and break out pipe
- 12,000 lbs to 18,000 pull back force and a total down force on the hammer of 10,000 lbs
- Horizontal cradle on which a mast and hammer can be mounted to push from 15 degrees to horizontal.

Atkins-EnergySolution’s Single String system driving and sampling system (used when only one sample is required at a given location) is deployed on 2.5-in. OD x 1.75-in. ID push rods and consists of three stainless steel liners contained within a rod-delivered sampler body. These three liners are each 1.66 in. OD x 1.53 in. ID x 6 in. long. The probe driving equipment is moved to the appropriate location and the sampler is advanced to the target depth. By use of a key release mechanism the removable tip is released and the open sampler is advanced through the targeting depth. The entire rod string and sampler are then retrieved to surface. The sampler is removed from the push tubing and the stainless steel liners are extracted from the sampler mechanism.

The proposed direct push tooling method for the Horn Rapids Landfill investigation project will be as follows.

- Drive down to target depth (100 to 120 ft bgs).
- Knock out drive tip and pull back a few inches to ensure tip is free.
- Run in a standard stainless steel well screen on tubing and place on the bottom of hole.
- Back pull direct push tubing approximately 5 ft.
- Run sampling pump and collect groundwater sample.
- Remove screen and tubing.
- Decommission push hole by introducing grout as drive tubing is removed.

The ground surface elevation at each of the proposed locations shown on Figure 4 will be surveyed in advance using GPS technology. The expected depth for encountering groundwater will be determined in advance based on projections from the calculated potentiometric groundwater surface as measured in the groundwater monitoring wells. The tooling will be driven to the targeted depth that will be 10 ft deeper than the calculated groundwater depth.

Under the assumption that the formation may not stand open, Atkins will install a 10-ft temporary standard stainless steel screen into each probe prior to sample collection. Since the formation is expected to contain approximately 10 to 15 percent fine-grained sand and/or silt, this screen will filter some of these particulates to reduce turbidity. The planned slot size of the screen will be 20 slot (0.2 inch) based on the anticipated sediment size in the screened zone. Although full development of the probe will not be possible, prior to sampling the portable bladder pump will be used to purge some water prior to sampling to reduce the amounts of fines. Potential impacts of sources of bias in concentrations of VOCs or dissolved gases during sampling are presented in Table 3.1 of EPA (2005). Turbidity present within the samples is not expected to cause significant bias in concentrations of VOCs or dissolved gases (EPA 2005, see Table 3.1).

Increases in temperature during sampling can potentially cause a negative bias in concentrations of VOCs or dissolved gases (EPA 2005, see Table 3.1). However, temperature increases related to the push probe drilling procedure are not expected to be a concern. Based on Atkins' experience related to soil sampling, there has never been any indication of excessive heat buildup at the drive point or any indication of a heat signature from the driving action when conducting temperature logs (part of their geophysical logging suite runs), and soil samples have never come up thermally hot. The only heat buildup occurs at the surface drive head where the force is applied directly from the hammer to the drive pipe. The procedure will consist of driving to target depth, dropping in a screen on tubing, then pulling back the drive tubing; therefore, the water sample collected will not contact the drive pipe.

In addition, due to the small diameter of the probe (about 2.5 inches), any heat buildup would not be expected to extend very far into the formation, especially below the water table. It is anticipated that the flow of water across the screened interval will dissipate any heat that has built up during the installation process. To monitor temperature during sampling, field parameters will be measured regularly during the purging process using a flow cell setup to confirm that the samples collected are representative of groundwater conditions.

The screen will be decontaminated between push probe installations using the procedures described in the Quality Assurance Project Plan (QAPP).

4.4.3 Push Probe Groundwater Sampling and Analysis

Groundwater samples will be collected at each probe location using a portable bladder pump (see examples presented in Appendix G) with a small diameter of 0.75 inches that will be easily accommodated within the temporary screen. EPA (2005, see Table 3.2) recommends using bladder pumps for low flow sampling for all types of analytes. The portable bladder pump will be decontaminated between push probe locations using the procedures described in the QAPP.

Groundwater sampling will be conducted using low flow purging techniques as detailed in SOPs presented in the QAPP (Parametrix 2016b). Field parameters (conductivity, pH, temperature, DO, and ORP) will be measured during sampling.

The groundwater samples will be hand delivered to a local analytical laboratory, Energy Northwest, located in Richland, WA, and tested for VOCs with a 24-hour turnaround so that the results can be used to confirm the location of subsequent push probes. A list of VOCs that will be analyzed and their expected reporting limits are presented in Appendix G. Laboratory procedures and analytical methods are presented in the QAPP (Parametrix 2016b).

In addition, probe groundwater samples will be tested for other parameters, if sample quantities are adequate. These additional parameters will consist of the additional natural attenuation parameters methane, ethane, and ethane (RSK parameters). Specific conductivity, pH, temperature, DO, and ORP will be measured in the field.

Ecology will be informed by email two weeks in advance of the tentative date that the push probe investigation will be initiated. Any subsequent changes to the schedule will be provided to Ecology by email and by phone.

Ecology will be furnished with laboratory results as soon as they become available. Ecology will be contacted in person or by phone, and by email.

4.5 Phase 2 - Groundwater Monitoring Well

One downgradient monitoring well will be installed on City Property southeast of the Horn Rapids Landfill in 2017 unless the push probe technology is unsuccessful during Phase 1. In the event direct push probe installation is not successful, the downgradient well will be installed in 2016, at the approximate location shown on Figure 4.

The proposed location of the monitoring well to be installed if push-probe technology does not work was selected with a data quality objective to confirm the absence of contamination downgradient from the center of the contaminant plume, at a distance from the edge of City Property that is sufficient to allow additional actions to be taken in the event that contaminants are identified. Any contaminants identified at the proposed location (greater than 1,000 ft from the City Property Boundary) would not move beyond the City Property for over 50 years at the calculated flow rate of approximately 20 ft per year.

The location is directly downgradient from well MW-9 along the City Facility Boundary that has shown the highest concentrations of VOCs. This well will be used as a sentinel well to identify potential contamination releases from the existing Landfill.

If push-probe technology does not work, the City will confirm the location with Ecology prior to installation.

The following activities will be conducted:

- One groundwater monitoring well will be installed into uppermost groundwater, to a total depth of approximately 100 ft using the air rotary method.
- The groundwater monitoring well will be 2-in diameter Schedule 80 PVC, with a 15-ft screened interval. The top of the screen will be set at a depth approximately 5 ft above the water table encountered during drilling. Construction of the monitoring well will follow the specification previously developed for well MW-11 (see Appendix H).
- Groundwater samples will be collected and tested for WAC 173-351 Appendix I and II parameters using existing procedures described in the QAPP.

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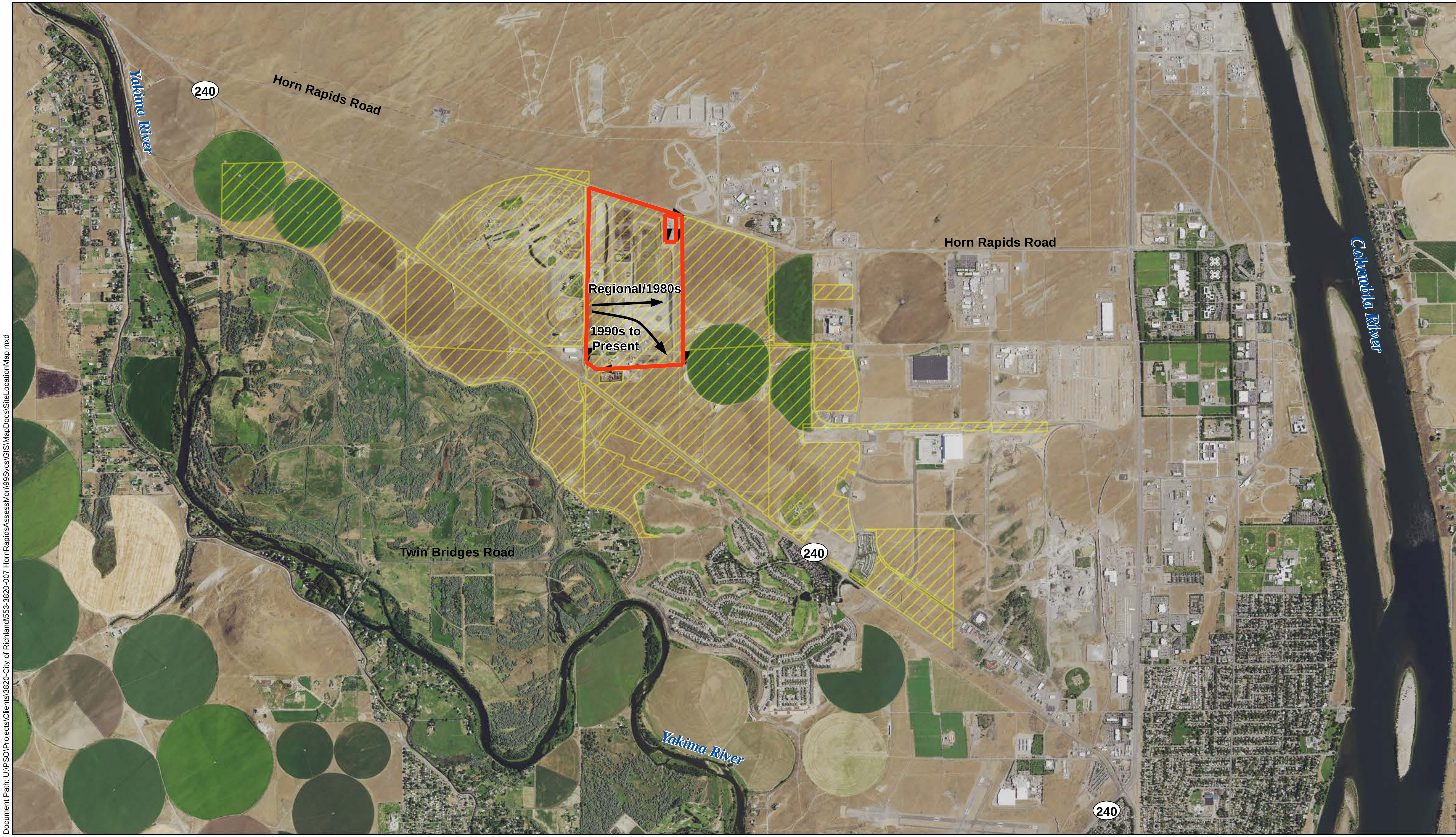
Figures



Parametrix
ENGINEERING . PLANNING . ENVIRONMENTAL SCIENCES

Miles
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Image Source: NAIP (2015 Imagery)

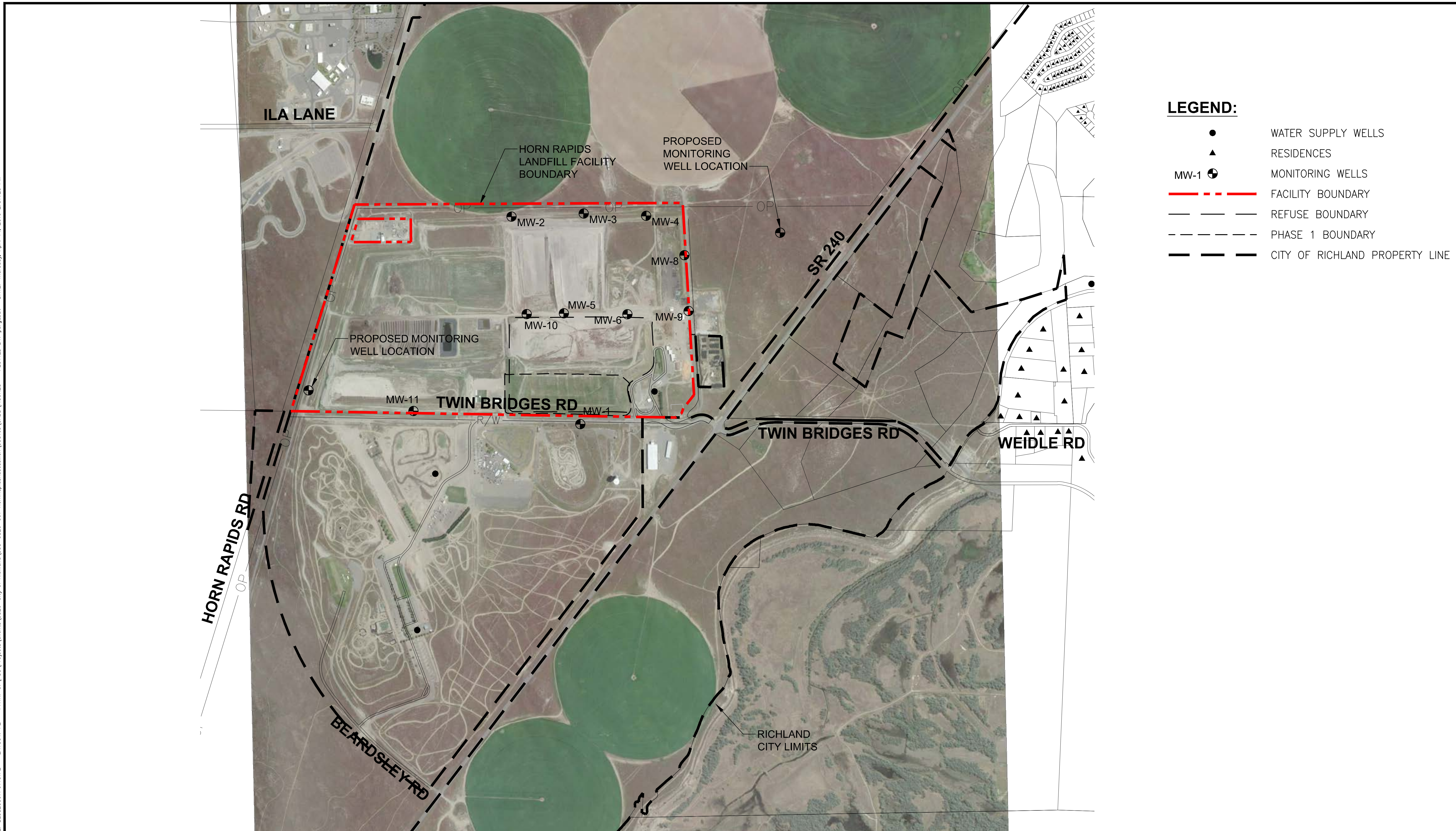
Legend

Facility Boundary

City Owned Property

Approximate Groundwater Flow Direction

FIGURE 1
Horn Rapids Landfill
Site Location Map



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SCALE IN FEET

Figure 2
Horn Rapids Landfill
Vicinity Plan

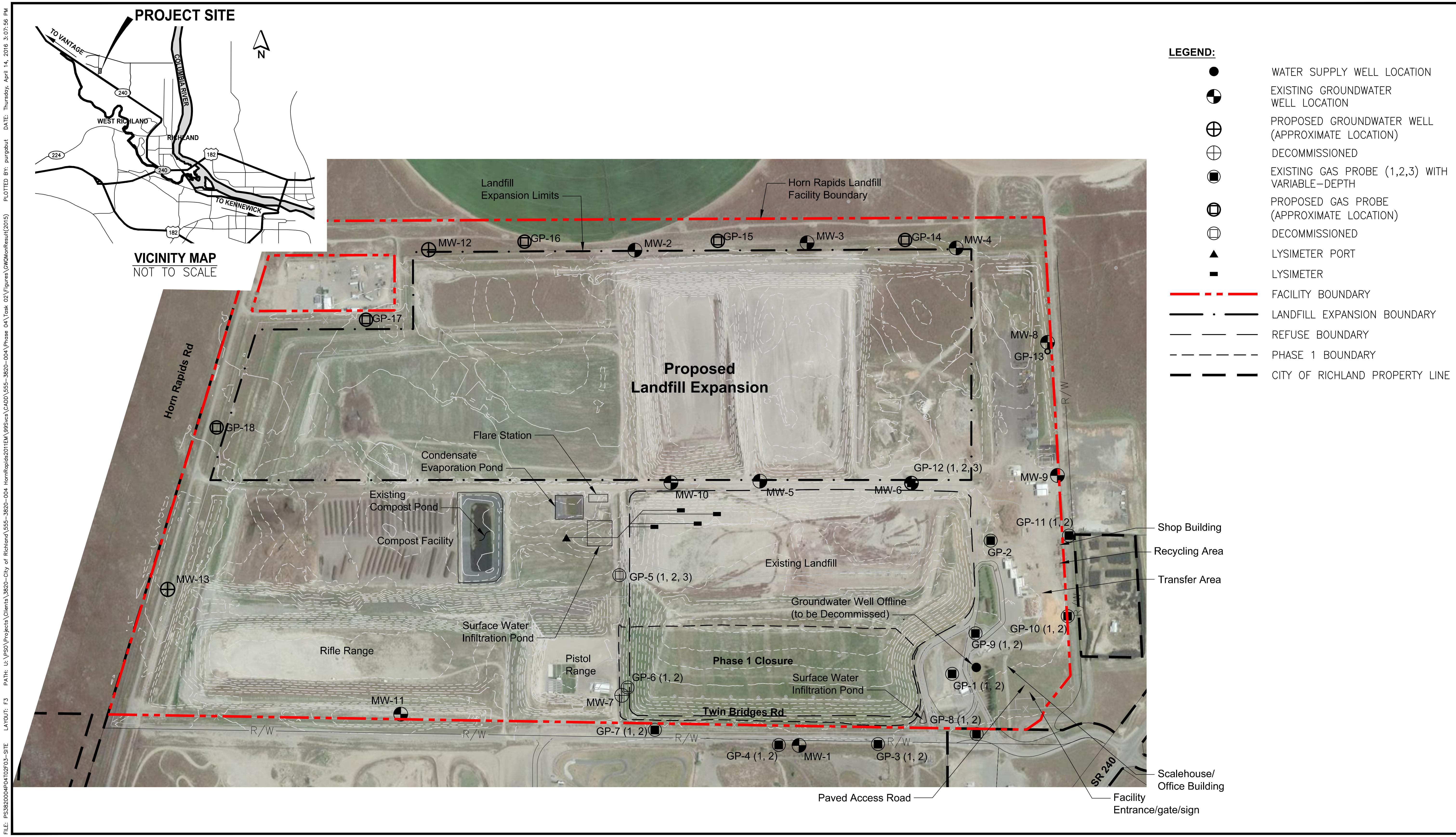

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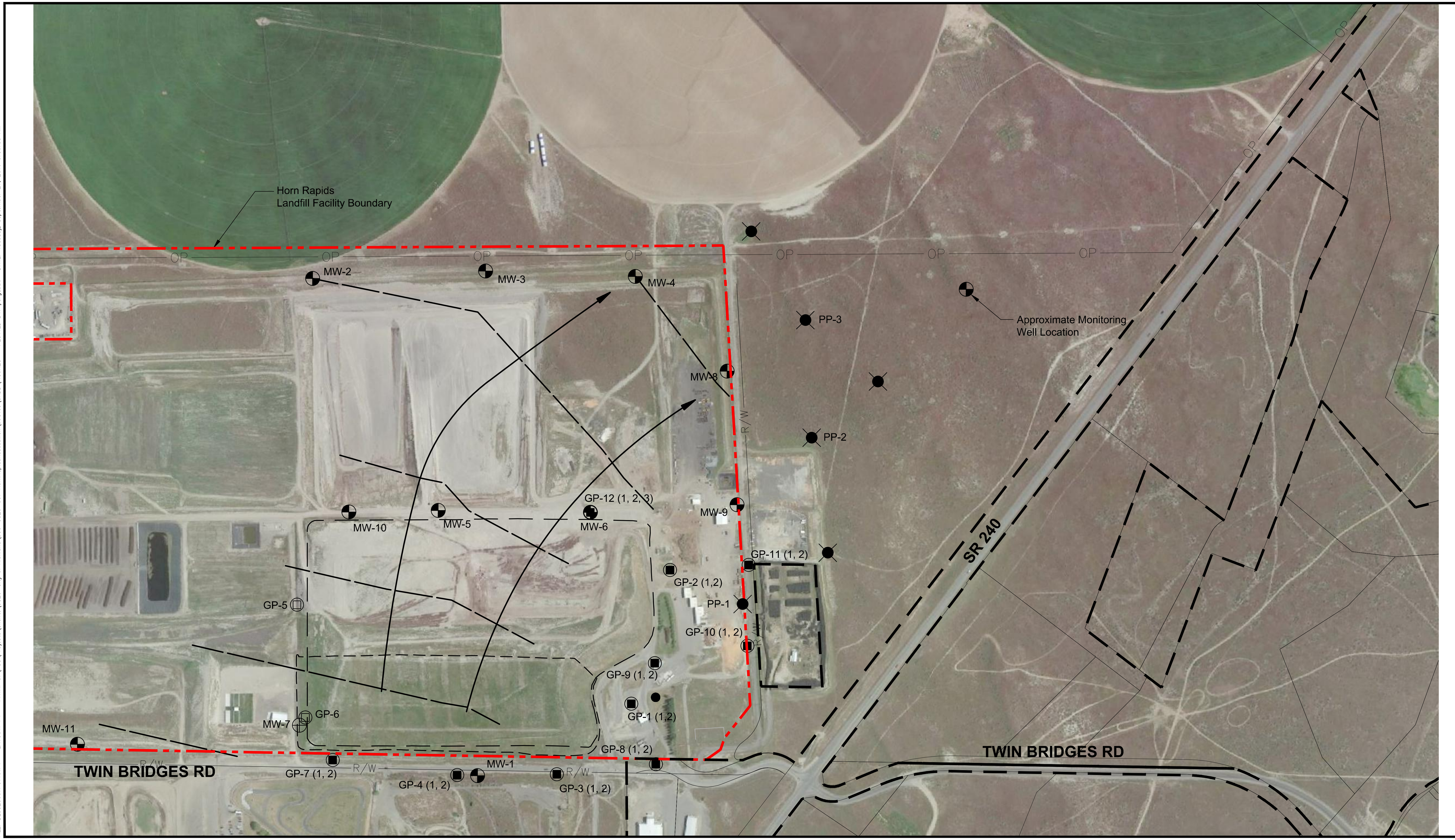
Figure 3
Horn Rapids Landfill
Site Plan



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SCALE IN FEET

Legend:

- Water Supply Wells
- Monitoring Wells
- Gas Probes
- Proposed Push Probe Locations
- Facility Boundary
- City of Richland Property Line
- Approximate Groundwater Flow Contours
- Groundwater Flow Direction
- Refuse Boundary
- Phase 1 Boundary

Figure 4
Proposed Push Probe and Monitoring Well Locations Horn Rapids Landfill

Appendix A

Geologic Cross Sections

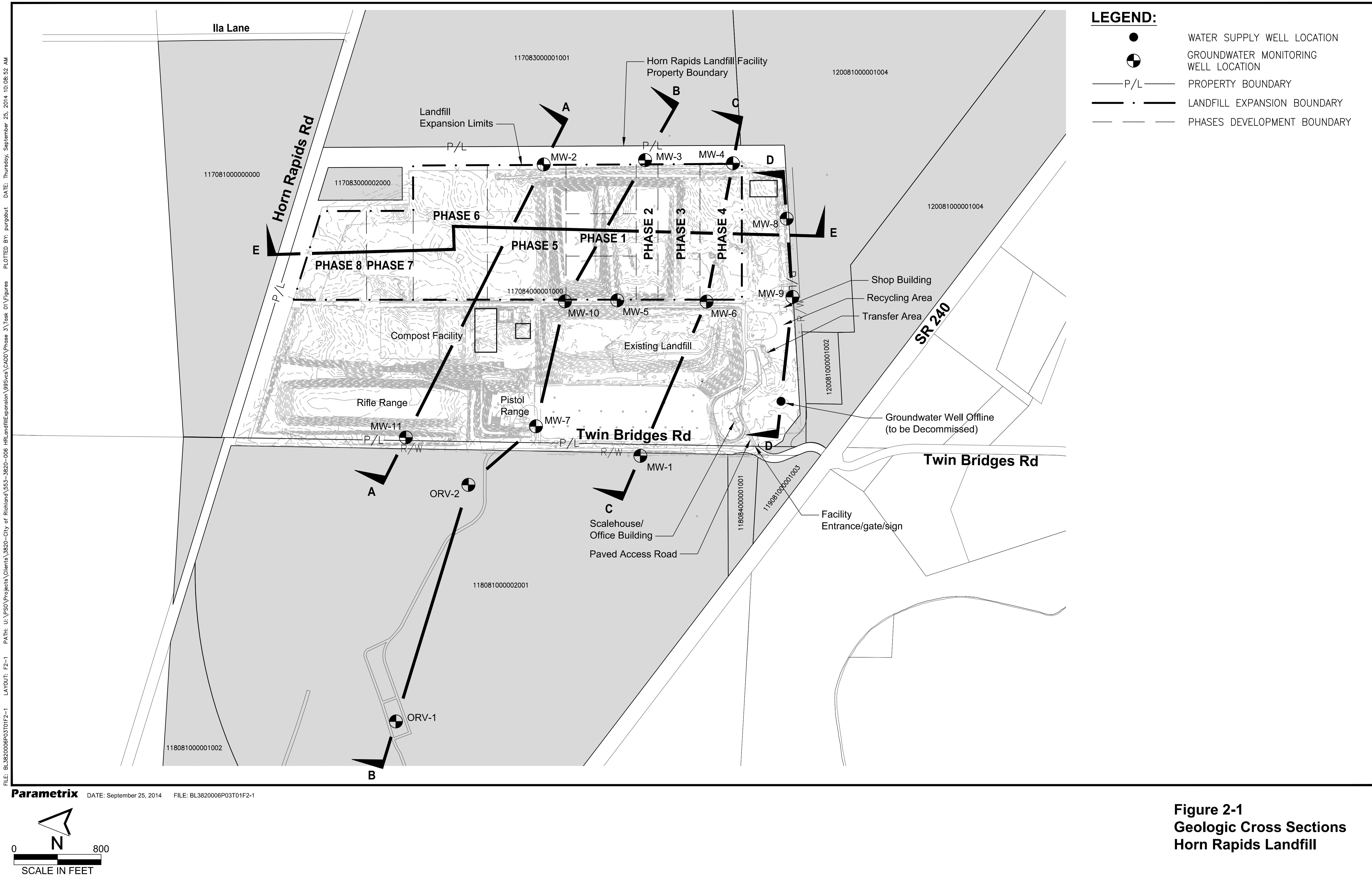
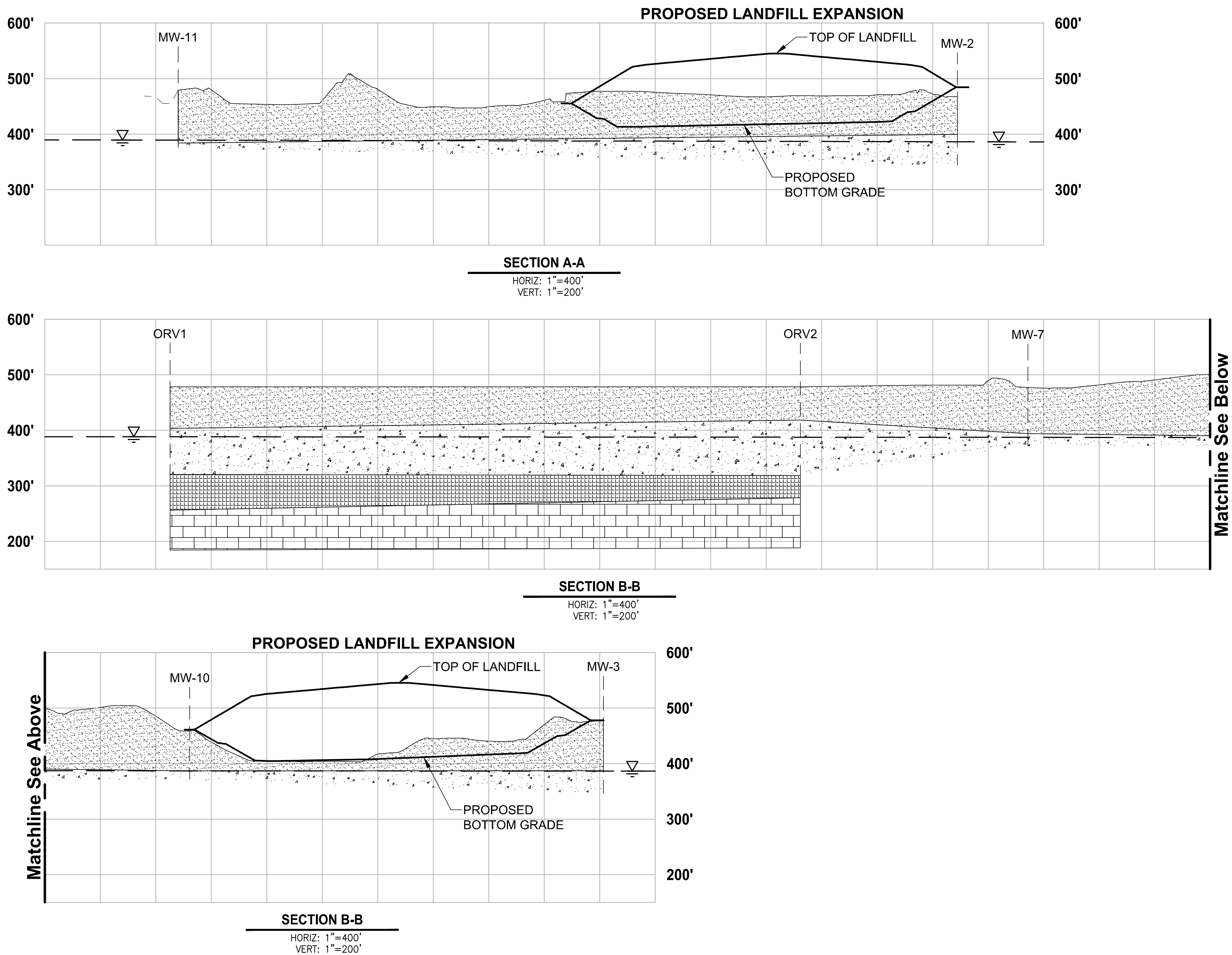


Figure 2-1
Geologic Cross Sections
Horn Rapids Landfill



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Parametrix DATE: April 13, 2016 FILE: BL3820006P03T01F4-1

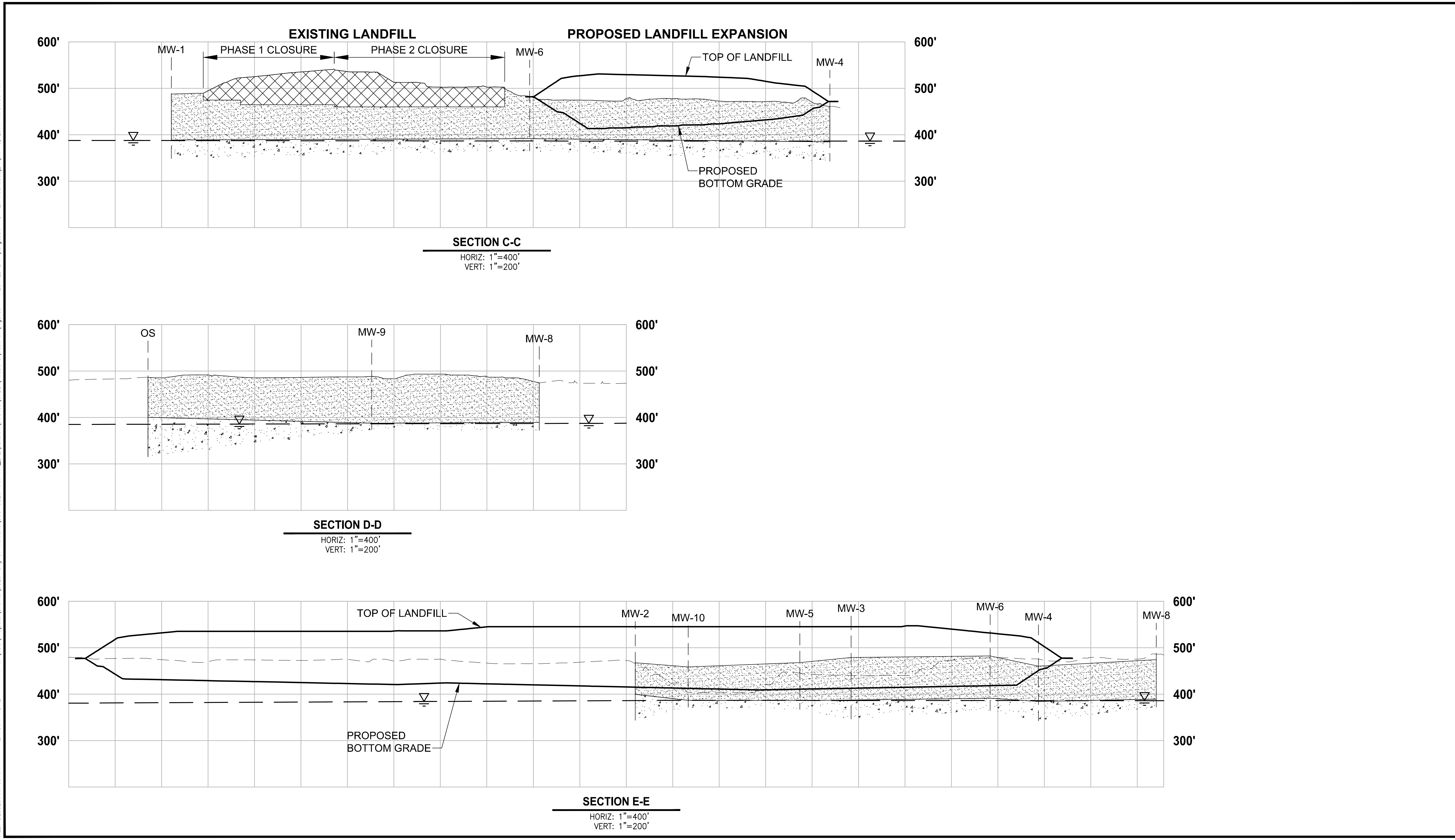
Legend:

- Sand
- Sand and Gravel
- Clay
- Basalt
- Groundwater Elevation

Note:

Vertical Datum: NAVD88

Figure B-1
Geologic Cross Sections
Horn Rapids Landfill



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Parametrix DATE: April 13, 2016 FILE: BL3820006P03T01F4-1

Legend:

- Sand
- Sand and Gravel
- Refuse
- Clay
- Basalt
- Groundwater Elevation

Note:

Vertical Datum: NAVD88

Figure B-2
Geologic Cross Sections
Horn Rapids Landfill

Appendix B

Potentiometric Surface Maps

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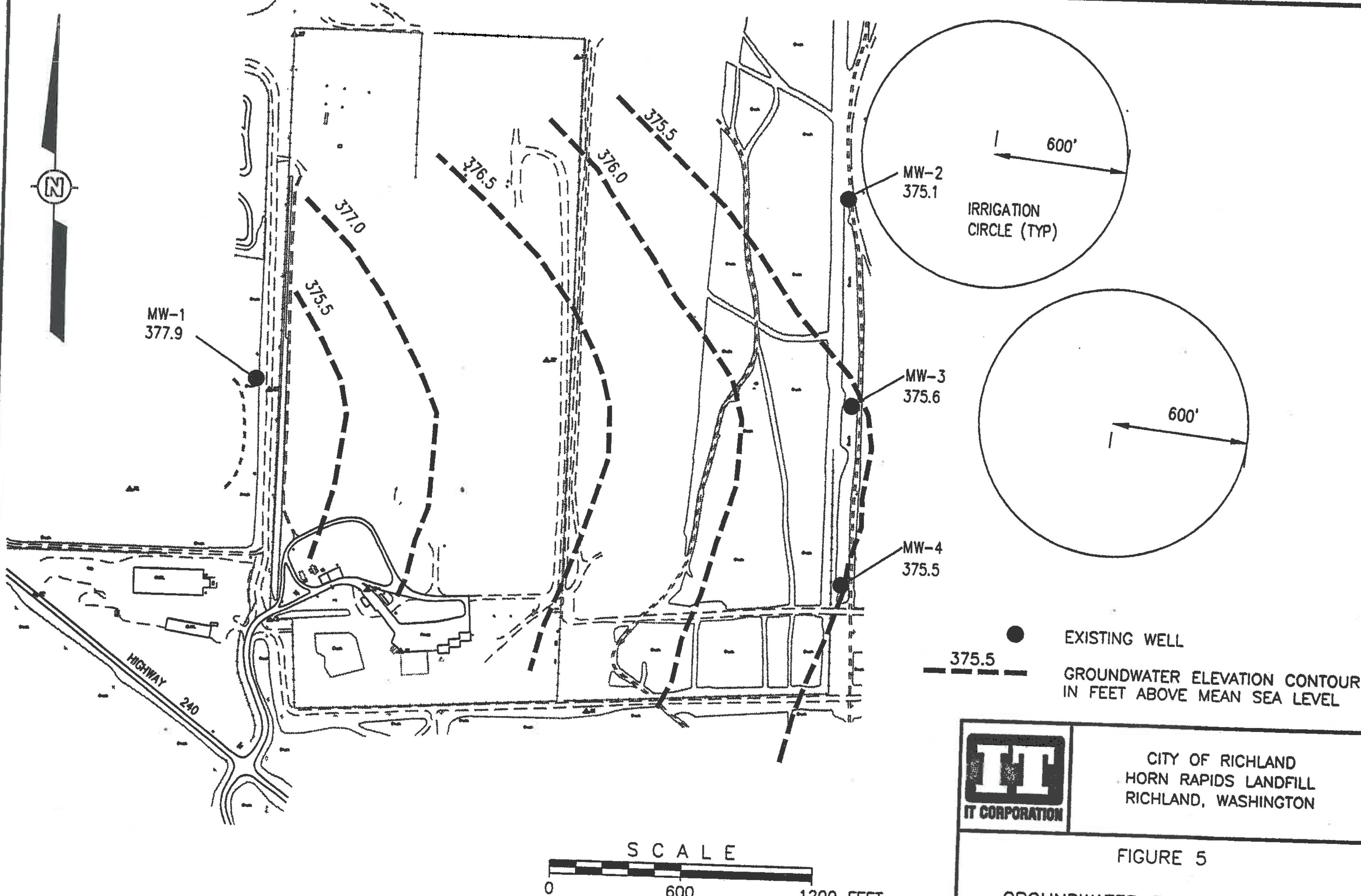


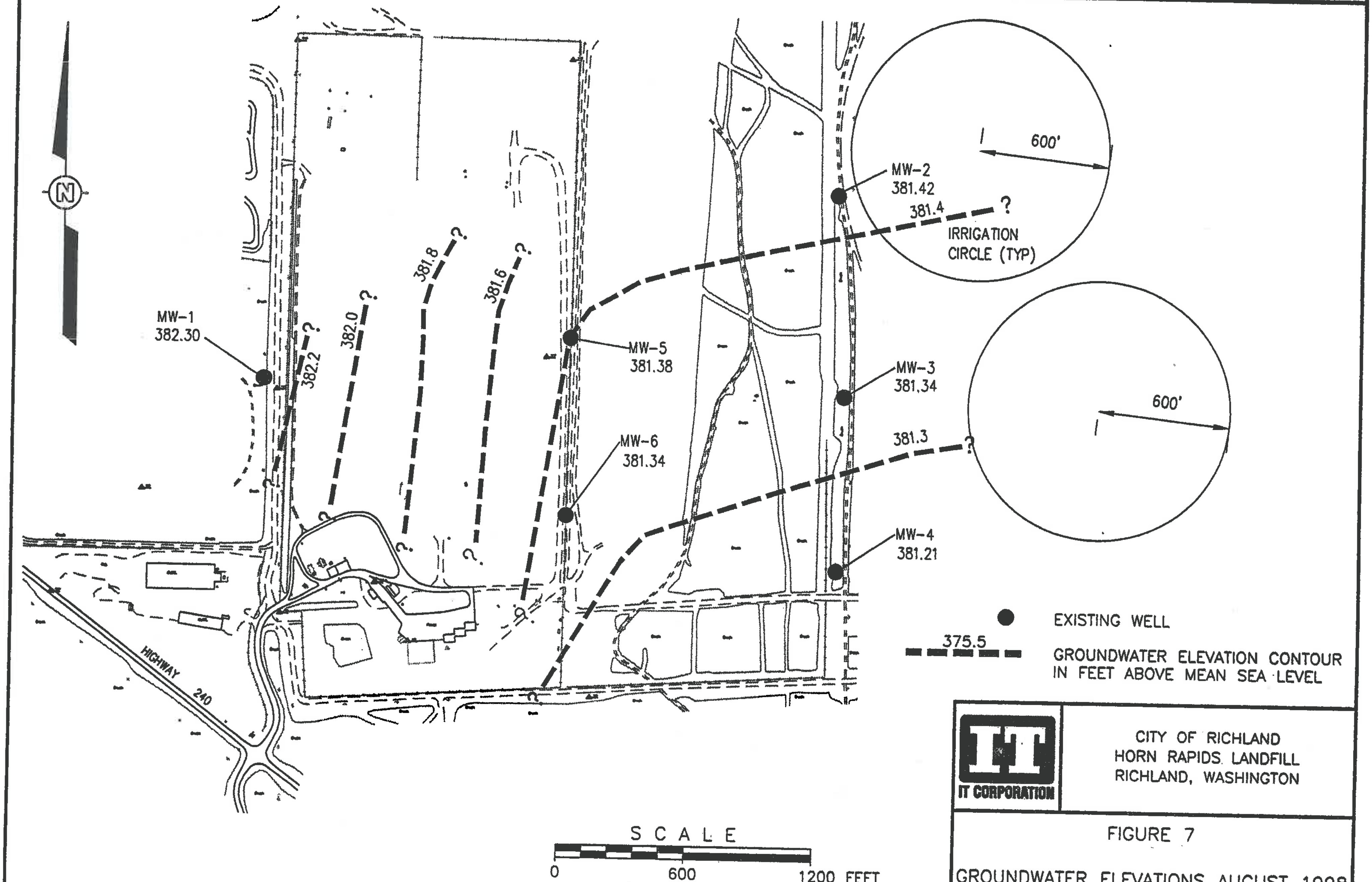
IT CORPORATION

CITY OF RICHLAND
HORN RAPIDS LANDFILL
RICHLAND, WASHINGTON

FIGURE 5

GROUNDWATER ELEVATIONS 1987
RICHLAND LANDFILL
RICHLAND, WASHINGTON

[redacted]	[redacted]	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER 810835_FIG3
---	---	RICHLAND, WA	J. WILLIAMS	9/5/00					



IT CORPORATION

CITY OF RICHLAND
HORN RAPIDS LANDFILL
RICHLAND, WASHINGTON

FIGURE 7

GROUNDWATER ELEVATIONS AUGUST 1998
RICHLAND LANDFILL
RICHLAND, WASHINGTON

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY	APPROVED BY		DRAWING NUMBER
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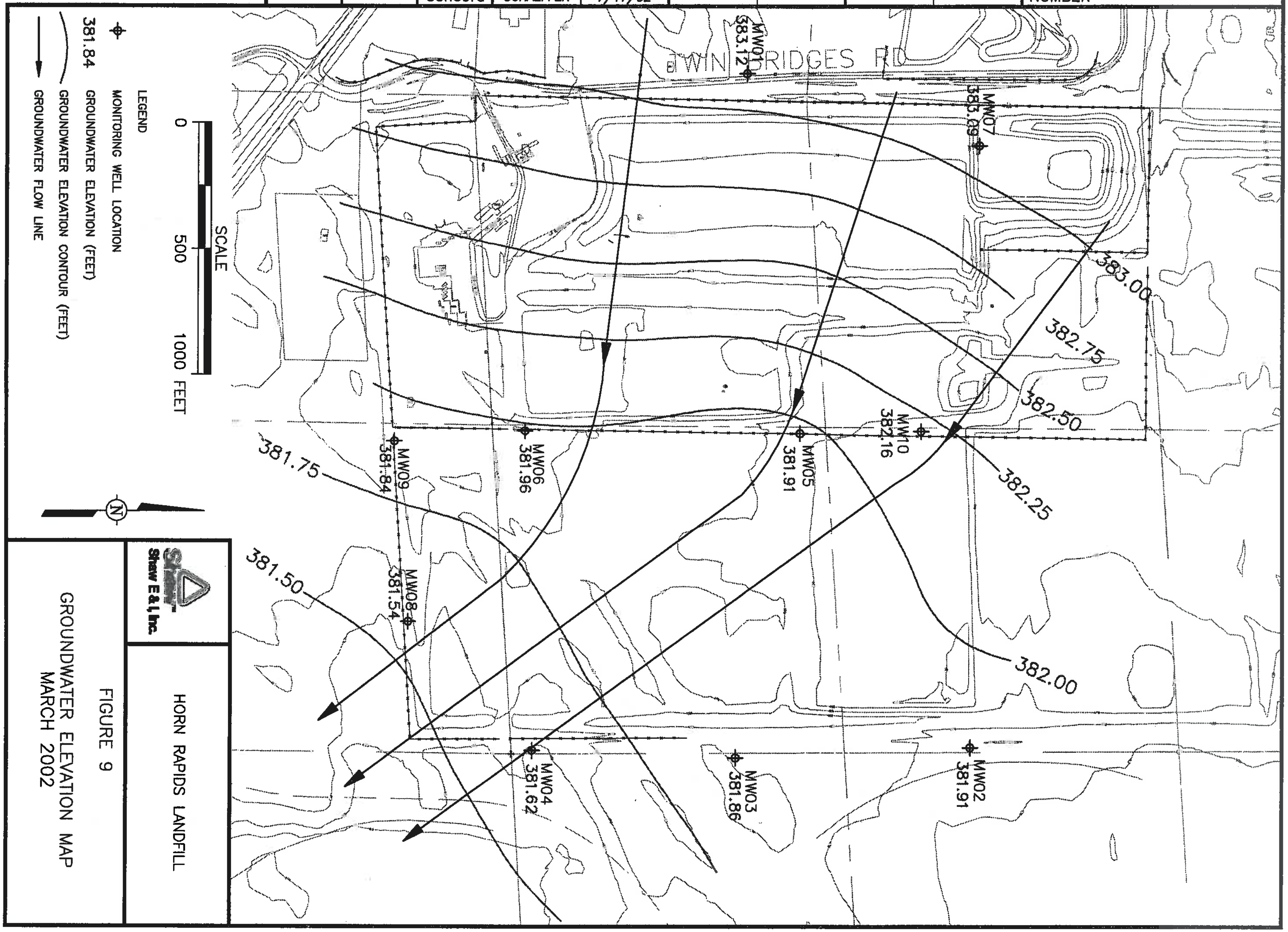

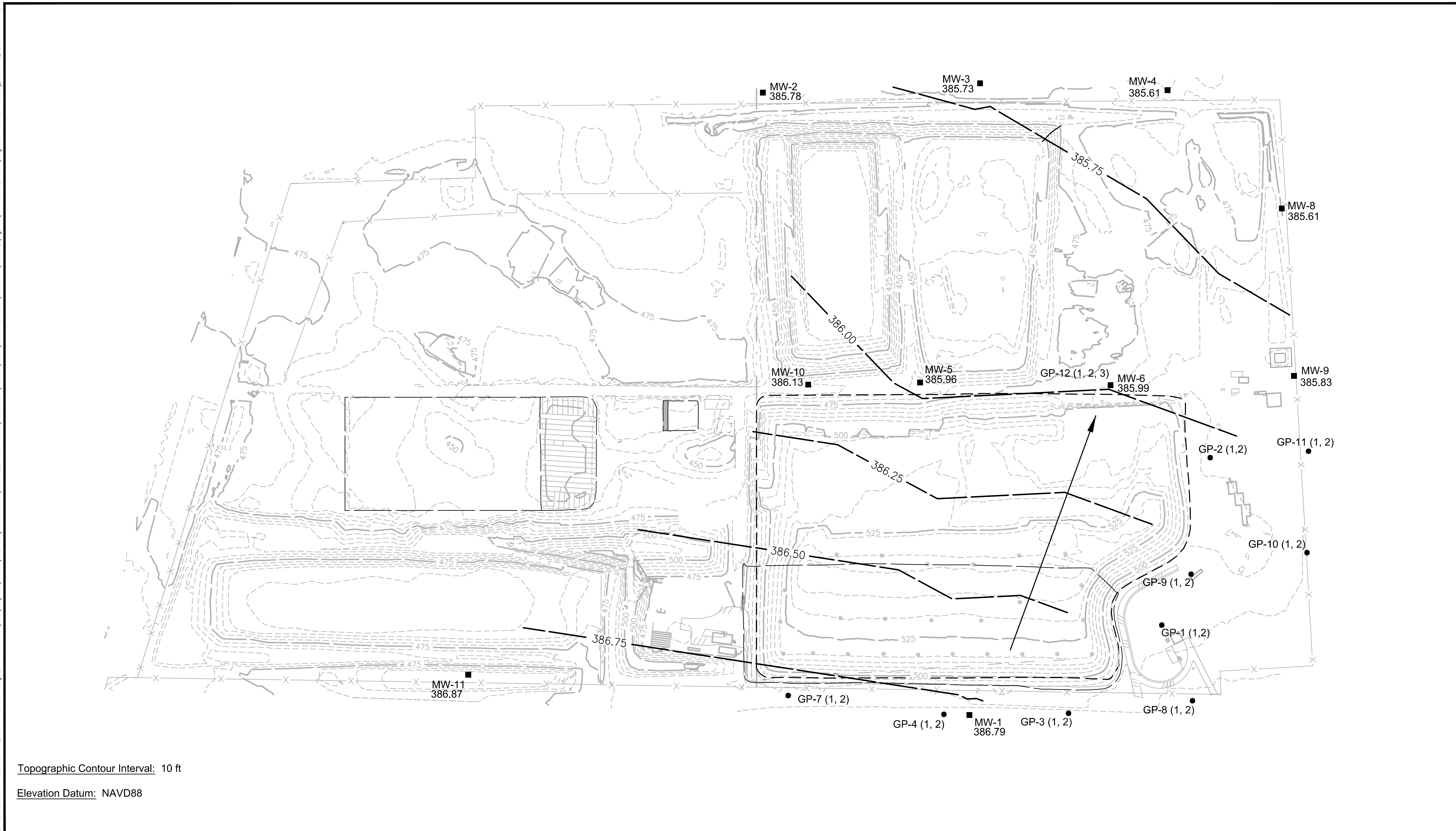

Parametrix DATE: Jun 02, 2015 FILE: BL3820004P04T02-F2-1stQ2015

LEGEND:

- Approximate extent of refuse
- Approximate site boundary
- Groundwater elevation contour
- Approximate groundwater flow direction

Monitoring Stations

- ■ Monitoring well, with groundwater elevation in ft NAVD88 measured March 30 and 31, 2015
- ● Gas Probe (1, 2, 3) with variable-depth screens

Figure 2
Potentiometric Surface Map
First Quarter 2015
Horn Rapids Landfill

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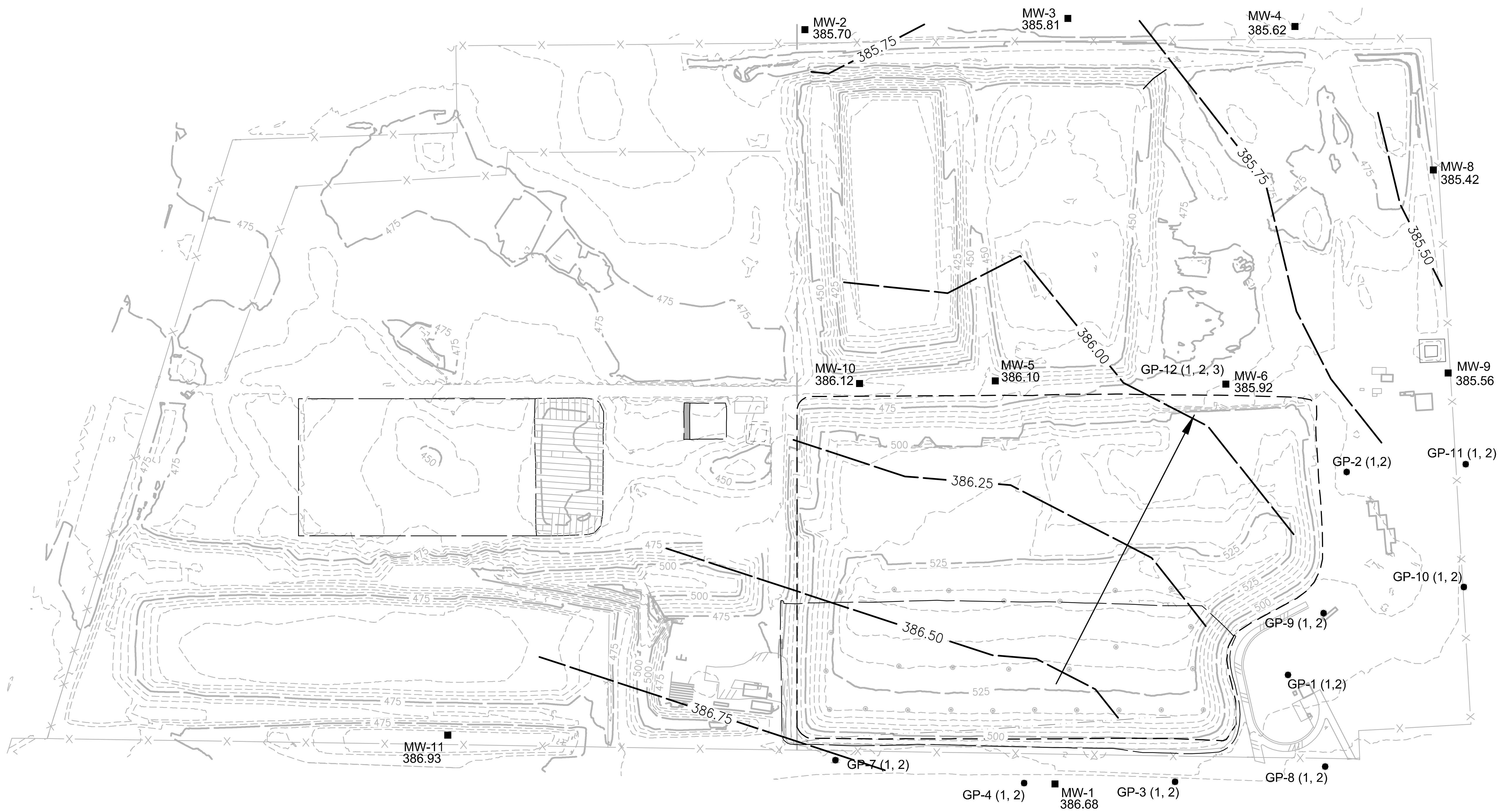


Topographic Contour Interval: 10 ft

Elevation Datum: NAVD88

Parametrix DATE: Oct 13, 2015 FILE: BL3820004P04T02-F2-3rdQ2015

N

0 400

SCALE IN FEET

LEGEND:

- Approximate extent of refuse
- Approximate site boundary
- Groundwater elevation contour
- Approximate groundwater flow direction

Monitoring Stations

- ■ Monitoring well, with groundwater elevation in ft NAVD88 measured September 16 and 17, 2015
- ● Gas Probe (1, 2, 3) with variable-depth screens

Figure 2
Potentiometric Surface Map
Third Quarter 2015
Horn Rapids Landfill

Appendix C

Landfill Gas Data

Summary of Methane Data in Gas Probes, Horn Rapids Landfill

Probe	Port	Ground Surface Elev	Top of Screen	Bottom of Screen	1/26/2006	10/7/2006	12/29/2006	3/15/2007	6/13/2007	9/27/2007	12/19/2007	3/26/2008	6/28/2008
GP-1	1	485.3	18.5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	485.3	8.5	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GP-2	1	489.1	36.5	38.0	37.1	14.6	30.5	16.2	31.7	2.8	1.9	41.9	32.1
	2	489.1	18.5	20.0	41.2	42.7	40.5	0.0	21.2	4.7	46.5	44.7	44.4
GP-3	1	477.1	36.5	38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	477.1	18.5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GP-4	1	477.5	36.5	38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	477.5	18.5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GP-5	1	479.4	56.5	58.0	6.4	10.1	12.3	0	2.0	0.8	13.9	12.7	0
	2	479.4	36.5	38.0	4.4	7.0	25.0	3.9	6.8	1.0	13.7	12.4	10.7
	3	479.4	18.5	20.0	0.1	0.0	10.4	0	0.0	0.5	4.1	1.2	0
GP-6	1	479.4	36.5	38.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	479.4	18.5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GP-7	1	479.4	24.0	28.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	479.4	11.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GP-8	1	478.8	26.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	478.8	11.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GP-9	1	489.3	26.0	30.0	6.3	0.1	7.8	0.0	0.0	1.2	2.2	17.0	9.0
	2	489.3	11.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
GP-10	1	484.5	11.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	484.5	26.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GP-11	1	486.0	36.0	39.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	486.0	14.0	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GP-12	1	480.3	22.5	32.5	8.6	11.3	0.0	9.7	16.3	1.4	29.0	26.2	16.9
	2	480.3	49.5	59.5	28.7	35.3	7.2	21.2	26.4	4.6	35.3	30.9	30.0
	3	480.3	76.5	86.5	21.3	22.9	0.0	10.4	14.1	1.4	21.2	22.0	22.0

Summary of Methane Data in Gas Probes, Horn Rapids Landfill

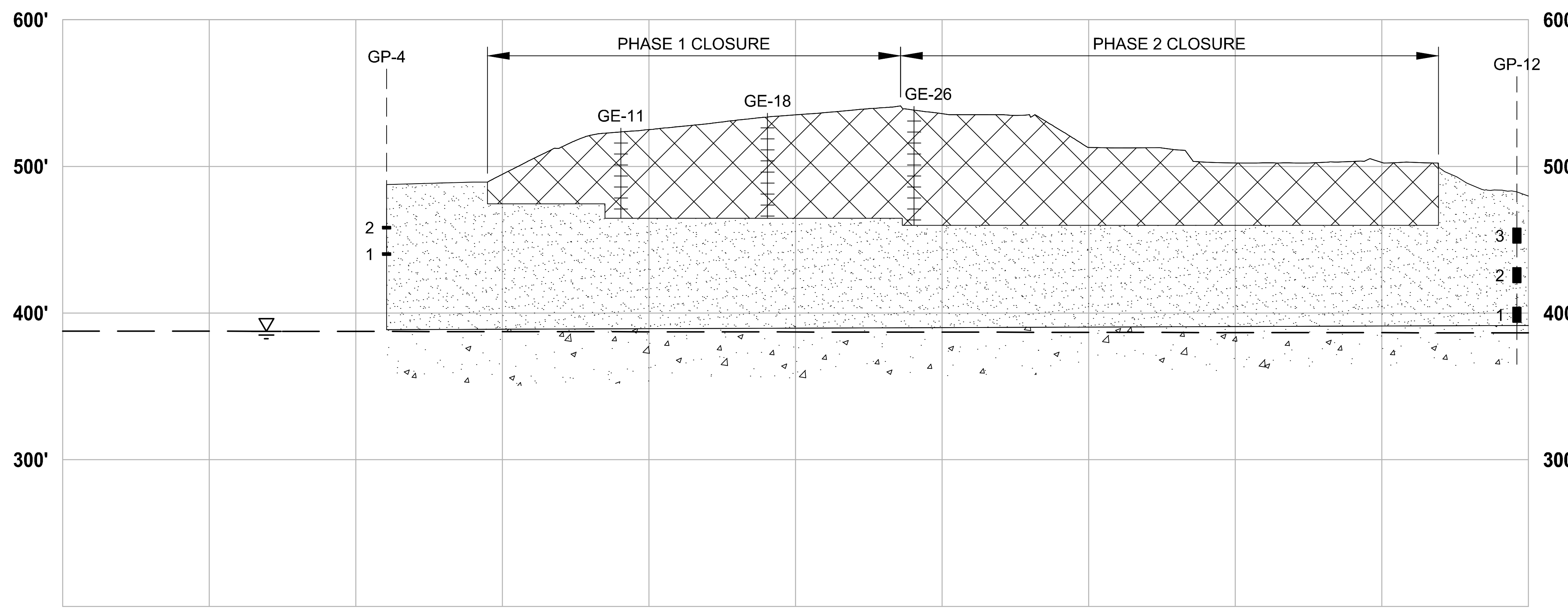
Probe	Port	Ground Surface Elev	Top of Screen	Bottom of Screen	9/26/2008	1/8/2009	3/19/2009	6/17/2009	9/24/2009	12/17/2009	3/11/2010	6/16/2010	9/8/2010	11/18/2010
GP-1	1	485.3	18.5	20.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
	2	485.3	8.5	10.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
GP-2	1	489.1	36.5	38.0	0.2	34.2	41.4	35.6	36.8	0.1	36.8	27.8	33.6	0.0
	2	489.1	18.5	20.0	0.2	45.2	42.0	1.0	40.8	0.1	40.9	38.3	33.8	0.0
GP-3	1	477.1	36.5	38.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0
	2	477.1	18.5	20.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
GP-4	1	477.5	36.5	38.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
	2	477.5	18.5	20.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
GP-5	1	479.4	56.5	58.0	1.0	15.2	13.7	1.8	0.4	8.7	14.7	NA	NA	NA
	2	479.4	36.5	38.0	11.2	9.7	12.6	13.9	0.2	10.9	13.0	NA	NA	NA
	3	479.4	18.5	20.0	0.3	0.0	2.6	0.5	3.1	8.9	2.0	NA	NA	NA
GP-6	1	479.4	36.5	38.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	NA	NA	NA
	2	479.4	18.5	20.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	NA	NA	NA
GP-7	1	479.4	24.0	28.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
	2	479.4	11.0	15.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
GP-8	1	478.8	26.0	30.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
	2	478.8	11.0	15.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
GP-9	1	489.3	26.0	30.0	0.0	16.4	16.4	17.7	18.1	0.1	2.6	0.0	11.3	0.0
	2	489.3	11.0	16.0	0.0	0.5	0.2	0.4	0.7	0.1	0.1	0.0	0.4	0.0
GP-10	1	484.5	11.0	15.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
	2	484.5	26.0	30.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
GP-11	1	486.0	36.0	39.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	2	486.0	14.0	17.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
GP-12	1	480.3	22.5	32.5	21.8	20.4	23.4	21.6	23.5	0.0	18.8	15.5	19.5	26.6
	2	480.3	49.5	59.5	24.7	34.1	32.9	28.8	15.8	2.1	28.0	24.5	24.9	31.5
	3	480.3	76.5	86.5	16.3	27.3	23.5	18.6	19.5	0.1	21.5	19.6	18.0	21.4

Summary of Methane Data in Gas Probes, Horn Rapids Landfill

Probe	Port	Ground Surface Elev	Top of Screen	Bottom of Screen	3/16/2011	6/21/2011	9/15/2011	12/16/2011	3/22/2012	6/20/2012	9/19/2012	10/16/2012	3/13/13	6/1/13
GP-1	1	485.3	18.5	20.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	2	485.3	8.5	10.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
GP-2	1	489.1	36.5	38.0	0.2	35	0	0	3.0	0.0	0.0	0.0	0.0	0.0
	2	489.1	18.5	20.0	0.0	40	0	0	2.9	0.0	0.0	0.0	0.0	0.0
GP-3	1	477.1	36.5	38.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	2	477.1	18.5	20.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
GP-4	1	477.5	36.5	38.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	2	477.5	18.5	20.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
GP-5	1	479.4	56.5	58.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	479.4	36.5	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	3	479.4	18.5	20.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GP-6	1	479.4	36.5	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	479.4	18.5	20.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GP-7	1	479.4	24.0	28.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	2	479.4	11.0	15.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
GP-8	1	478.8	26.0	30.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	2	478.8	11.0	15.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
GP-9	1	489.3	26.0	30.0	0.0	0	0	2	0.0	0.0	0.0	0.0	0.0	0.0
	2	489.3	11.0	16.0	0.5	16	3	0	0.0	0.0	0.0	0.0	0.0	0.0
GP-10	1	484.5	11.0	15.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	2	484.5	26.0	30.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
GP-11	1	486.0	36.0	39.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	2	486.0	14.0	17.0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
GP-12	1	480.3	22.5	32.5	15.0	11	16	10	7.0	8.0	8.0	8.0	5.0	4.0
	2	480.3	49.5	59.5	19.5	20	23	26	17.0	20.0	18.0	18.0	12.0	10.0
	3	480.3	76.5	86.5	17.2	16	17	17	16.0	17.0	20.0	15.0	14.0	11.0

Summary of Methane Data in Gas Probes, Horn Rapids Landfill

Probe	Port	Ground Surface Elev	Top of Screen	Bottom of Screen	9/20/13	1/8/14	3/13/14	6/18/14	9/29/14	12/12/14	3/19/2015	7/14/2015	10/7/2015	1/7/2016
GP-1	1	485.3	18.5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	2	485.3	8.5	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
GP-2	1	489.1	36.5	38.0	0.0	0.0	0.0	18.0	0.0	0.0	19.0	4.0	4.0	0
	2	489.1	18.5	20.0	0.0	0.0	0.0	2.0	0.0	0.0	28.0	0.0	2.7	0
GP-3	1	477.1	36.5	38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	2	477.1	18.5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
GP-4	1	477.5	36.5	38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	2	477.5	18.5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
GP-5	1	479.4	56.5	58.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	479.4	36.5	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	3	479.4	18.5	20.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GP-6	1	479.4	36.5	38.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	479.4	18.5	20.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GP-7	1	479.4	24.0	28.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	2	479.4	11.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
GP-8	1	478.8	26.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	2	478.8	11.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
GP-9	1	489.3	26.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0
	2	489.3	11.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0
GP-10	1	484.5	11.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	2	484.5	26.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
GP-11	1	486.0	36.0	39.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	2	486.0	14.0	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
GP-12	1	480.3	22.5	32.5	0.0	0.0	5.0	1.0	0.0	0.0	5.0	0.0	0.0	0
	2	480.3	49.5	59.5	0.0	4.0	12.0	2.0	0.0	0.0	0.0	0.0	0.8	1
	3	480.3	76.5	86.5	0.0	5.0	14.0	0.0	1.0	0.0	1.0	0.0	0.0	1



SECTION A
HORIZ: 1"=200'
VERT: 1"=100'

Note:

Vertical Datum: NAVD88

Parametrix DATE: April 14, 2016 FILE: BL3820004P04T03F1

Legend:

- Sand
- Sand and Gravel
- Clay
- Basalt
- Groundwater Elevation
- GE-11 Gas Extraction Well
- GP-12 / 3 Gas Probe, Showing Screened Intervals

Geologic Cross Section
Showing Gas Probes
Horn Rapids Landfill

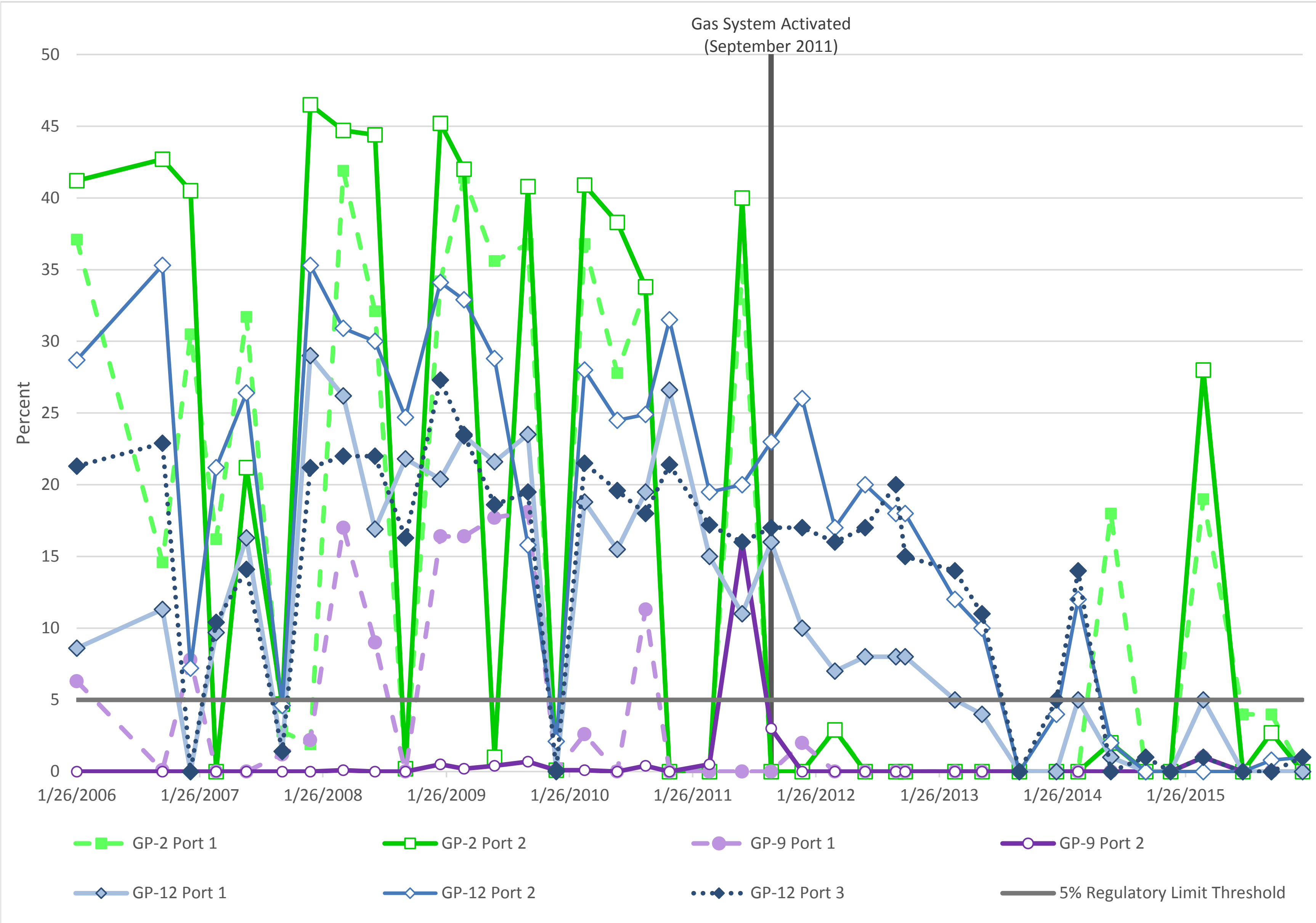
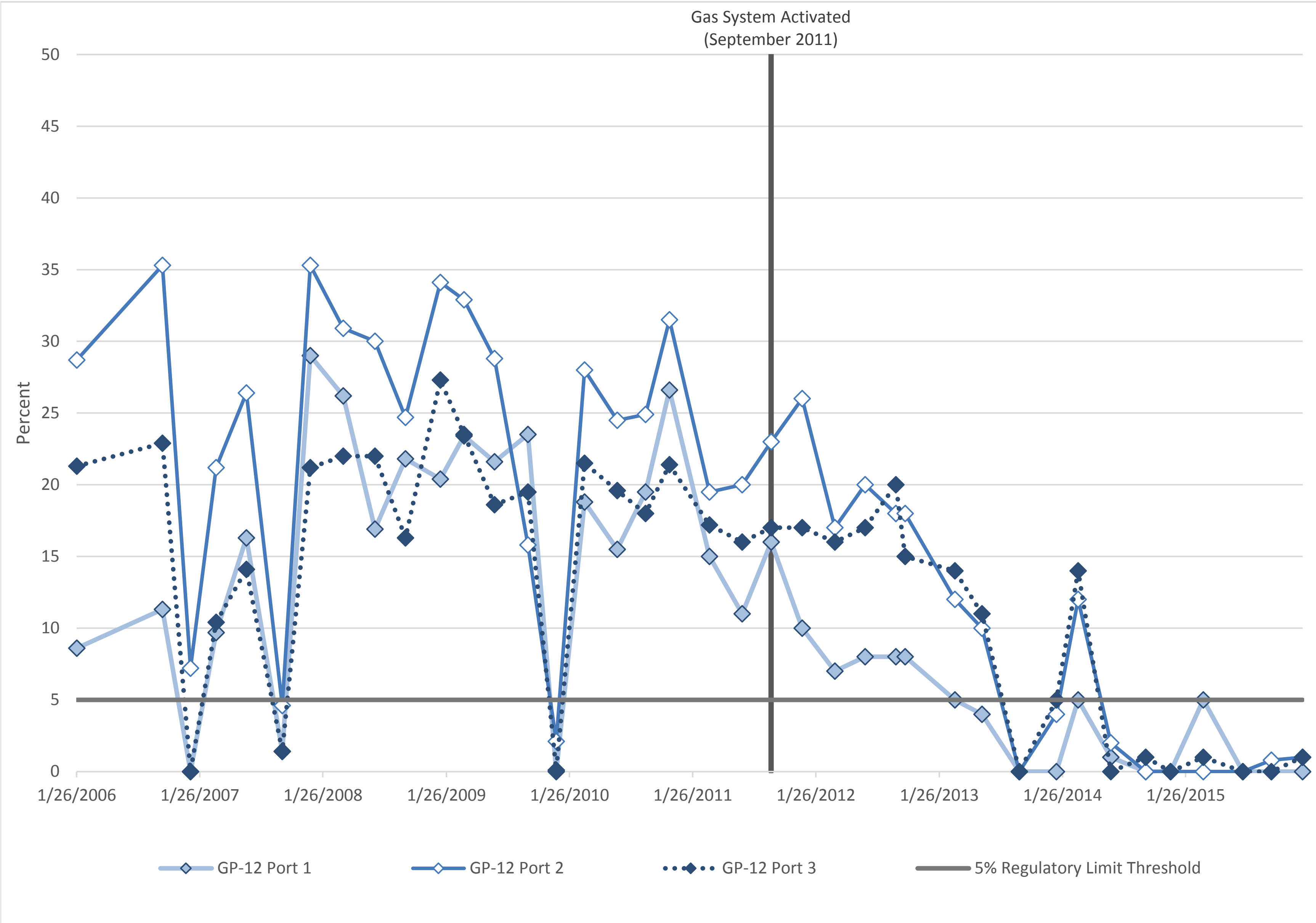
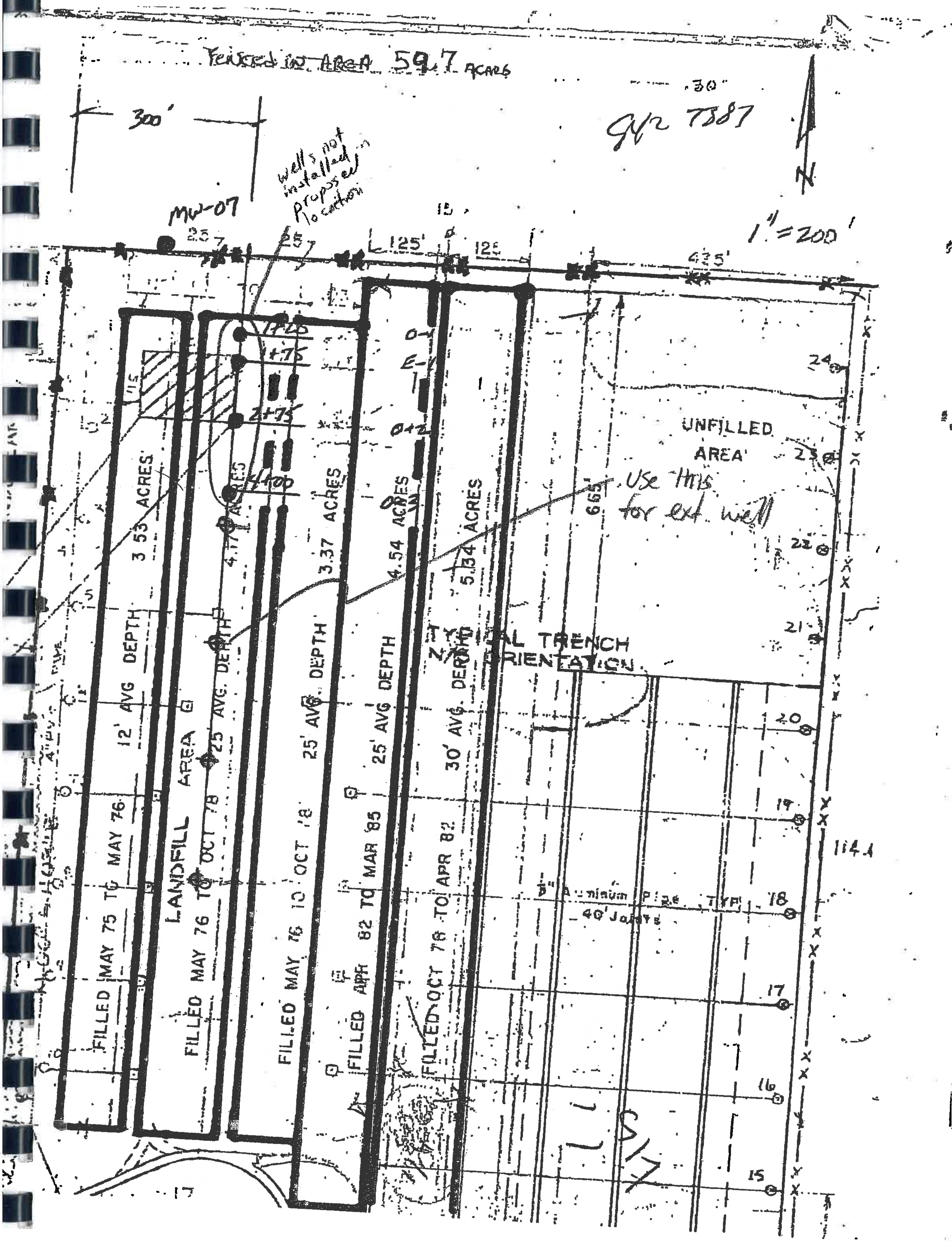


Figure 2
Methane in Landfill Gas Probes, Horn Rapids Landfill



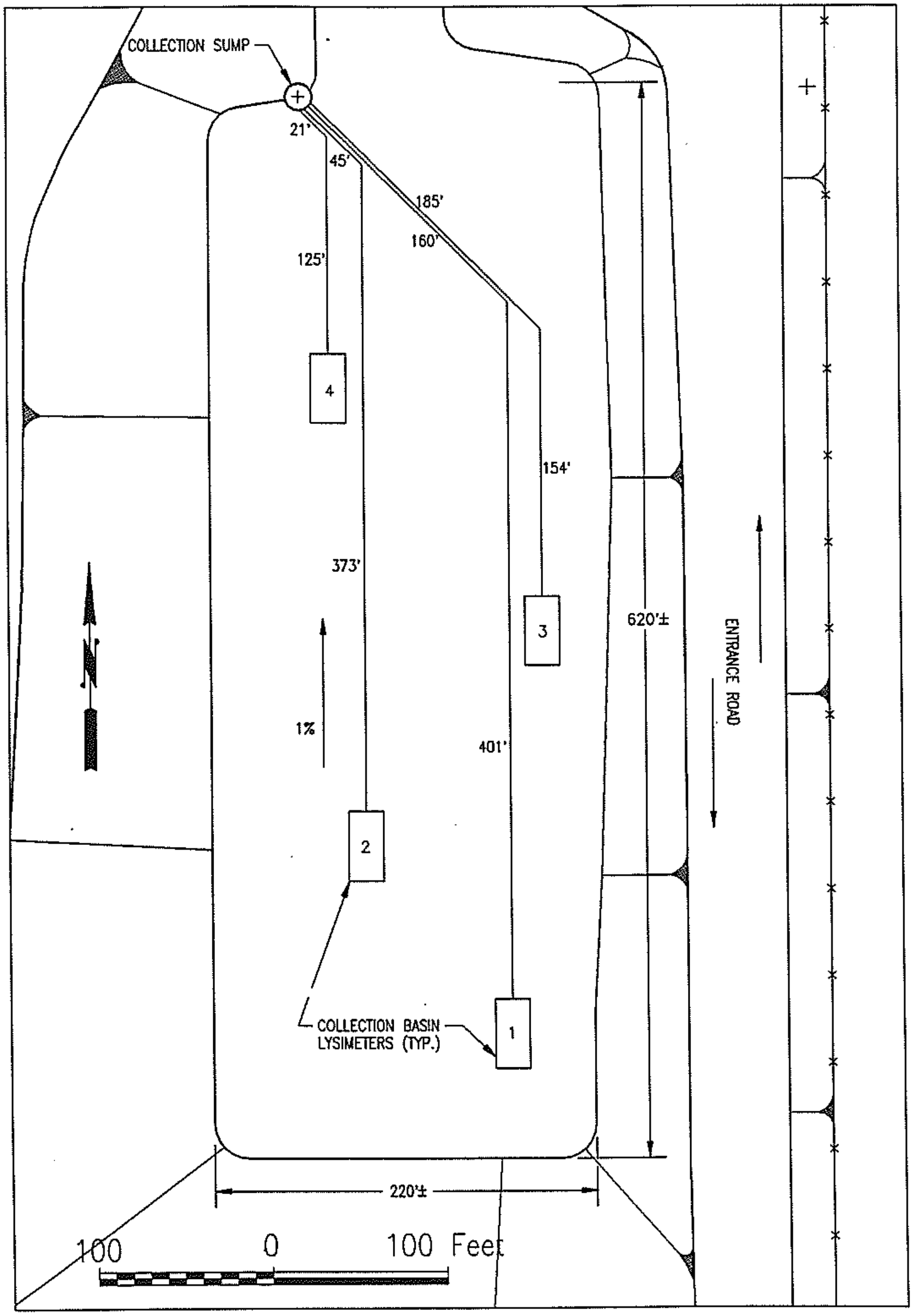
Methane in Landfill Gas Probe 12, Horn Rapids Landfill



Fenced in Area 59.7 acres
300'
9/2 7387
N
1" = 200'
MW-07
wells not installed in proposed location
25
125'
125'
425'
30
1+25
1+75
2+75
3+00
0-1
E-1
0+2
0+3
UNFILLED AREA
24
23
22
21
20
19
18
17
16
15
Use this for ext well
665'
3.53 ACRES
12' AVG DEPTH
FILLED MAY 75 TO MAY 76
LANDFILL AREA
4.17 ACRES
25' AVG. DEPTH
FILLED MAY 76 TO OCT 78
3.37 ACRES
25' AVG. DEPTH
FILLED MAY 76 TO OCT 78
4.54 ACRES
25' AVG DEPTH
FILLED APR 82 TO MAR 85
5.34 ACRES
30' AVG. DEPTH
FILLED OCT 78 TO APR 82
TYPICAL TRENCH N/S ORIENTATION
8" Aluminum Pipe TYP.
40' Joints
114.4
1 5/7

Appendix D

Leachate Data


COLLECTION SUMP
21'
45'
185'
160'
125'
4
154'
373'
3
620'±
ENTRANCE ROAD
1%
401'
2
COLLECTION BASIN
LYSIMETERS (TYP.)
1
220'±
100
0
100 Feet

VAA00805

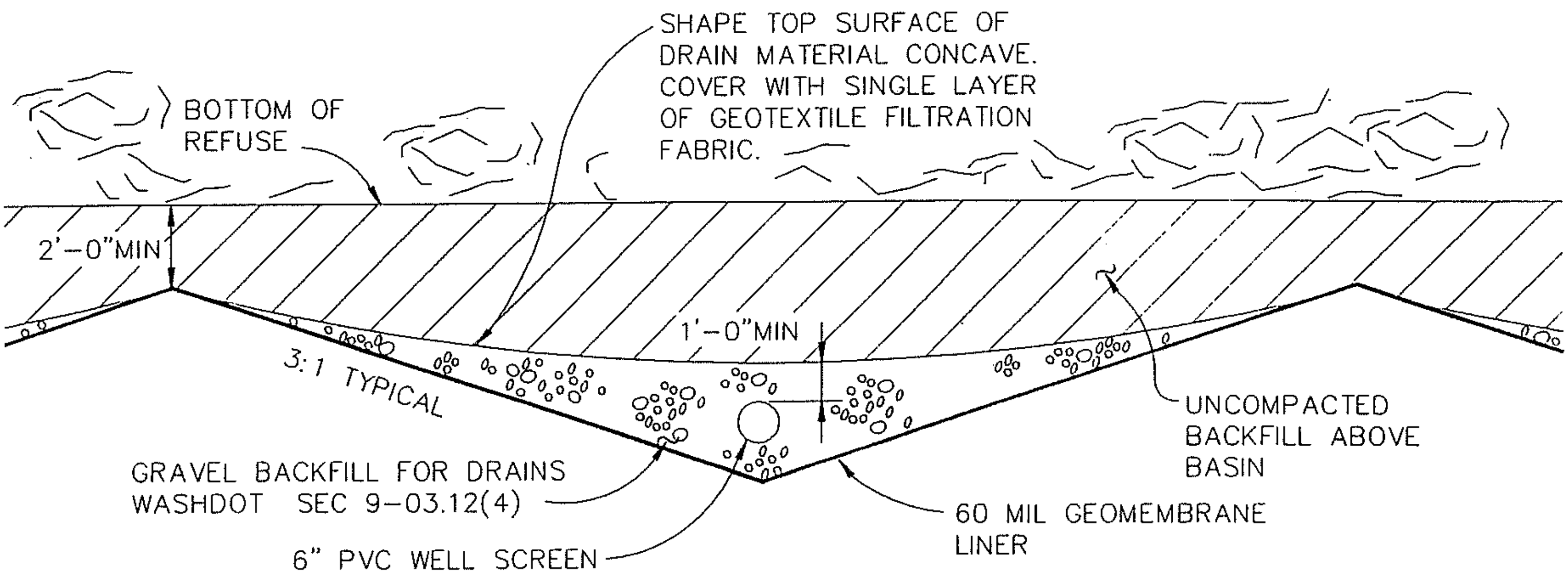
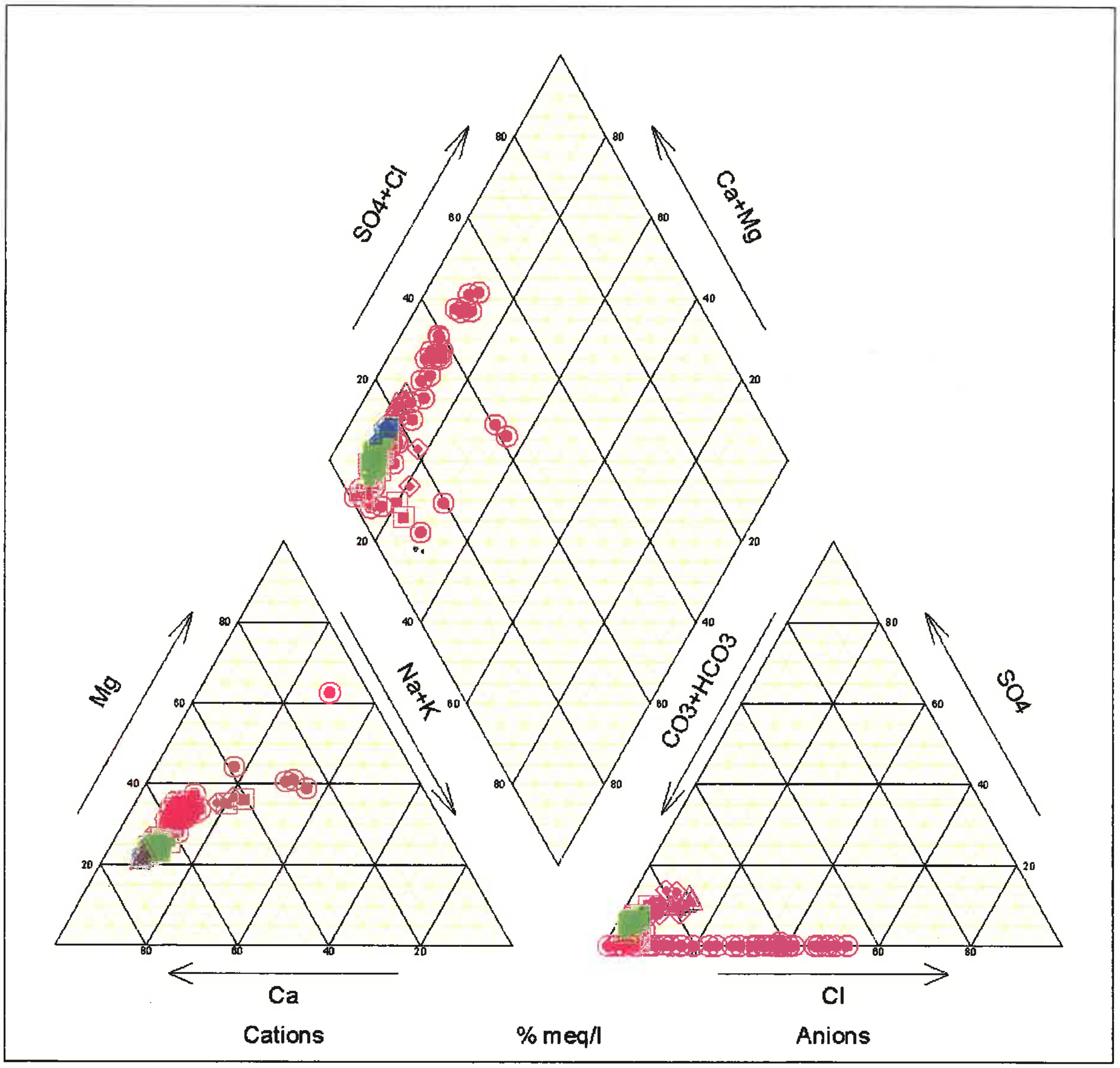


Figure III-3
Richland Landfill Closure

Cross-Section
Collection Basin Lysimeter

R.W. BECK
AND ASSOCIATES

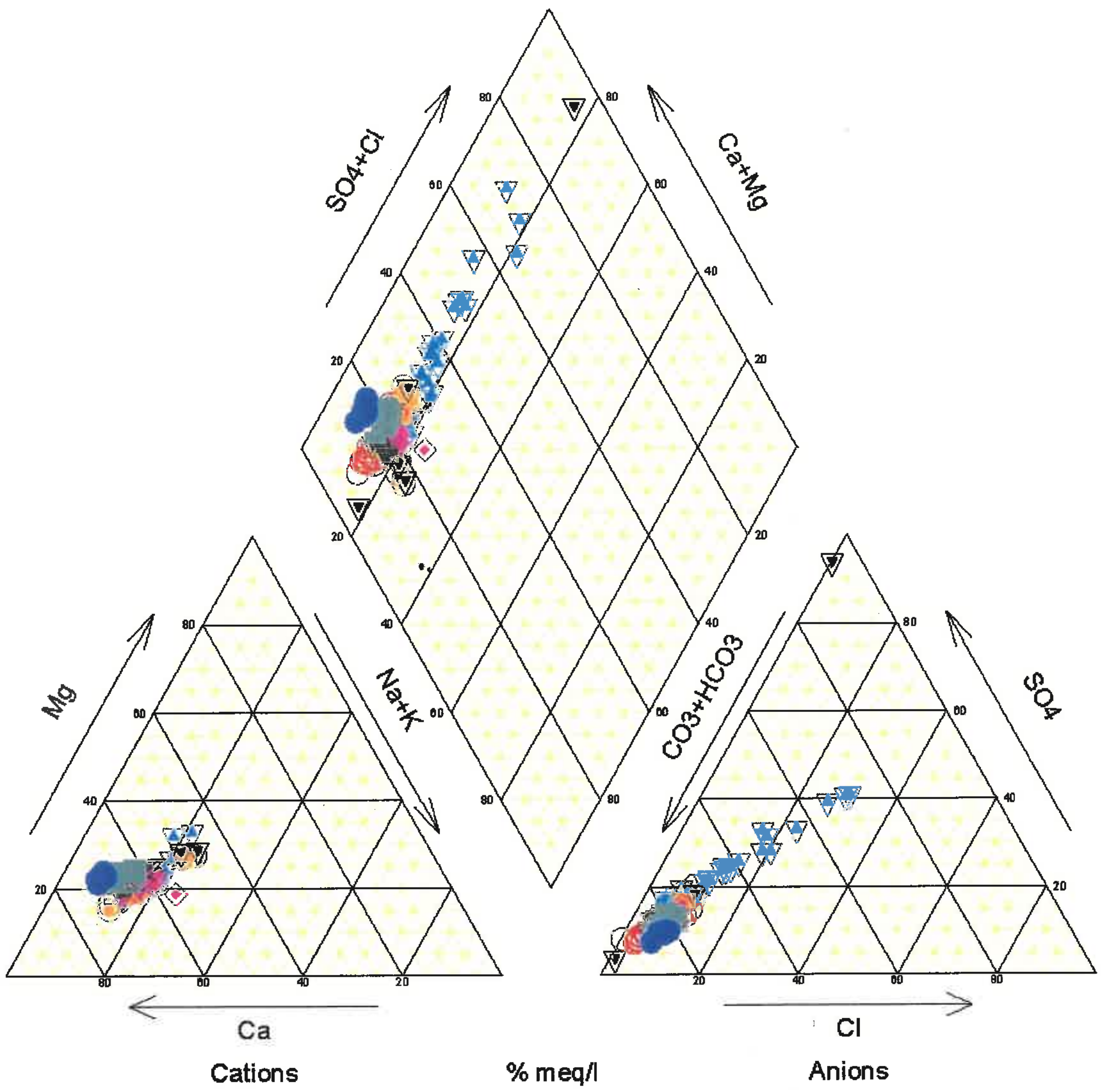
Figure 3-1
Piper (Trilinear) Diagram Showing Ionic Chemistry of MW05, MW06 and MW07 Groundwater Samples and Lysimeter LIquid Samples
Horn Rapids Landfill



port 1	5/18/1994 - 6/08/1994	port 3	4/15/1997	port 4	12/21/1999 - 1/11/2000	MW05	10/16/2001	MW06	11/08/2000 - 12/05/2000
port 1	10/13/1994	port 3	9/23/1997	port 4	1/11/2000 - 2/08/2000	MW05	12/05/2001 - 12/18/2001	MW06	3/20/2001 - 4/10/2001
port 1	2/22/1995 - 3/01/1995	port 3	4/08/1998	port 4	11/08/2000 - 12/05/2000	MW05	3/20/2002	MW06	7/25/2001
port 1	8/15/1996 - 9/12/1996	port 3	10/21/1998 - 11/16/1998	port 4	6/18/2001	MW05	7/03/2002	MW06	10/16/2001
port 1	4/15/1997	port 3	6/29/1999	port 4	12/05/2001 - 12/18/2001	MW05	10/15/2002	MW06	12/05/2001 - 12/18/2001
port 1	9/23/1997	port 3	12/21/1999 - 1/11/2000	MW05	5/18/1998	MW05	12/17/2002 - 12/31/2002	MW06	3/20/2002
port 1	4/08/1998	port 3	1/11/2000 - 2/08/2000	MW05	6/30/1998 - 7/07/1998	MW05	3/26/2003	MW06	7/03/2002
port 1	10/21/1998 - 11/16/1998	port 3	11/08/2000 - 12/05/2000	MW05	8/10/1998	MW05	6/11/2003	MW06	10/15/2002
port 1	12/21/1999 - 1/11/2000	port 3	6/18/2001	MW05	10/21/1998 - 11/16/1998	MW06	5/18/1998	MW06	12/17/2002 - 12/31/2002
port 1	1/11/2000 - 2/08/2000	port 3	12/05/2001 - 12/18/2001	MW05	1/26/1999	MW06	6/30/1998 - 7/07/1998	MW06	3/26/2003
port 1	11/08/2000 - 12/05/2000	port 4	5/18/1994 - 6/08/1994	MW05	5/12/1999	MW06	8/10/1998	MW06	6/11/2003
port 1	6/18/2001	port 4	10/13/1994	MW05	10/05/1999	MW06	10/21/1998 - 11/16/1998	MW07	3/20/2001 - 4/10/2001
port 1	12/05/2001 - 12/18/2001	port 4	2/22/1995 - 3/01/1995	MW05	12/21/1999 - 1/11/2000	MW06	1/26/1999	MW07	7/25/2001
port 2	2/22/1995 - 3/01/1995	port 4	7/19/1995 - 7/21/1995	MW05	1/11/2000 - 2/08/2000	MW06	5/12/1999	MW07	10/16/2001
port 2	7/19/1995 - 7/21/1995	port 4	8/15/1996 - 9/12/1996	MW05	5/16/2000	MW06	10/05/1999	MW07	12/05/2001 - 12/18/2001
port 2	8/15/1996 - 9/12/1996	port 4	4/15/1997	MW05	8/30/2000	MW06	12/21/1999 - 1/11/2000	MW07	7/03/2002
port 2	4/15/1997	port 4	9/23/1997	MW05	11/08/2000 - 12/05/2000	MW06	1/11/2000 - 2/08/2000	MW07	3/26/2003
port 2	9/23/1997	port 4	4/08/1998	MW05	3/20/2001 - 4/10/2001	MW06	5/16/2000	MW07	6/11/2003
port 3	8/15/1996 - 9/12/1996	port 4	6/29/1999	MW05	7/25/2001	MW06	8/30/2000		

Prepared by: EMCON / OWT,Inc.

Figure 3-2
Trilinear (Piper) Diagram Showing Ionic Chemistry of MW01, MW02, MW03, MW04, MW08, MW09 and MW10 Groundwater Samples
Horn Rapids Landfill



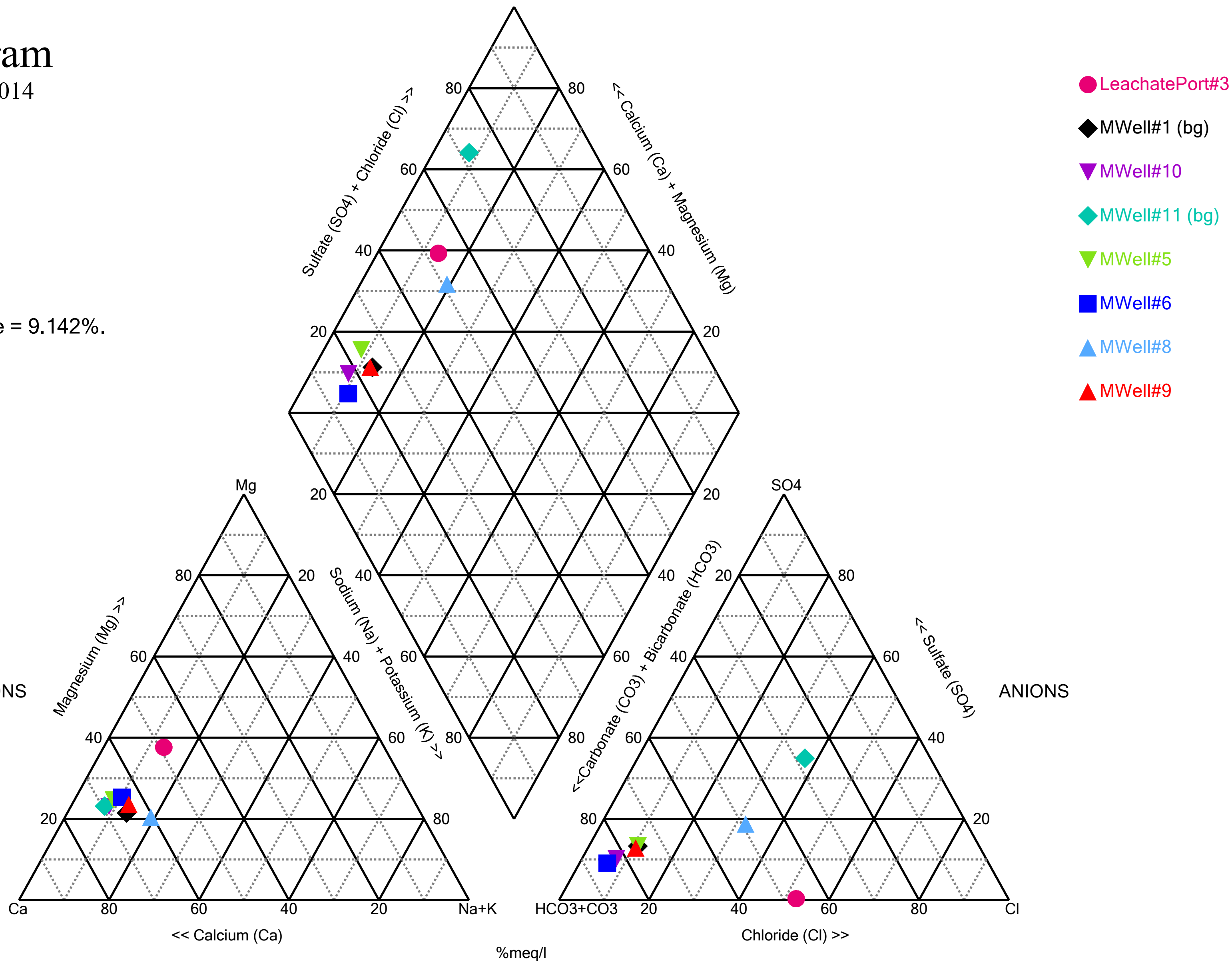
MW01	2/22/1995 - 3/01/1995
MW01	4/13/1995
MW01	7/19/1995 - 7/21/1995
MW01	10/12/1995
MW01	12/27/1995
MW01	2/29/1996 - 3/13/1996
MW01	4/30/1996 - 5/30/1996
MW01	5/30/1996 - 6/27/1996
MW01	7/31/1996 - 8/15/1996
MW01	8/15/1996 - 9/12/1996
MW01	11/21/1996
MW01	2/27/1997
MW01	5/20/1997
MW01	8/14/1997
MW01	12/10/1997
MW01	2/24/1998
MW01	5/18/1998
MW01	8/10/1998
MW01	10/21/1998 - 11/16/1998
MW01	1/19/1999 - 1/26/1999
MW01	5/12/1999
MW01	10/05/1999
MW01	12/21/1999 - 1/11/2000
MW01	1/11/2000 - 2/08/2000
MW01	5/16/2000
MW01	8/30/2000
MW01	11/08/2000 - 12/05/2000
MW01	3/20/2001 - 4/10/2001
MW01	7/25/2001
MW01	9/16/2001 - 10/16/2001
MW01	12/05/2001 - 12/18/2001
MW01	3/20/2002
MW01	7/03/2002
MW01	10/15/2002
MW01	12/17/2002 - 12/31/2002
MW01	3/26/2003
MW01	6/11/2003
MW02	2/22/1995 - 3/01/1995
MW02	4/13/1995
MW02	7/19/1995 - 7/21/1995
MW02	10/12/1995
MW02	12/27/1995
MW02	2/29/1996 - 3/13/1996
MW02	4/30/1996 - 5/30/1996
MW02	5/30/1996 - 6/27/1996
MW02	7/31/1996 - 8/15/1996
MW02	8/15/1996 - 9/12/1996
MW02	11/21/1996
MW02	2/27/1997
MW02	5/20/1997
MW02	8/14/1997
MW02	12/10/1997
MW02	2/24/1998
MW02	5/18/1998
MW02	8/10/1998
MW02	10/21/1998 - 11/16/1998
MW02	1/19/1999 - 1/26/1999
MW02	5/12/1999
MW02	10/05/1999
MW02	12/21/1999 - 1/11/2000
MW02	1/11/2000 - 2/08/2000
MW02	5/16/2000
MW02	8/30/2000
MW02	11/08/2000 - 12/05/2000
MW02	3/20/2001 - 4/10/2001
MW02	7/25/2001
MW02	9/16/2001 - 10/16/2001
MW02	12/05/2001 - 12/18/2001
MW02	3/20/2002
MW02	7/03/2002
MW02	10/15/2002
MW02	12/17/2002 - 12/31/2002
MW02	3/26/2003
MW02	6/11/2003
MW03	2/22/1995 - 3/01/1995
MW03	4/13/1995
MW03	7/19/1995 - 7/21/1995
MW03	10/12/1995
MW03	12/27/1995
MW03	2/29/1996 - 3/13/1996
MW03	4/30/1996 - 5/30/1996
MW03	5/30/1996 - 6/27/1996
MW03	7/31/1996 - 8/15/1996
MW03	8/16/1996 - 9/12/1996
MW03	11/21/1996
MW03	2/27/1997
MW03	5/20/1997
MW03	8/14/1997
MW03	12/10/1997
MW03	2/24/1998
MW03	5/18/1998
MW03	8/10/1998
MW03	10/21/1998 - 11/16/1998
MW03	1/19/1999 - 1/26/1999
MW03	5/12/1999
MW03	10/05/1999
MW03	12/21/1999 - 1/11/2000
MW03	1/11/2000 - 2/08/2000
MW03	5/16/2000
MW03	8/30/2000
MW03	11/08/2000 - 12/05/2000
MW03	3/20/2001 - 4/10/2001
MW03	7/25/2001
MW03	9/16/2001 - 10/16/2001
MW03	12/05/2001 - 12/18/2001
MW03	3/20/2002
MW03	7/03/2002
MW03	10/15/2002
MW03	12/17/2002 - 12/31/2002
MW03	3/26/2003
MW03	6/11/2003
MW04	2/22/1995 - 3/01/1995
MW04	4/13/1995
MW04	7/19/1995 - 7/21/1995
MW04	10/12/1995
MW04	12/27/1995
MW04	2/29/1996 - 3/13/1996
MW04	4/30/1996 - 5/30/1996
MW04	5/30/1996 - 6/27/1996
MW04	7/31/1996 - 8/15/1996
MW04	8/15/1996 - 9/12/1996
MW04	11/21/1996
MW04	2/27/1997
MW04	5/20/1997
MW04	8/14/1997
MW04	12/10/1997
MW04	2/24/1998
MW04	5/18/1998
MW04	8/10/1998
MW04	10/21/1998 - 11/16/1998
MW04	1/19/1999 - 1/26/1999
MW04	5/12/1999
MW04	10/05/1999
MW04	12/21/1999 - 1/11/2000
MW04	1/11/2000 - 2/08/2000
MW04	5/16/2000
MW04	8/30/2000
MW04	11/08/2000 - 12/05/2000
MW04	3/20/2001 - 4/10/2001
MW04	7/25/2001
MW04	9/16/2001 - 10/16/2001
MW04	12/05/2001 - 12/18/2001
MW04	3/20/2002
MW04	7/03/2002
MW04	10/15/2002
MW04	12/17/2002 - 12/31/2002
MW04	3/26/2003
MW04	6/11/2003
MW08	3/20/2001 - 4/10/2001
MW08	7/25/2001
MW08	9/16/2001 - 10/16/2001
MW08	12/05/2001 - 12/18/2001
MW08	3/20/2002
MW08	7/03/2002
MW08	10/15/2002
MW08	12/17/2002 - 12/31/2002
MW08	3/26/2003
MW08	6/11/2003
MW09	3/20/2001 - 4/10/2001
MW09	7/25/2001
MW09	9/16/2001 - 10/16/2001
MW09	12/05/2001 - 12/18/2001
MW09	3/20/2002
MW09	7/03/2002
MW09	10/16/2002
MW09	12/17/2002 - 12/31/2002
MW09	3/26/2003
MW09	6/11/2003
MW10	3/20/2001 - 4/10/2001
MW10	7/25/2001
MW10	9/16/2001 - 10/16/2001
MW10	12/05/2001 - 12/18/2001
MW10	3/20/2002
MW10	7/03/2002
MW10	10/15/2002
MW10	12/17/2002 - 12/31/2002
MW10	3/26/2003
MW10	6/11/2003

Prepared by: EMCON / OWT, Inc.

Piper Diagram

11/20/2014, 11/19/2014

Cation-Anion Balance = 9.142%.



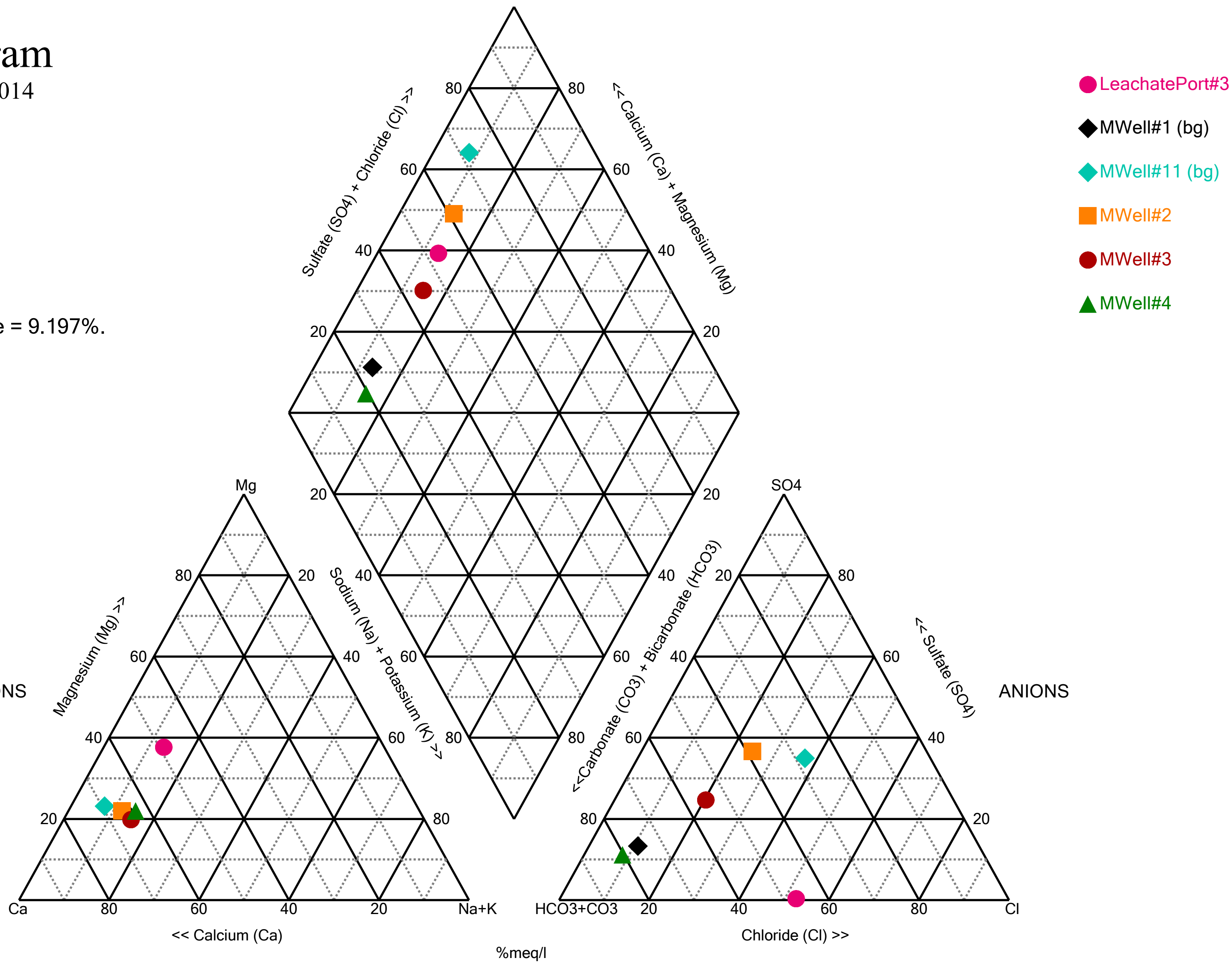
Analysis Run 2/19/2015 4:36 PM

Facility: Horn Rapids LF Client: City of Richland Data File: 4Q_14_PIPER2

Piper Diagram

11/20/2014, 11/19/2014

Cation-Anion Balance = 9.197%.



Analysis Run 2/19/2015 4:35 PM

Facility: Horn Rapids LF   Client: City of Richland   Data File: 4Q_14_PIPER2

Appendix E

Groundwater Data and Isoconcentration Maps

Table E-1. Groundwater Quality Results, Appendix I and II[1], Horn Rapids Landfill, 2015

	Analyte		Units	GWQS	MCL	MW-1 3/31/2015	MW-1 6/24/2015	MW-1 9/16/2015	MW-1 12/2/2015	MW-2 3/30/2015	MW-2 6/24/2015	MW-2 9/17/2015	MW-2 12/3/2015	MW-3 3/30/2015	MW-3 6/24/2015	MW-3 9/17/2015	MW-3 12/3/2015	MW-4 3/31/2015	MW-4 6/24/2015	MW-4 9/17/2015	MW-4 12/3/2015	MW-5 3/30/2015	MW-5 6/25/2015	MW-5 9/16/2015	MW-5 12/2/2015	MW-6 3/30/2015
FIELD DATA	Conductivity		µmhos/cm		700 **	**887.0**	**879**	**850**	**998**	**752.0**	553	607	563	662.0	677	663	651	460.0	483	476	461	**1189**	**1384**	**1202**	**1168**	**1102**
	pH		units	6.5-8.5		7.06	7.74	7.24	7.12	7.54	7.90	7.75	7.63	7.62	8.13	7.79	7.64	7.57	8.08	7.71	7.55	6.55	7.22	6.74	6.71	6.50
	Temperature		C°			20.13	21.30	21.11	20.16	20.71	21.85	21.26	19.81	20.83	22.72	22.80	21.76	18.69	21.46	20.41	19.71	24.68	25.23	23.21	21.85	23.68
	Oxidation-Reduction Potential		mv			140	120.2	-54.2	0.2	84	108.8	-108.0	-70.5	83	102.0	-80.8	-41.4	164	110.4	-114.5	-87.4	-30	19.7	-261.8	-275.6	51
	Dissolved Oxygen		mg/L			5.69	5.30	4.84	5.64	7.30	6.54	5.18	6.05	7.95	7.35	4.49	7.03	4.32	3.81	1.58	3.45	0.85	1.06	0.38	0.63	0.47
WATER QUALITY PARAMETERS	Nitrate-Nitrogen		mg/L as N	10 *	10 *	8.7	8.9	8.6	8.4	**25**	**15 H**	**18 H**	**19 H**	7.4	7.6	7.5	7.7	2.2	2.4	2.3	2.4	3.2	**35**	5.4 H	3.1 H	2.0
	Calcium	Dissolved	mg/L			120	130	120	110	99	70	76	81	88	88	85	90	65	65	67	70	180	200	180	200	160
		Total	mg/L			120	120	NA	NA	98	71	NA	NA	88	88	NA	NA	64	63	NA	NA	180	200	NA	NA	160
	Sodium	Dissolved	mg/L			23	23	22	21	17	13	14	15	18	18	18	18	13	13	14	14	21	22	21	22	23
		Total	mg/L			23	22	NA	NA	17	14	NA	NA	18	18	NA	NA	14	13	NA	NA	20	22	NA	NA	23
	Bicarbonate Alkalinity		mg/L as CaCO3			350	330	330	290	120	110	120	120	170	160	170	150	200	210	210	190	540	460	520	490	540
	Chloride		mg/L	250 **	250 **	27	27	26	27	41	27	30	29	40	44	44	48	10	11	11	11	43	40	45	50	19
	Magnesium	Dissolved	mg/L			25	25	23	23	21	15	16	17	17	16	15	16	14	14	14	14	42	44	39	41	40
		Total	mg/L			26	24	NA	NA	22	15	NA	NA	17	16	NA	NA	14	14	NA	NA	40	43	NA	NA	39
	Potassium	Dissolved	mg/L			8.7	8.3	8.0	7.8	7.5	6.0	6.1	6.5	8.1	7.9	7.4	8.0	6.4	6.3	6.2	6.6	12	12	11	12	12
		Total	mg/L			9.2	7.9	NA	NA	8.3	6.1	NA	NA	8.8	7.8	NA	NA	6.7	6.2	NA	NA	12	12	NA	NA	12
	Sulfate		mg/L	250 **	250 **	49	49	46	50	92	64	67	71	70	78	77	84	22	23	21	24	55	73	54	59	46
	Total Alkalinity		mg/L as CaCO3			350	330	330	290	120	110	120	120	170	160	170	150	200	210	210	190	540	460	520	490	540
	Iron	Dissolved	mg/L	0.3 **	0.3 **	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		Total	mg/L	0.3 **	0.3 **	<0.5	<0.5	NA	NA	<0.5	<0.5	NA	NA	<0.5	<0.5	NA	NA	<0.5	<0.5	NA	NA	<0.5	<0.5	NA	NA	<0.5
	Manganese	Dissolved	mg/L	0.05 **	0.05 **	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.039	0.029	0.026	0.037	0.03
		Total	mg/L	0.05 **	0.05 **	<0.02	<0.02	NA	NA	<0.02	<0.02	NA	NA	<0.02	<0.02	NA	NA	<0.02	<0.02	NA	NA	0.04	0.028	NA	NA	0.031
	Ammonia-Nitrogen		mg/L as N			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Total Organic Carbon		mg/L			1.7	1.9	1.5	1.4	1.5	1.1	<1.0	1.0	1.3	1.2	1.1	1.2	<1.0	<1.0	<1.0	<1.0	4.5	3.1	3.2	3.9	1.7
	Total Dissolved Solids		mg/L	500 **	500 **	**530**	**520**	**540**	**510**	**520**	360	410	390	430	400	440	420	300	290	290	300	**760**	**870**	**760**	**750**	**690**
	Total Suspended Solids		mg/L			<2.5	<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	<2.0	<2.0	<2.5
METALS	Antimony	Dissolved	mg/L		6 *	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004
	Antimony	Total	mg/L		6 *	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
	Arsenic	Dissolved	mg/L	0.00005 ***	0.01 *	**0.0057**	**0.0037**	NA	NA	**0.0046**	**0.0033**	NA	NA	**0.0081**	**0.0061**	NA	NA	**0.0052**	**0.0043**	NA	NA	**0.0043**	**0.0022**	NA	NA	**0.0036**
	Arsenic	Total	mg/L	0.00005 ***	0.01 *	**0.0055**	**0.0038**	**0.0042**	**0.0044**	**0.0046**	**0.0035**	**0.0037**	**0.0038**	**0.0080**	**0.0063**	**0.0070**	**0.0072**	**0.0052**	**0.0041**	**0.0043**	**0.0048**	**0.0042**	**0.0022**	**0.0023**	**0.0027**	**0.0032**
	Barium	Dissolved	mg/L	1 *	2 *	0.052	0.055	NA	NA	0.043	0.034	NA	NA	0.034	0.037	NA	NA	0.033	0.038	NA	NA	0.099	0.130	NA	NA	0.091
	Barium	Total	mg/L	1 *	2 *	0.054	0.055	0.055	0.058	0.046	0.035	0.038	0.043	0.036	0.037	0.038	0.043	0.034	0.036	0.035	0.042	0.100	0.130	0.110	0.130	0.092
	Beryllium	Dissolved	mg/L		0.004 *	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004
	Beryllium	Total	mg/L		0.004 *	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
	Cadmium	Dissolved	mg/L	0.01 *	0.005 *	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004
	Cadmium	Total	mg/L	0.01 *	0.005 *	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
	Chromium	Dissolved	mg/L	0.05 *	0.1 *	0.0021	0.0022	NA	NA	0.0029	0.0019	NA	NA	0.0029	0.0034	NA	NA	0.0014	0.0015	NA	NA	0.00074	0.0014	NA	NA	<0.0004
	Chromium	Total	mg/L	0.05 *	0.1 *	0.004	0.0036	0.0033	0.0029	0.025	0.006	0.0035	0.007	0.0089	0.014	0.0075	0.0067	0.0021	0.0018	0.0017	0.0018	0.0011	0.0023	0.00093	0.0015	<0.0004
	Cobalt	Dissolved	mg/L			0.018	0.028	NA	NA	<0.0004	<0.0004	NA	NA	0.0015	0.0027	NA	NA	0.0028	0.003	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004
	Cobalt	Total	mg/L			0.033	0.036	0.019	0.022	0.00044	<0.0004	<0.0004	<0.0004	0.0057	0.0096	0.0063	0.0033	0.0045	0.0041	0.0023	0.0015	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
	Copper	Dissolved	mg/L	1 **		<0.002	0.0023	NA	NA	<0.002	<0.002	NA	NA	0.0032	<0.002	NA	NA	<0.002	0.0029	NA	NA	<0.002	<0.002	NA	NA	<0.002
	Copper	Total	mg/L	1 **		<0.002	<0.002	<0.002	<0.002	0.0022	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.0056	0.0038	0.0024	0.004	<0.002
	Lead	Dissolved	mg/L	0.05 *		<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	0.0011	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004
	Lead	Total	mg/L	0.05 *		<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	0.00043	0.00058	<0.0004	<0.0004	<0.0004
	Nickel	Dissolved	mg/L		0.1 *	<0.003	<0.003	NA	NA	<0.003	<0.003	NA	NA	0.003	0.0056	NA	NA	<0.003	<0.003	NA	NA	0.0036	<0.003	NA	NA	<0.003
	Nickel	Total	mg/L		0.1 *	<0.003	<0.003	<0.003	<0003	0.0055	<0.003	<0.003	<0003	0.0062	0.011	0.005	<0003	<0.003	<0.003	<0.003	<0003	0.0038	<0.003	<0.003	0.0031	<0.003
	Selenium	Dissolved	mg/L	0.01 *	0.05 *	0.0017	0.0013	NA	NA	0.0023	0.0014	NA	NA	0.0021	0.0019	NA	NA	<0.001	<0.001	NA	NA	<0.001	<0.001	NA	NA	<0.001
	Selenium	Total	mg/L	0.01 *	0.05 *	0.0019	0.0015	0.0016	0.0015	0.0025	0.0014	0.0018	0.0016	0.002	0.0017	0.002	0.0023	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Silver	Dissolved	mg/L	0.05 *	0.1 **	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004
	Silver	Total	mg/L	0.05 *	0.1 **	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
	Thallium	Dissolved	mg/L		0.002 *	<0.001	<0.001	NA	NA	<0.001	<0.001	NA	NA	<0.001	<0.001	NA	NA	<0.001	<0.001	NA	NA	<0.001	<0.001	NA	NA	<0.001
	Thallium	Total	mg/L		0.002 *	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Vanadium	Dissolved	mg/L			0.0097	0.0084	NA	NA	0.0089	0.0090	NA	NA	0.012	0.011	NA	NA	0.011	0.011	NA	NA	0.008	0.0067	NA	NA	0.0076
	Vanadium	Total	mg/L			0.0093	0.0085	0.0092	0.0100	0.0095	0.0093	0.0099	0.0110	0.0120	0.0120	0.0120	0.0140	0.0110	0.0110	0.0110	0.0130	0.0079	0.0068	0.0073	0.0085	0.0068
	Zinc	Dissolved	mg/L	5 **	5 **	<0.007	<0.007	NA	NA	<0.007	<0.007	NA	NA	<0.007	<0.007	NA	NA	<0.007	0.050	NA	NA	0.026	0.034	NA	NA	<0.007
	Zinc	Total	mg/L	5 **	5 **	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	0.0092	<0.007	<0.007	<0.007	<0.007	0.023	0.039	0.016	0.020	<0.007
VOLATILE ORGANIC COMPOUNDS	Chloromethane		µg/L			<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
	Vinyl Chloride		µg/L	0.02 ***	2 *	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	**0.047**	**0.042**	<0.020	**0.069**	**7.8**	**2.8**	**7.5**	**6.8**	**3.9**
	Bromomethane		µg/L			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	Chloroethane		µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Trichlorofluoromethane		µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.59	0.80	0.78	0.81	0.73	0.91	1.0	0.97	<0.50	<0.50	<0.50	<0.50	<0.50
	1,1-Dichloroethene		µg/L		7 *	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.13	<0.10	<0.10	0.12	0.14	0.10	0.18	<0.10	0.32	<0.10	0.25	0.16	0.36
	Iodomethane		µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50

Table E-1. Groundwater Quality Results, Appendix I and II[1], Horn Rapids Landfill, 2015

	Analyte		Units	GWQS	MCL	MW-6 6/25/2015	MW-6 9/16/2015	MW-6 12/2/2015	MW-21 (MW-6 Dup) 12/2/2015	MW-8 3/31/2015	MW-8 6/24/2015	MW-8 9/17/2015	MW-8 12/3/2015	MW-9 3/30/2015	MW-21 (MW-9 Dup) 3/30/2015	MW-9 6/24/2015	MW-9 9/17/2015	MW-9 12/3/2015	MW-10 3/30/2015	MW-10 6/24/2015	MW-10 9/16/2015	MW-21 (MW-10 Dup) 9/16/2015	MW-10 12/2/2015	MW-11 3/30/2015	MW-11 6/24/2015
FIELD DATA	Conductivity		µmhos/cm		700 **	**1110**	**1081**	**1064**	NA	**739.0**	579	**929**	564	**934.0**	NA	**999**	**1032**	**851**	**1320**	**1322**	**1313**	NA	**1262**	**1459**	**1546**
	pH		units	6.5-8.5		7.77	6.64	6.60	NA	7.59	8.72	7.82	7.72	6.91	NA	7.81	6.97	6.96	**6.46**	7.25	6.65	NA	6.60	7.32	8.07
	Temperature		C°			23.45	26.04	22.52	NA	18.80	24.37	21.53	20.65	21.41	NA	22.39	22.50	21.21	23.92	22.82	24.52	NA	23.29	20.56	23.53
	Oxidation-Reduction Potential		mv			97.1	-215.0	-216.3	NA	75	110.0	-84.7	-65.3	31	NA	96.9	-130.3	-87.0	70	88.6	-224.7	NA	-224.0	28	101.1
	Dissolved Oxygen		mg/L			0.87	0.44	0.47	NA	8.96	8.07	7.79	7.53	3.23	NA	2.84	2.98	2.73	0.81	0.63	0.40	NA	0.35	7.97	7.18
WATER QUALITY PARAMETERS	Nitrate-Nitrogen		mg/L as N	10 *	10 *	1.8	2.0 H	2.2 H	2.2 H	**14**	8.2	**17 H**	8.4	3.4	3.4	3.2	3.5	3.9	4.2	3.2	4.1	4.1	4.3	**36**	**37**
	Calcium	Dissolved	mg/L			160	160	170	160	98	67	120	67	130	140	140	150	130	220	200	200	210	210	220	220
		Total	mg/L			160	NA	NA	NA	98	68	NA	NA	130	140	140	NA	NA	210	200	NA	NA	NA	210	210
	Sodium	Dissolved	mg/L			22	22	24	24	24	19	28	19	24	25	26	30	22	23	22	22	22	23	20	19
		Total	mg/L			22	NA	NA	NA	24	19	NA	NA	23	24	28	NA	NA	23	22	NA	NA	NA	20	18
	Bicarbonate Alkalinity		mg/L as CaCO3			500	520	490	500	120	110	130	120	400	400	410	430	340	640	610	620	620	580	180	170
	Chloride		mg/L	250 **	250 **	19	19	22	22	110	59	130	59	29	29	30	35	31	30	30	30	30	33	160	170
	Magnesium	Dissolved	mg/L			38	36	39	39	21	13	24	13	30	31	30	32	27	46	43	42	42	42	46	44
		Total	mg/L			38	NA	NA	NA	20	14	NA	NA	29	30	31	NA	NA	45	42	NA	NA	NA	44	42
	Potassium	Dissolved	mg/L			12	11	12	12	8.9	6.9	10	6.8	9.5	9.9	9.1	9.6	8.7	13	12	12	12	12	12	11
		Total	mg/L			12	NA	NA	NA	8.9	6.9	NA	NA	9.4	9.7	9.4	NA	NA	13	12	NA	NA	NA	12	11
	Sulfate		mg/L	250 **	250 **	45	42	50	50	54	37	63	43	53	53	52	55	58	60	61	57	57	62	200	230
	Total Alkalinity		mg/L as CaCO3			500	520	490	500	120	110	130	120	400	400	410	430	340	640	610	620	620	580	180	170
	Iron	Dissolved	mg/L	0.3 **	0.3 **	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	< 0.5	<0.5	<0.5	<0.5
		Total	mg/L	0.3 **	0.3 **	<0.5	NA	NA	NA	<0.5	<0.5	NA	NA	<0.5	<0.5	<0.5	NA	NA	<0.5	<0.5	NA	NA	NA	<0.5	<0.5
	Manganese	Dissolved	mg/L	0.05 **	0.05 **	0.034	0.029	0.038	0.038	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.024	0.025	0.023	0.023	0.023	<0.02	<0.02
		Total	mg/L	0.05 **	0.05 **	0.034	NA	NA	NA	<0.02	<0.02	NA	NA	<0.02	<0.02	<0.02	NA	NA	0.023	0.027	NA	NA	NA	<0.02	<0.02
	Ammonia-Nitrogen		mg/L as N			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Total Organic Carbon		mg/L			2.6	1.8	1.7	2.3	1.5	1.2	1.4	1.1	1.7	1.8	2.4	1.2	1.3	3.0	5.7	2.8	2.6	2.7	2.0	2.2
	Total Dissolved Solids		mg/L	500 **	500 **	**680**	**660**	**680**	**660**	**510**	370	**620**	380	**590**	**600**	**590**	**650**	**550**	**840**	**820**	**820**	**810**	**810**	**1000**	**1100**
	Total Suspended Solids		mg/L			<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	<2.0	18	<2.0
METALS	Antimony	Dissolved	mg/L		6 *	<0.0004	NA	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	NA	<0.0004	<0.0004
	Antimony	Total	mg/L		6 *	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	0.0005	<0.0004	<0.0004	<0.0004	<0.0004	< 0.0004	<0.0004	<0.0004	<0.0004
	Arsenic	Dissolved	mg/L	0.00005 ***	0.01 *	**0.0017**	NA	NA	NA	**0.010**	**0.011**	NA	NA	**0.0034**	**0.0036**	**0.002**	NA	NA	**0.004**	**0.002**	NA	NA	NA	**0.0064**	**0.0042**
	Arsenic	Total	mg/L	0.00005 ***	0.01 *	**0.0016**	**0.0017**	**0.0019**	**0.0019**	**0.011**	**0.011**	**0.0086**	**0.011**	**0.0035**	**0.0035**	**0.002**	**0.0022**	**0.0023**	**0.0037**	**0.0019**	**0.0017**	**0.0017**	**0.0019**	**0.0068**	**0.0042**
	Barium	Dissolved	mg/L	1 *	2 *	0.099	NA	NA	NA	0.059	0.044	NA	NA	0.066	0.067	0.081	NA	NA	0.100	0.110	NA	NA	NA	0.092	0.110
	Barium	Total	mg/L	1 *	2 *	0.100	0.093	0.110	0.110	0.063	0.044	0.078	0.050	0.069	0.071	0.082	0.086	0.080	0.110	0.110	0.110	0.110	0.130	0.100	0.110
	Beryllium	Dissolved	mg/L		0.004 *	<0.0004	NA	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	NA	<0.0004	<0.0004
	Beryllium	Total	mg/L		0.004 *	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	< 0.0004	<0.0004	<0.0004	<0.0004
	Cadmium	Dissolved	mg/L	0.01 *	0.005 *	<0.0004	NA	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	NA	<0.0004	<0.0004
	Cadmium	Total	mg/L	0.01 *	0.005 *	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	< 0.0004	<0.0004	<0.0004	<0.0004
	Chromium	Dissolved	mg/L	0.05 *	0.1 *	0.00081	NA	NA	NA	0.0026	0.0019	NA	NA	0.0013	0.0013	0.0021	NA	NA	0.0008	0.0014	NA	NA	NA	0.0047	0.003
	Chromium	Total	mg/L	0.05 *	0.1 *	0.00082	0.00042	0.00080	0.00053	0.0074	0.0026	0.0074	0.0051	0.0017	0.002	0.0024	0.0051	0.0027	0.00069	0.0024	0.00079	0.00085	0.00098	0.038	0.012
	Cobalt	Dissolved	mg/L			0.0063	NA	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	NA	0.00043	<0.0004
	Cobalt	Total	mg/L			0.0062	0.002	0.00089	0.00080	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	< 0.0004	<0.0004	0.0012	<0.0004
	Copper	Dissolved	mg/L	1 **		0.0052	NA	NA	NA	<0.002	<0.002	NA	NA	0.0023	<0.002	0.003	NA	NA	<0.002	0.0023	NA	NA	NA	0.0021	0.0024
	Copper	Total	mg/L	1 **		<0.002	0.0068	0.0026	<0.002	0.003	0.0026	<0.002	<0.002	<0.002	0.0038	<0.002	<0.002	<0.002	<0.002	0.0025	<0.002	< 0.002	0.0024	0.0067	0.002
	Lead	Dissolved	mg/L	0.05 *		<0.0004	NA	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	<0.0004	NA	NA	<0.0004	0.00041	NA	NA	NA	<0.0004	<0.0004
	Lead	Total	mg/L	0.05 *		<0.0004	0.0018	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	< 0.0004	<0.0004	<0.0004	<0.0004
	Nickel	Dissolved	mg/L		0.1 *	<0.003	NA	NA	NA	0.004	<0.003	NA	NA	<0.003	<0.003	<0.003	NA	NA	0.003	<0.003	NA	NA	NA	0.0091	0.0051
	Nickel	Total	mg/L		0.1 *	<0.003	<0.003	<0003	<0003	0.0053	0.003	0.0049	0.0035	<0.003	<0.003	<0.003	<0.003	<0003	<0.003	<0.003	<0.003	< 0.003	<0003	0.021	0.0061
	Selenium	Dissolved	mg/L	0.01 *	0.05 *	<0.001	NA	NA	NA	0.0026	0.0014	NA	NA	0.0014	0.0014	0.0024	NA	NA	<0.001	<0.001	NA	NA	NA	0.0093	**0.011**
	Selenium	Total	mg/L	0.01 *	0.05 *	<0.001	<0.001	<0.001	<0.001	0.0029	0.0015	0.0035	0.0015	0.0015	0.0016	0.0024	0.0037	<0.001	<0.001	<0.001	<0.001	< 0.001	<0.001	0.010	0.010
	Silver	Dissolved	mg/L	0.05 *	0.1 **	<0.0004	NA	NA	NA	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	<0.0004	NA	NA	<0.0004	<0.0004	NA	NA	NA	<0.0004	<0.0004
	Silver	Total	mg/L	0.05 *	0.1 **	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	< 0.0004	<0.0004	<0.0004	<0.0004
	Thallium	Dissolved	mg/L		0.002 *	<0.001	NA	NA	NA	<0.001	<0.001	NA	NA	<0.001	<0.001	<0.001	NA	NA	<0.001	<0.001	NA	NA	NA	<0.001	<0.001
	Thallium	Total	mg/L		0.002 *	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	< 0.001	<0.001	<0.001	<0.001
	Vanadium	Dissolved	mg/L			0.0065	NA	NA	NA	0.014	0.017	NA	NA	0.0072	0.0072	0.0070	NA	NA	0.0077	0.0063	NA	NA	NA	0.0094	0.0091
	Vanadium	Total	mg/L			0.0062	0.0063	0.0073	0.0076	0.0150	0.0170	0.0140	0.0190	0.0074	0.0076	0.0070	0.0068	0.0079	0.0076	0.0060	0.0067	0.0068	0.0078	0.0110	0.0092
	Zinc	Dissolved	mg/L	5 **	5 **	0.013	NA	NA	NA	<0.007	<0.007	NA	NA	<0.007	<0.007	0.014	NA	NA	<0.007	0.018	NA	NA	NA	<0.007	0.010
	Zinc	Total	mg/L	5 **	5 **	0.018	0.0071	<0.007	<0.007	<0.007	0.0083	<0.007	<0.007	<0.007	<0.007	0.012	<0.007	<0.007	<0.007	0.014	0.0072	0.0080	0.0089	<0.007	<0.007
VOLATILE ORGANIC COMPOUNDS	Chloromethane		µg/L			<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
	Vinyl Chloride		µg/L	0.02 ***	2 *	**2.9**	**3.5**	**3.3**	**3.2**	<0.020	<0.020	<0.020	<0.020	**0.040**	**0.046**	<0.020	<0.020	**0.068**	**2.4**	**1.8**	**1.9**	**2.1**	**0.89**	<0.020	<0.020
	Bromomethane		µg/L			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	Chloroethane		µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	1.8	<0.50	0.51	<0.50	0.73	<0.50	<0.50
	Trichlorofluoromethane		µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	1,1-Dichloroethene		µg/L		7 *	0.27	0.27	0.32	0.25	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.68	0.61	0.56	0.68	0.29	<0.10	<0.10
	Iodomethane		µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50

Table E-1. Groundwater Quality Results, Appendix I and II[1], Horn Rapids Landfill, 2015

	Analyte		Units	GWQS	MCL	MW-21 (MW-11 Dup) 6/24/2015	MW-11 9/16/2015	MW-11 12/2/2015	Trip Blank 3/30/2015	Trip Blank 6/24/2015	Trip Blank 9/16/2015	Trip Blank 12/2/2015	Port 3 6/25/2015
FIELD DATA	Conductivity		µmhos/cm		700 **	NA	**1643**	**1680**	NA	NA	NA	NA	NA
	pH		units	6.5-8.5		NA	7.43	7.29	NA	NA	NA	NA	NA
	Temperature		C°			NA	22.22	19.15	NA	NA	NA	NA	NA
	Oxidation-Reduction Potential		mv			NA	-55.5	-11.5	NA	NA	NA	NA	NA
	Dissolved Oxygen		mg/L			NA	7.24	8.65	NA	NA	NA	NA	NA
WATER QUALITY PARAMETERS	Nitrate-Nitrogen		mg/L as N	10 *	10 *	**38 H**	**38**	**36**	NA	NA	NA	NA	NA
	Calcium	Dissolved	mg/L			230	240	240	NA	NA	NA	NA	NA
		Total	mg/L			210	NA	NA	NA	NA	NA	NA	NA
	Sodium	Dissolved	mg/L			20	21	20	NA	NA	NA	NA	NA
		Total	mg/L			19	NA	NA	NA	NA	NA	NA	NA
	Bicarbonate Alkalinity		mg/L as CaCO3			180	180	170	NA	NA	NA	NA	NA
	Chloride		mg/L	250 **	250 **	170	200	220	NA	NA	NA	NA	NA
	Magnesium	Dissolved	mg/L			47	47	50	NA	NA	NA	NA	NA
		Total	mg/L			43	NA	NA	NA	NA	NA	NA	NA
	Potassium	Dissolved	mg/L			12	11	12	NA	NA	NA	NA	NA
		Total	mg/L			11	NA	NA	NA	NA	NA	NA	NA
	Sulfate		mg/L	250 **	250 **	230	230	**270**	NA	NA	NA	NA	NA
	Total Alkalinity		mg/L as CaCO3			180	180	170	NA	NA	NA	NA	NA
	Iron	Dissolved	mg/L	0.3 **	0.3 **	<0.5	<0.5	<0.5	NA	NA	NA	NA	NA
		Total	mg/L	0.3 **	0.3 **	<0.5	NA	NA	NA	NA	NA	NA	NA
	Manganese	Dissolved	mg/L	0.05 **	0.05 **	<0.02	<0.02	<0.02	NA	NA	NA	NA	NA
		Total	mg/L	0.05 **	0.05 **	<0.02	NA	NA	NA	NA	NA	NA	NA
	Ammonia-Nitrogen		mg/L as N			<0.20	<0.20	<0.20	NA	NA	NA	NA	NA
	Total Organic Carbon		mg/L			2.0	2.2	2.4	NA	NA	NA	NA	NA
	Total Dissolved Solids		mg/L	500 **	500 **	**1100**	**1200**	**1300**	NA	NA	NA	NA	NA
	Total Suspended Solids		mg/L			<2.0	<2.0	<2.0	NA	NA	NA	NA	NA
METALS	Antimony	Dissolved	mg/L		6 *	<0.0004	NA	NA	NA	NA	NA	NA	NA
	Antimony	Total	mg/L		6 *	<0.0004	<0.0004	<0.0004	NA	NA	NA	NA	NA
	Arsenic	Dissolved	mg/L	0.00005 ***	0.01 *	**0.0043**	NA	NA	NA	NA	NA	NA	NA
	Arsenic	Total	mg/L	0.00005 ***	0.01 *	**0.0043**	**0.0045**	**0.0045**	NA	NA	NA	NA	NA
	Barium	Dissolved	mg/L	1 *	2 *	0.110	NA	NA	NA	NA	NA	NA	NA
	Barium	Total	mg/L	1 *	2 *	0.110	0.110	0.130	NA	NA	NA	NA	NA
	Beryllium	Dissolved	mg/L		0.004 *	<0.0004	NA	NA	NA	NA	NA	NA	NA
	Beryllium	Total	mg/L		0.004 *	<0.0004	<0.0004	<0.0004	NA	NA	NA	NA	NA
	Cadmium	Dissolved	mg/L	0.01 *	0.005 *	<0.0004	NA	NA	NA	NA	NA	NA	NA
	Cadmium	Total	mg/L	0.01 *	0.005 *	<0.0004	<0.0004	<0.0004	NA	NA	NA	NA	NA
	Chromium	Dissolved	mg/L	0.05 *	0.1 *	0.0032	NA	NA	NA	NA	NA	NA	NA
	Chromium	Total	mg/L	0.05 *	0.1 *	0.024	0.0048	0.0031	NA	NA	NA	NA	NA
	Cobalt	Dissolved	mg/L			<0.0004	NA	NA	NA	NA	NA	NA	NA
	Cobalt	Total	mg/L			0.00051	<0.0004	<0.0004	NA	NA	NA	NA	NA
	Copper	Dissolved	mg/L	1 **		0.0045	NA	NA	NA	NA	NA	NA	NA
	Copper	Total	mg/L	1 **		0.0037	0.0053	<0.002	NA	NA	NA	NA	NA
	Lead	Dissolved	mg/L	0.05 *		<0.0004	NA	NA	NA	NA	NA	NA	NA
	Lead	Total	mg/L	0.05 *		<0.0004	<0.0004	<0.0004	NA	NA	NA	NA	NA
	Nickel	Dissolved	mg/L		0.1 *	0.005	NA	NA	NA	NA	NA	NA	NA
	Nickel	Total	mg/L		0.1 *	0.012	<0.003	<0003	NA	NA	NA	NA	NA
	Selenium	Dissolved	mg/L	0.01 *	0.05 *	**0.011**	NA	NA	NA	NA	NA	NA	NA
	Selenium	Total	mg/L	0.01 *	0.05 *	**0.011**	**0.011**	**0.011**	NA	NA	NA	NA	NA
	Silver	Dissolved	mg/L	0.05 *	0.1 **	<0.0004	NA	NA	NA	NA	NA	NA	NA
	Silver	Total	mg/L	0.05 *	0.1 **	<0.0004	<0.0004	<0.0004	NA	NA	NA	NA	NA
	Thallium	Dissolved	mg/L		0.002 *	<0.001	NA	NA	NA	NA	NA	NA	NA
	Thallium	Total	mg/L		0.002 *	<0.001	<0.001	<0.001	NA	NA	NA	NA	NA
	Vanadium	Dissolved	mg/L			0.0092	NA	NA	NA	NA	NA	NA	NA
	Vanadium	Total	mg/L			0.0095	0.0090	0.0100	NA	NA	NA	NA	NA
	Zinc	Dissolved	mg/L	5 **	5 **	<0.007	NA	NA	NA	NA	NA	NA	NA
	Zinc	Total	mg/L	5 **	5 **	0.0093	<0.007	<0.007	NA	NA	NA	NA	NA
VOLATILE ORGANIC COMPOUNDS	Chloromethane		µg/L			<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
	Vinyl Chloride		µg/L	0.02 ***	2 *	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	**2.5**
	Bromomethane		µg/L			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	Chloroethane		µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	1.9
	Trichlorofluoromethane		µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	1,1-Dichloroethene		µg/L		7 *	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.13
	Iodomethane		µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50

Table E-1. Groundwater Quality Results, Appendix I and II[1], Horn Rapids Landfill, 2015

	Analyte	Units	GWQS	MCL	MW-1 3/31/2015	MW-1 6/24/2015	MW-1 9/16/2015	MW-1 12/2/2015	MW-2 3/30/2015	MW-2 6/24/2015	MW-2 9/17/2015	MW-2 12/3/2015	MW-3 3/30/2015	MW-3 6/24/2015	MW-3 9/17/2015	MW-3 12/3/2015	MW-4 3/31/2015	MW-4 6/24/2015	MW-4 9/17/2015	MW-4 12/3/2015	MW-5 3/30/2015	MW-5 6/25/2015	MW-5 9/16/2015	MW-5 12/2/2015	MW-6 3/30/2015
	Carbon Disulfide	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
VOLATILE ORGANIC COMPOUNDS (Cont.)	Acetone	µg/L			<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	<2.0	<2.0	<2.0	<2.0
	Methylene Chloride	µg/L	5 ***	5 *	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	trans-1,2-Dichloroethene	µg/L		100 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.75	0.42	0.78	0.58	2.4
	Acrylonitrile	µg/L	0.07 ***		<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	1,1-Dichloroethane	µg/L	1 ***		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	**1.8**	**1.4**	**1.6**	**1.5**	**3.2**	**3.3**	**4.0**	**3.5**	**8.3**	**4.6**	**8.8**	**7.0**	**6.8**
	Vinyl Acetate	µg/L			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	cis-1,2-Dichloroethene	µg/L		70 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	1.1	0.99	0.91	0.91	2.7	3.0	3.1	2.7	37	20	38	32	62
	2-Butanone	µg/L			<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15
	Bromochloromethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Chloroform	µg/L	7 ***	100 * THM	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.31	0.38	0.46	0.48	0.23	0.38	0.46	0.38	<0.20	0.23	0.22	<0.20	<0.20
	1,1,1-Trichloroethane	µg/L	200 *	200 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Carbon Tetrachloride	µg/L	0.3 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Benzene	µg/L	1 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.37	<0.20	0.33	0.30	0.47
	1,2-Dichloroethane	µg/L	0.5 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	**0.95**	0.49	**1.1**	**1.1**	**0.54**
	Trichloroethene	µg/L	3 ***	5 *	0.35	0.32	0.27	0.21	<0.20	<0.20	<0.20	<0.20	<0.20	0.20	0.22	<0.20	<0.20	0.26	0.25	0.20	**7.6**	**5.0**	**7.4**	**6.5**	**20**
	1,2-Dichloropropane	µg/L	0.6 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.53	0.23	0.51	0.47	0.49
	Dibromomethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Bromodichloromethane	µg/L	0.3 ***	100 * THM	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	cis-1,3-Dichloropropene	µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	4-Methyl-2-pentanone	µg/L			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	Toluene	µg/L		1000 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	trans-1,3-Dichloropropene	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,1,2-Trichloroethane	µg/L		5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Tetrachloroethene	µg/L	0.8 ***	5 *	**4.8**	**4.9**	**4.4**	**4.2**	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	**17**	**11**	**17**	**20**	**38**
	2-Hexanone	µg/L			<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	<2.0	<2.0	<2.0	<2.0
	Dibromochloromethane	µg/L		100 * THM	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,2-Dibromoethane	µg/L	0.001 ***	0.05 *	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
	Chlorobenzene	µg/L		100 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,1,1,2-Tetrachloroethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Ethylbenzene	µg/L		700 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	m,p-Xylene	µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	o-Xylene	µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Styrene	µg/L		100 *	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Bromoform	µg/L	5 ***	100 * THM	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	1,1,2,2-Tetrachloroethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,2,3-Trichloropropane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	trans-1,4-Dichloro-2-butene	µg/L			<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	<2.0	<2.0	<2.0	<2.0
	1,4-Dichlorobenzene	µg/L	4 ***	75 *	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
	1,2-Dichlorobenzene	µg/L		600 *	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
	1,2-Dibromo-3-Chloropropane	µg/L		0.2 *	<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	<2.0	<2.0	<2.0	<2.0
	Total Xylenes	µg/L		10000 * XYL	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
ATTENUATION PARAMETERS	Methane	µg/L			<1.2	<5	<5	<5	<1.2	<5	<5	<5	<1.2	5.5	<5	<5	<1.2	<5	<5	<5	1300	550	1800	2200	2000
	Ethane	µg/L			<10	<5	<5	<5	<10	<5	<5	<5	<10	<5	<5	<5	<10	<5	<5	<5	<10	<5	<5	<5	<10
	Ethene	µg/L			<10	<5	<5	<5	<10	<5	<5	<5	<10	<5	<5	<5	<10	<5	<5	<5	<10	<5	<5	<5	<10

Notes:

[1] = Chapter 173-351 WAC
GWQS = Water Quality Standards for Ground Waters of the State of Washington (WAC 173-200)
MCL = Maximum Contaminant Level, State Drinking Water Regulations (WAC 246-290)
* = Primary
** = Secondary
*** = Carcinogen
*THM = Primary MCL for the sum of all trihalomethanes
*XYL = Primary MCL for the sum of all xylenes
H = Estimated value; analyzed beyond specified holding time
Bold = Does not meet GWQS or MCL
NA = Not analyzed

Table E-1. Groundwater Quality Results, Appendix I and II[1], Horn Rapids Landfill, 2015

	Analyte	Units	GWQS	MCL	MW-6 6/25/2015	MW-6 9/16/2015	MW-6 12/2/2015	MW-21 (MW-6 Dup) 12/2/2015	MW-8 3/31/2015	MW-8 6/24/2015	MW-8 9/17/2015	MW-8 12/3/2015	MW-9 3/30/2015	MW-21 (MW-9 Dup) 3/30/2015	MW-9 6/24/2015	MW-9 9/17/2015	MW-9 12/3/2015	MW-10 3/30/2015	MW-10 6/24/2015	MW-10 9/16/2015	MW-21 (MW-10 Dup) 9/16/2015	MW-10 12/2/2015	MW-11 3/30/2015	MW-11 6/24/2015
VOLATILE ORGANIC COMPOUNDS (Cont.)	Carbon Disulfide	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Acetone	µg/L			<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	<2.0	<2.0	<2.0
	Methylene Chloride	µg/L	5 ***	5 *	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	4.8	4.2	3.7	3.7	4.2	<0.50	<0.50
	trans-1,2-Dichloroethene	µg/L		100 *	1.9	2.0	2.0	1.7	<0.20	<0.20	<0.20	<0.20	0.25	0.24	<0.20	0.26	0.40	0.27	0.24	0.24	0.27	0.21	<0.20	<0.20
	Acrylonitrile	µg/L	0.07 ***		<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	1,1-Dichloroethane	µg/L	1 ***		**5.4**	**6.0**	**5.7**	**4.7**	<0.20	<0.20	<0.20	<0.20	**3.2**	**3.3**	**2.3**	**2.7**	**4.6**	**9.6**	**8.0**	**9.2**	**9.0**	**7.5**	<0.20	<0.20
	Vinyl Acetate	µg/L			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	cis-1,2-Dichloroethene	µg/L		70 *	53	56	58	49	<0.20	<0.20	<0.20	<0.20	8.7	9.2	6.3	7.3	14	16	15	16	15	14	<0.20	<0.20
	2-Butanone	µg/L			<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15	<15
	Bromochloromethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Chloroform	µg/L	7 ***	100 * THM	<0.20	<0.20	<0.20	<0.20	6.3	**9.8**	5.3	**9.8**	0.25	0.25	<0.20	0.24	1.2	0.88	0.73	0.88	0.81	0.70	<0.20	<0.20
	1,1,1-Trichloroethane	µg/L	200 *	200 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Carbon Tetrachloride	µg/L	0.3 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Benzene	µg/L	1 ***	5 *	0.38	0.38	0.40	0.34	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.50	0.28	0.53	0.53	0.44	<0.20	<0.20
	1,2-Dichloroethane	µg/L	0.5 ***	5 *	0.49	**0.64**	**0.65**	**0.61**	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	**0.52**	0.46	**0.61**	**0.58**	**0.57**	<0.20	<0.20
	Trichloroethene	µg/L	3 ***	5 *	**18**	**17**	**18**	**15**	<0.20	<0.20	<0.20	<0.20	**4.5**	**4.8**	**3.4**	**3.8**	**6.8**	**4.0**	**3.7**	**3.5**	**3.4**	**3.2**	<0.20	<0.20
	1,2-Dichloropropane	µg/L	0.6 ***	5 *	0.38	0.41	0.45	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.22	<0.20	<0.20	<0.20	0.20	<0.20	<0.20
	Dibromomethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Bromodichloromethane	µg/L	0.3 ***	100 * THM	<0.20	<0.20	<0.20	<0.20	**0.44**	**0.73**	**0.41**	**0.78**	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	cis-1,3-Dichloropropene	µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	4-Methyl-2-pentanone	µg/L			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	Toluene	µg/L		1000 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	trans-1,3-Dichloropropene	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,1,2-Trichloroethane	µg/L		5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Tetrachloroethene	µg/L	0.8 ***	5 *	**38**	**37**	**40**	**41**	<0.50	<0.50	<0.50	<0.50	**11**	**11**	**11**	**13**	**13**	**7.5**	**7.1**	**6.6**	**6.4**	**7.6**	<0.50	<0.50
	2-Hexanone	µg/L			<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	<2.0	<2.0	<2.0
	Dibromochloromethane	µg/L		100 * THM	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,2-Dibromoethane	µg/L	0.001 ***	0.05 *	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
	Chlorobenzene	µg/L		100 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,1,1,2-Tetrachloroethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Ethylbenzene	µg/L		700 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	m,p-Xylene	µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	o-Xylene	µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Styrene	µg/L		100 *	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Bromoform	µg/L	5 ***	100 * THM	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	1,1,2,2-Tetrachloroethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,2,3-Trichloropropane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	trans-1,4-Dichloro-2-butene	µg/L			<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	<2.0	<2.0	<2.0
	1,4-Dichlorobenzene	µg/L	4 ***	75 *	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
	1,2-Dichlorobenzene	µg/L		600 *	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
	1,2-Dibromo-3-Chloropropane	µg/L		0.2 *	<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	<2.0	<2.0	<2.0
	Total Xylenes	µg/L		10000 * XYL	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
ATTENUATION PARAMETERS	Methane	µg/L			2300	5100	3500	3600	5.4	<5 H	<5	<5	<1.2	<1.2	<5 H	<5	<5	1100	820 H	1600	1700	1900	5.4	<5 H
	Ethane	µg/L			<5	<5	<5	<5	<10	<5 H	<5	<5	<10	<10	<5 H	<5	<5	<10	<5 H	<5	<5	<5	<10	<5 H
	Ethene	µg/L			<5	<5	<5	<5	<10	<5 H	<5	<5	<10	<10	<5 H	<5	<5	<10	<5 H	<5	<5	<5	<10	<5 H

Notes:

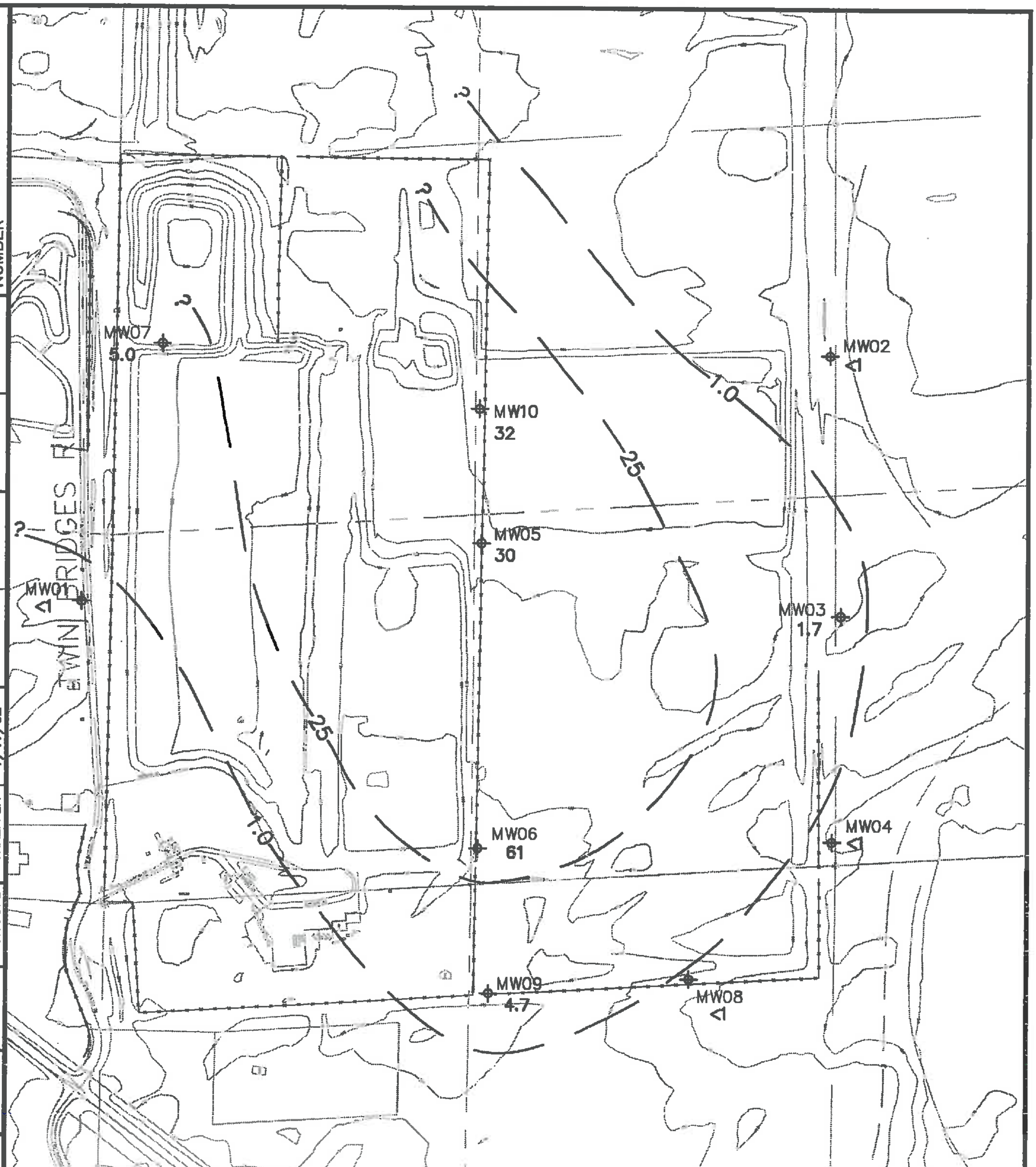
1 = Chapter 173-351 WAC
GWQS = Water Quality Standards for Ground Waters of the State of Washington (WAC 173-200)
MCL = Maximum Contaminant Level, State Drinking Water Regulations (WAC 246-290)
* = Primary
** = Secondary
*** = Carcinogen
*THM = Primary MCL for the sum of all trihalomethanes
*XYL = Primary MCL for the sum of all xylenes
H = Estimated value; analyzed beyond specified holding time
Bold = Does not meet GWQS or MCL
NA = Not analyzed

Table E-1. Groundwater Quality Results, Appendix I and II[1], Horn Rapids Landfill, 2015

	Analyte	Units	GWQS	MCL	MW-21 (MW-11 Dup) 6/24/2015	MW-11 9/16/2015	MW-11 12/2/2015	Trip Blank 3/30/2015	Trip Blank 6/24/2015	Trip Blank 9/16/2015	Trip Blank 12/2/2015	Port 3 6/25/2015
VOLATILE ORGANIC COMPOUNDS (Cont.)	Carbon Disulfide	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	5.7
	Acetone	µg/L			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	47
	Methylene Chloride	µg/L	5 ***	5 *	<0.50	<0.50	<0.50	0.66	1.4	<0.50	<0.50	2.3
	trans-1,2-Dichloroethene	µg/L		100 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Acrylonitrile	µg/L	0.07 ***		<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	12
	1,1-Dichloroethane	µg/L	1 ***		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	**3.3**
	Vinyl Acetate	µg/L			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	cis-1,2-Dichloroethene	µg/L		70 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	6.2
	2-Butanone	µg/L			<15	<15	<15	<15	<15	<15	<15	<15
	Bromochloromethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Chloroform	µg/L	7 ***	100 * THM	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,1,1-Trichloroethane	µg/L	200 *	200 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Carbon Tetrachloride	µg/L	0.3 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Benzene	µg/L	1 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	1.0
	1,2-Dichloroethane	µg/L	0.5 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	**0.71**
	Trichloroethene	µg/L	3 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.29
	1,2-Dichloropropane	µg/L	0.6 ***	5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Dibromomethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Bromodichloromethane	µg/L	0.3 ***	100 * THM	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	cis-1,3-Dichloropropene	µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	4-Methyl-2-pentanone	µg/L			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	5400
	Toluene	µg/L		1000 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	3.8
	trans-1,3-Dichloropropene	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,1,2-Trichloroethane	µg/L		5 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Tetrachloroethene	µg/L	0.8 ***	5 *	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	**0.82**
	2-Hexanone	µg/L			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
	Dibromochloromethane	µg/L		100 * THM	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,2-Dibromoethane	µg/L	0.001 ***	0.05 *	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
	Chlorobenzene	µg/L		100 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,1,1,2-Tetrachloroethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Ethylbenzene	µg/L		700 *	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	2.6
	m,p-Xylene	µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	16
	o-Xylene	µg/L			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	15
	Styrene	µg/L		100 *	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Bromoform	µg/L	5 ***	100 * THM	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	1,1,2,2-Tetrachloroethane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	1,2,3-Trichloropropane	µg/L			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	trans-1,4-Dichloro-2-butene	µg/L			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
	1,4-Dichlorobenzene	µg/L	4 ***	75 *	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
	1,2-Dichlorobenzene	µg/L		600 *	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
	1,2-Dibromo-3-Chloropropane	µg/L		0.2 *	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
	Total Xylenes	µg/L		10000 * XYL	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	31
ATTENUATION PARAMETERS	Methane	µg/L			<5 H	<5	<5	<1.2	<5	<5	<5 H	NA
	Ethane	µg/L			<5 H	<5	<5	<10	<5	<5	<5 H	NA
	Ethene	µg/L			<5 H	<5	<5	<10	<5	<5	<5 H	NA

Notes:

1 = Chapter 173-351 WAC
GWQS = Water Quality Standards for Ground Waters of the State of Washington (WAC 173-200)
MCL = Maximum Contaminant Level, State Drinking Water Regulations (WAC 246-290)
* = Primary
** = Secondary
*** = Carcinogen
*THM = Primary MCL for the sum of all trihalomethanes
*XYL = Primary MCL for the sum of all xylenes
H = Estimated value; analyzed beyond specified holding time
Bold = Does not meet GWQS or MCL
NA = Not analyzed



SCALE

0 500 1000 FEET

LEGEND

MONITORING WELL LOCATION

30 1,1-DCA CONCENTRATION IN μg/L

1,1-DCA ISOCONCENTRATION CONTOUR

Shaw E & I, Inc.

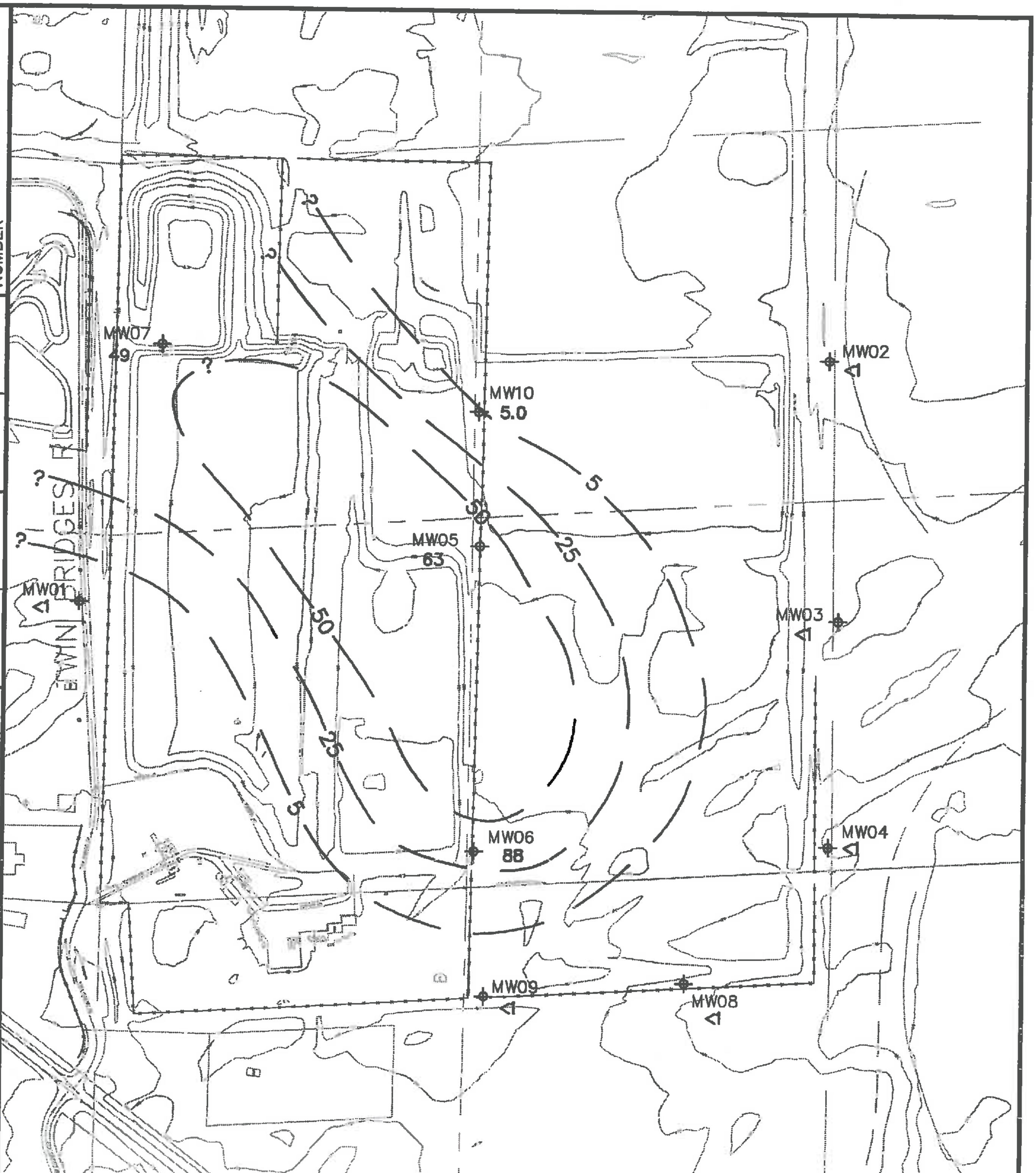
HORN RAPIDS LANDFILL

FIGURE 18

1,1-DCA ISOCONCENTRATION MAP
MARCH 2002

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY	APPROVED BY	DRAWING NUMBER
---	---	Concord	SCHAEFFER	7/17/02			810835-A2

IMAGE	X-REF	OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	DRAWING NUMBER
---	---	Concord	SCHAEFFER 7/17/02			810835-A3



SCALE

0 500 1000 FEET

LEGEND

⊕ MONITORING WELL LOCATION

63 CIS-1,2-DCE CONCENTRATION IN μg/L

——— CIS-1,2-DCE ISOCONCENTRATION CONTOUR

(N)

Shaw™
Shaw E & I, Inc.

HORN RAPIDS LANDFILL

FIGURE 19

CIS-1,2-DCE ISOCONCENTRATION MAP
MARCH 2002

DRAWING NUMBER 810835-A4

APPROVED BY

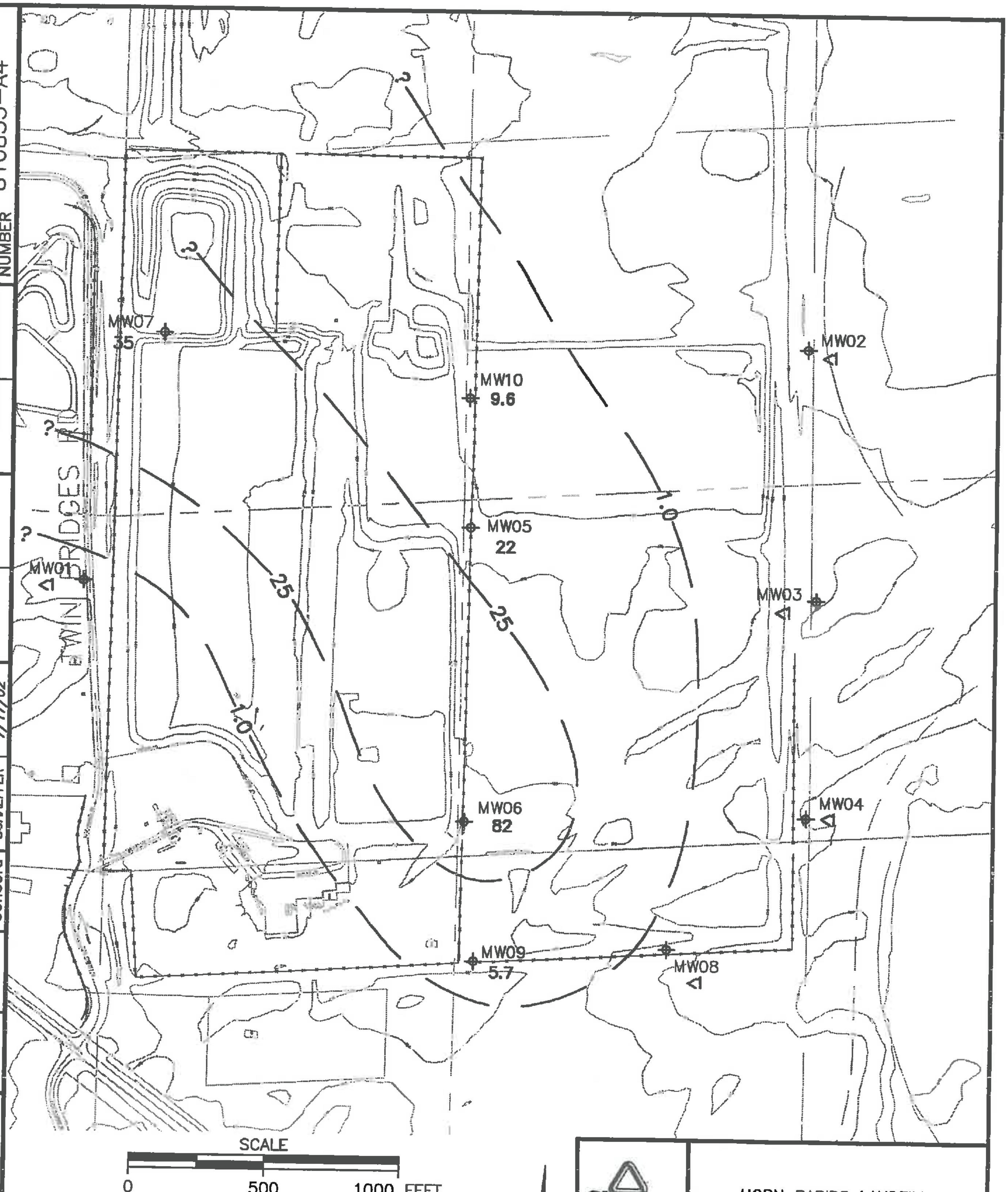
CHECKED BY

DRAWN BY SCHAEFFER 7/17/02

OFFICE Concord

X-REF --

IMAGE --



LEGEND

MONITORING WELL LOCATION

22 PCE CONCENTRATION IN µg/L

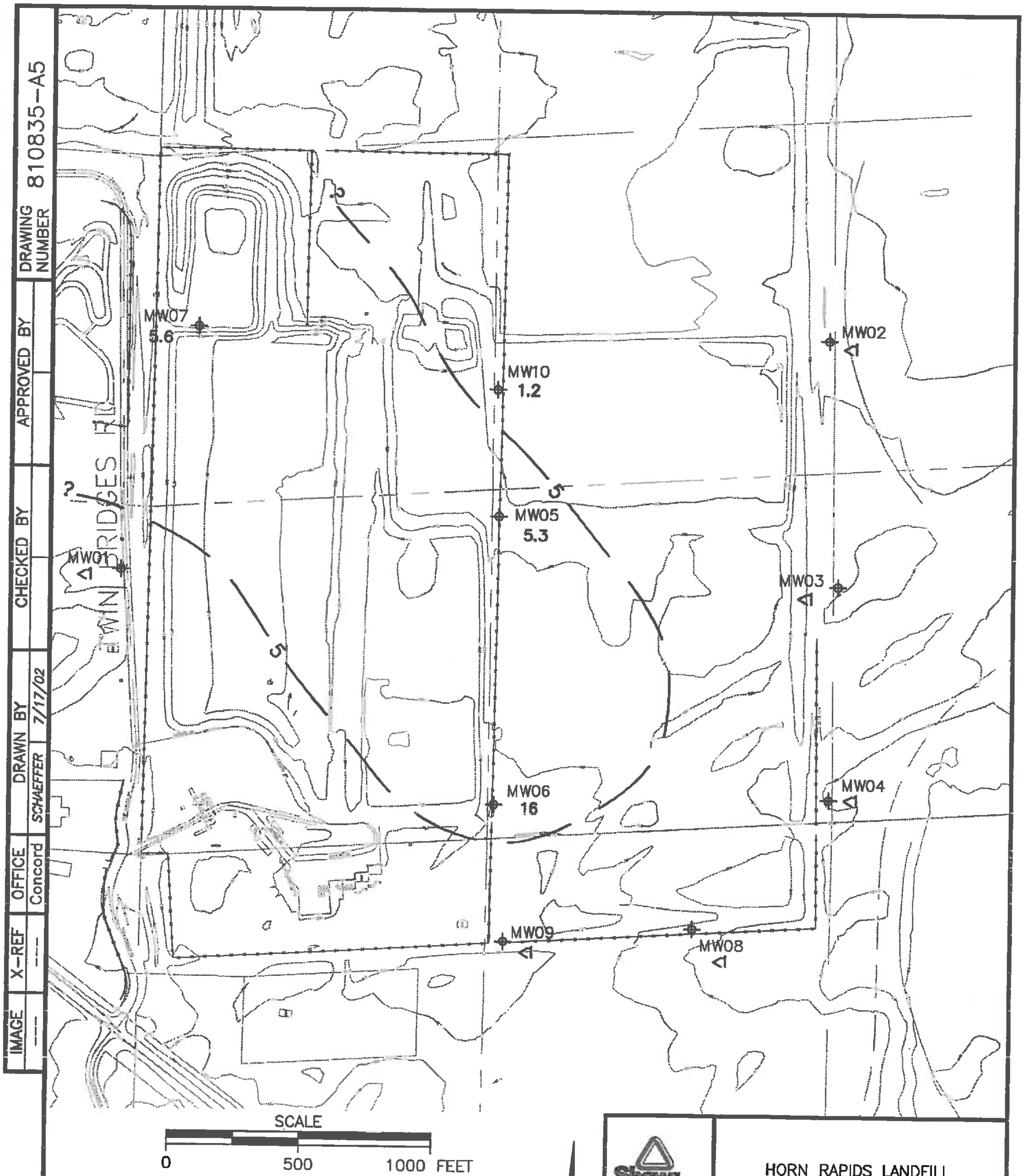
PCE ISOCONCENTRATION CONTOUR

Shaw™ Shaw E & I, Inc.

HORN RAPIDS LANDFILL

FIGURE 20

PCE ISOCONCENTRATION MAP
MARCH 2002



LEGEND

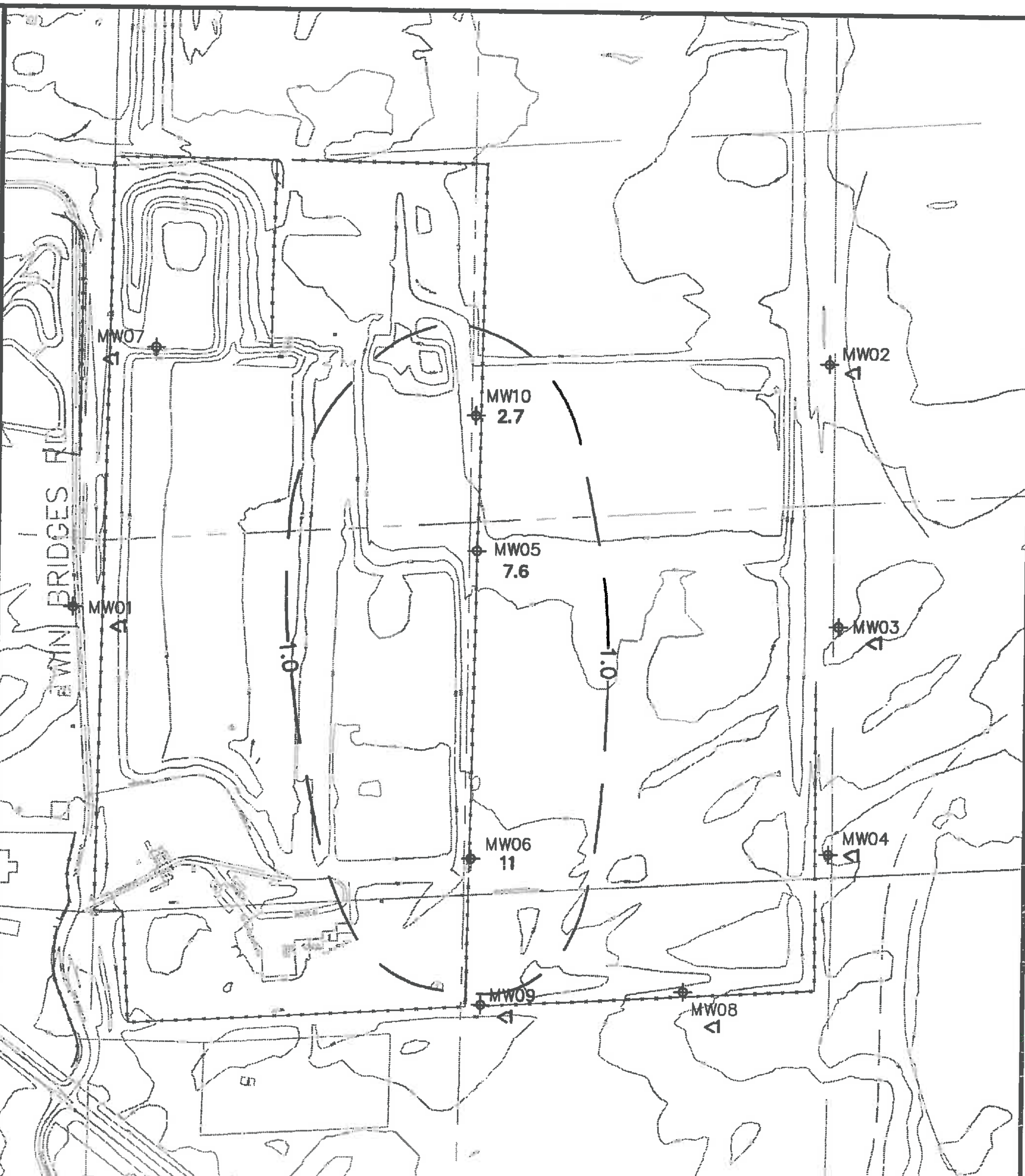
- ⌖ MONITORING WELL LOCATION
- 5.3 TCE CONCENTRATION IN μg/L
- ⁀ TCE ISOCONCENTRATION CONTOUR

Shaw E & I, Inc.

HORN RAPIDS LANDFILL

FIGURE 21

TCE ISOCONCENTRATION MAP
MARCH 2002



SCALE

0 500 1000 FEET

LEGEND

MONITORING WELL LOCATION

2.7 VINYL CHLORIDE CONCENTRATION IN μg/L

VINYL CHLORIDE ISOCONCENTRATION CONTOUR

N

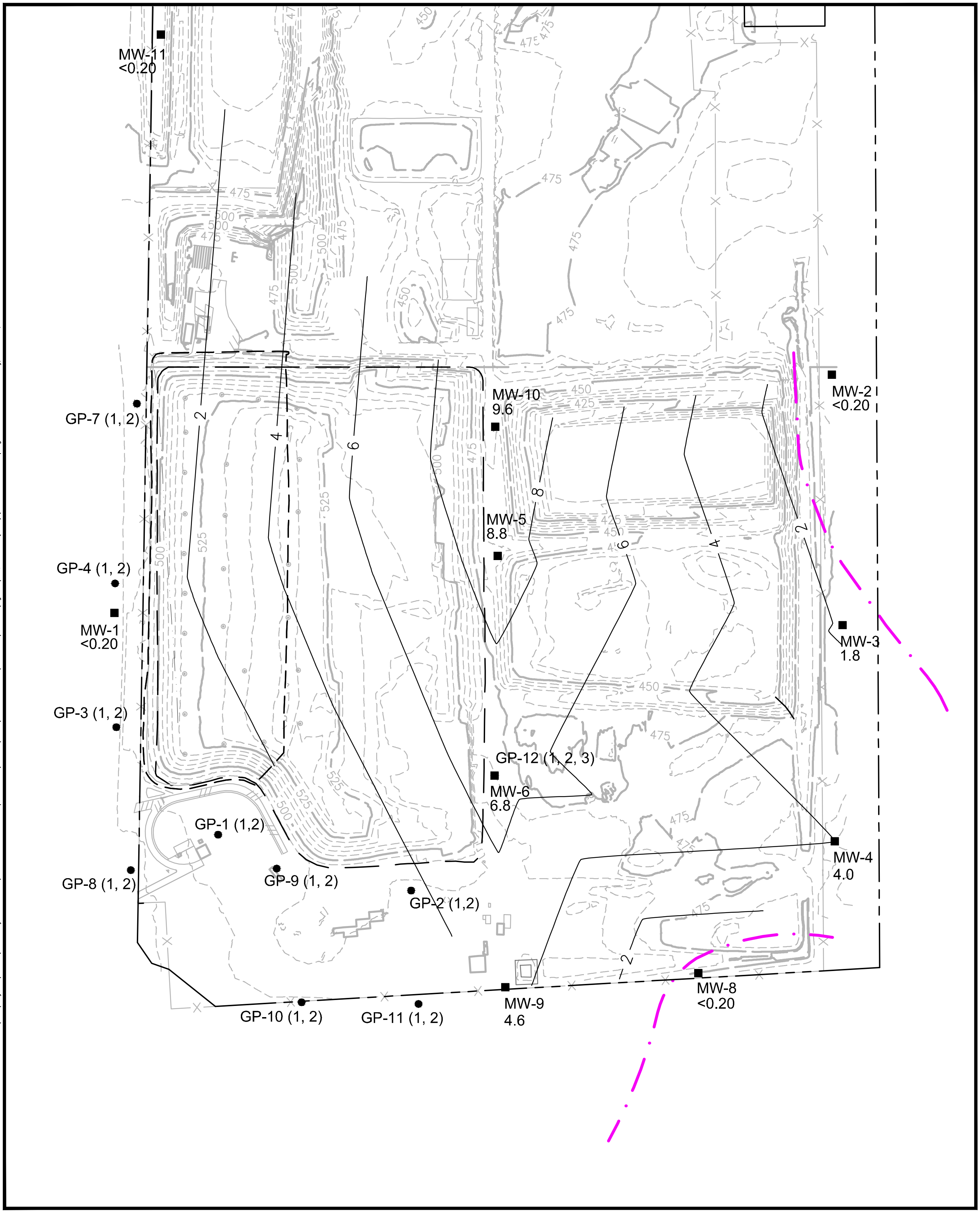
Shaw E & I, Inc.

HORN RAPIDS LANDFILL

FIGURE 22

VINYL CHLORIDE ISOCONCENTRATION MAP
MARCH 2002

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY	APPROVED BY	DRAWING NUMBER
---	---	Concord	SCHAEFFER	7/17/02			810835-A6



Parametrix DATE: March 16, 2016 FILE: PS3820004P04T02-F1

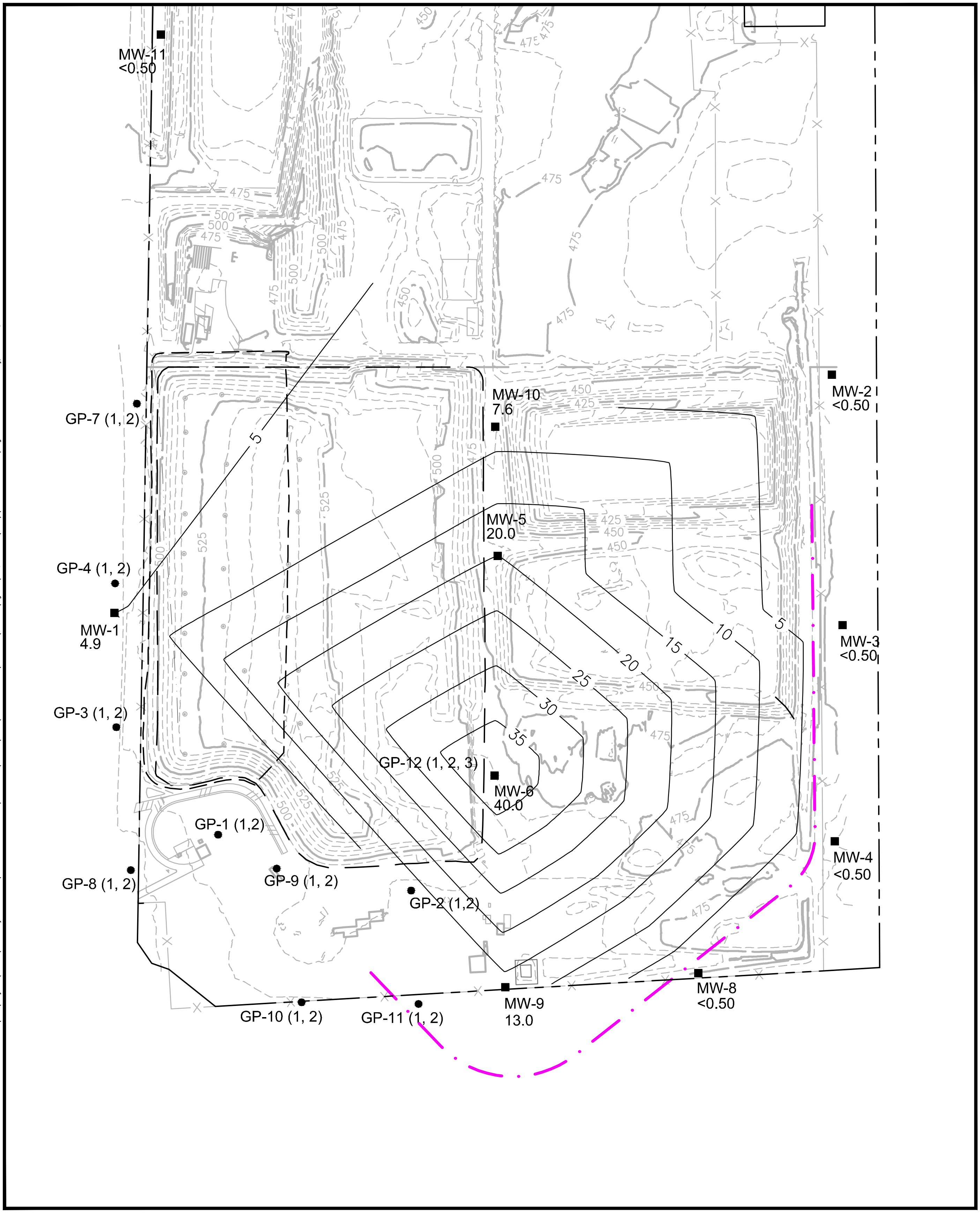
N

0 500
SCALE IN FEET

Legend:

- Facility Boundary
- Refuse Limit
- Closure Limit
- Isoconcentration Contour (2)
- 1,1-Dichloroethane GWQS = 1 µg/L

Figure 1
Maximum 2015 Concentrations of 1,1-Dichloroethane (µg/L) in Groundwater
Horn Rapids Landfill



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Parametrix

DATE: March 16, 2016 FILE: PS3820004P04T02-F2

N

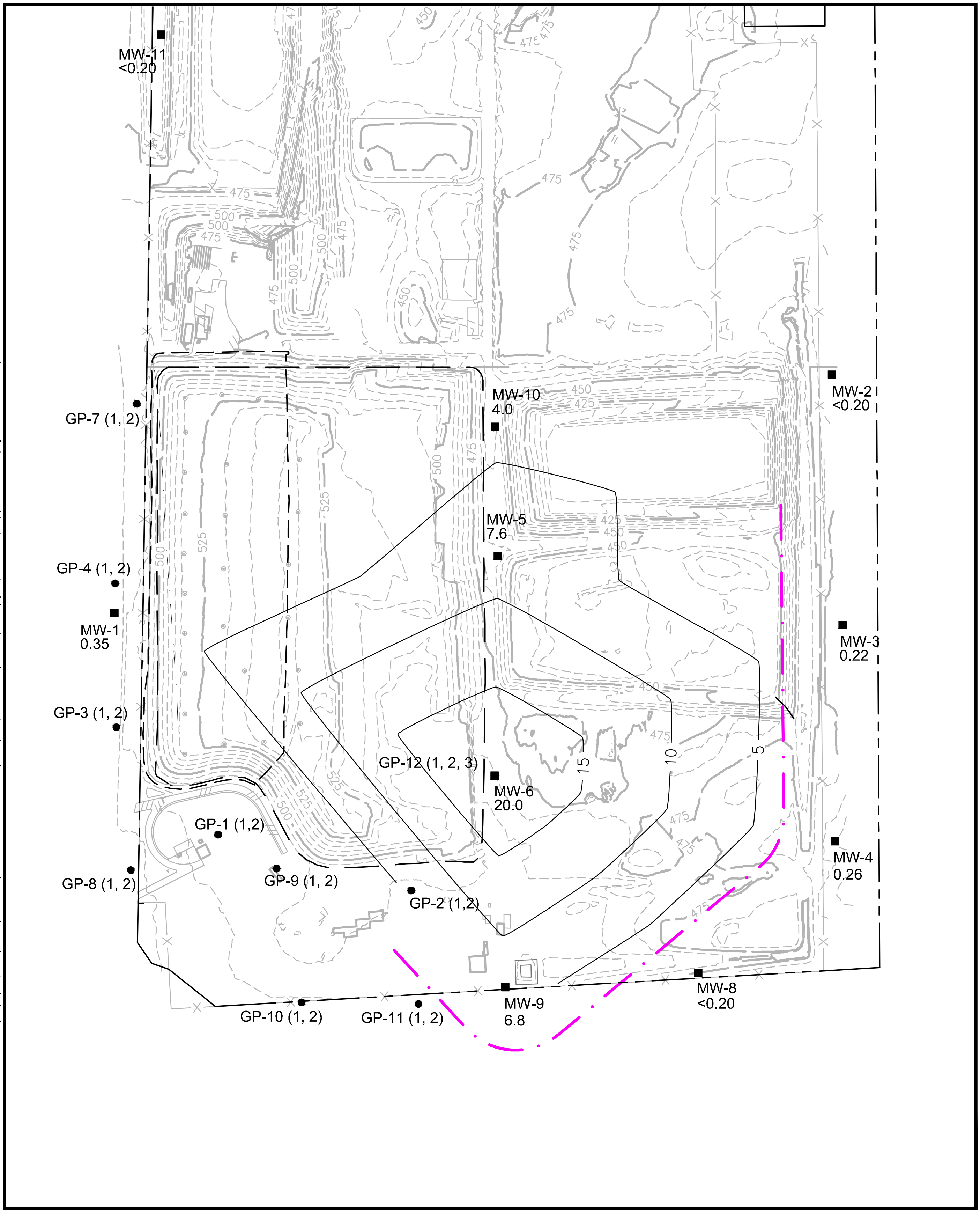
0 500

SCALE IN FEET

Legend:

- Facility Boundary
- Refuse Limit
- Closure Limit
- Isoconcentration Contour (2)
- Tetrachloroethene GWQS = 0.8 µg/L

Figure 2
Maximum 2015 Concentrations of Tetrachloroethene (µg/L) in Groundwater Horn Rapids Landfill



Parametrix

DATE: March 16, 2016 FILE: PS3820004P04T02-F3

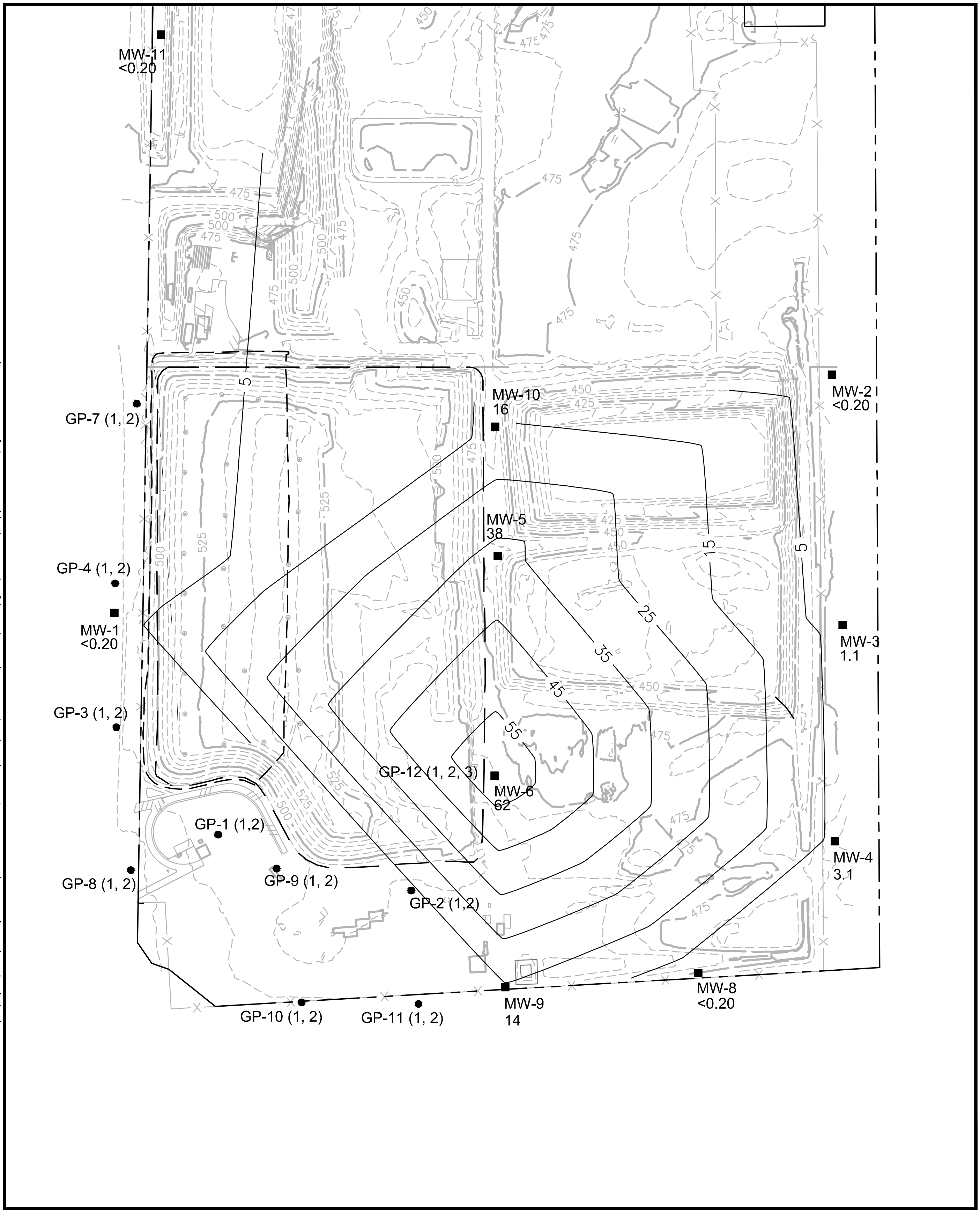
N

0 500
SCALE IN FEET

Legend:

- Facility Boundary
- Refuse Limit
- Closure Limit
- Isoconcentration Contour (2)
- Trichloroethene GWQS = 3 µg/L

Figure 3
Maximum 2015 Concentrations of Trichloroethene (µg/L) in Groundwater
Horn Rapids Landfill



Parametrix

DATE: March 16, 2016 FILE: PS3820004P04T02-F4

N

0 500

SCALE IN FEET

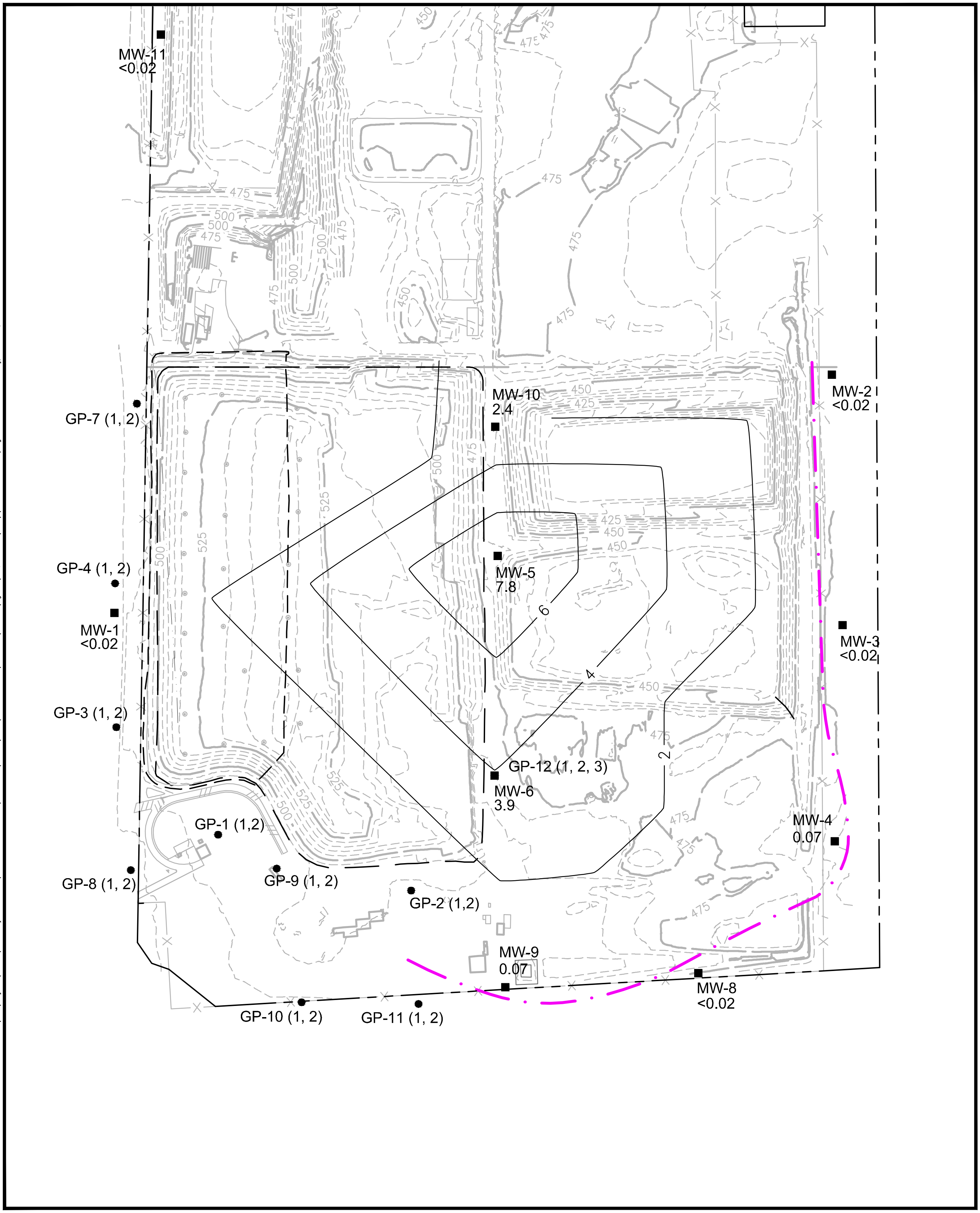
Legend:

- Facility Boundary
- Refuse Limit
- Closure Limit
- Isoconcentration Contour (2)
- cis-1, 2-Dichloroethene MCL = 70 µg/L

Figure 4

Maximum 2015 Concentrations of cis-1, 2-Dichloroethene (µg/L) in Groundwater

Horn Rapids Landfill



Parametrix

DATE: March 16, 2016 FILE: PS3820004P04T02-F5

N

0 500

SCALE IN FEET

Legend:

- Facility Boundary
- Refuse Limit
- Closure Limit
- Isoconcentration Contour (2)
- Vinyl Chloride GWQS = 0.02 µg/L

Figure 5
Maximum 2015 Concentrations of Vinyl Chloride (µg/L) in Groundwater
Horn Rapids Landfill

Appendix F

Push Probe Equipment Information

Energy*Solutions*
Three Rivers Scientific

October-2011

Hydraulic Hammer
Direct Push

Kent Reynolds-ES
Dr. R. Randall- TRS

SYSTEM DESIGN

- Intended as an exploration and sampling system
- Utilizes 2 ½ In closed end probe for exploring, log data collection and placement of specialty constructions.
- Utilizes 2 5/8 In removable tip design for multi-point sampling.
- Hammer system has high energy impact (450-650 ft/lbs per cycle @ 2000 cycles per minute) and rotates the pipe while driving.

WRPS/ES

- Four direct push units are available
- Three rubber tire-4 wheel drive back hoe units
- One crawler mounted heavy duty unit
- Since 2005 over 32,000 feet of 2 ½" and 2 5/8"

  of pipe have been driven in and around Hanford tank farms-additional footage (approx. 6,000 ft) has been placed for Fluor and CHPRC
- 390+ individual probe holes
- Logging of the exploration holes (2 ½") vastly improves worker safety by identifying radioactive contamination intervals.

Vadose Characterization

- Since 2005 over 17,000 feet of logging data (gross, spectral gamma and neutron-neutron moisture) and 370+ soil samples have been collected in tank farms using hydraulic hammer direct push technology.
- This methodology was awarded DOE Best In Class (Vadose Characterization) in 2007.

Unit #1

Unit # 2

Unit # 3

Unit # 4 XL

Angle Capabilities

Base Plate and Angle Guides for Angle and Azimuth Control

Depth Capabilities

- In 200 E (C Farm) vertical pushes have reached 220+ feet on 95+% attempts for that depth
- Angle pushes in 200 E have achieved over 260+ feet of pipe run at 30 degrees from vertical (95+% success results) and 200+ ft at 28 degrees from horizontal
- In 200 West able to push to top of Lower Cold Creek (caliche unit- 130 to 150+ feet) in most areas T-TX-TY, U, and S- SX

Unique tooling designs and hammer properties allow for deep vadose direct push exploration

2.5 in. disposable tip and holder

Exploration 2 ½" Drive Pipe Tip Holder & tip

2 5/8” Multi-point Sampling

- Uses a 2 5/8” outer casing and 1 ½” inner string to hold a temporary point in place while driving to sample depth
- The temporary tip is removed and a sampler is placed on the 1 ½” inner pipe and placed into the outer casing.
- The dual casings are advanced through the selected sample zone (approximately 22-24 inches)
- Sampler is pulled to surface and packaged
- Inner string with temporary tip placed into the casing and entire system is advanced to next sample zone.

Sampling System

- 3 - 6” X 1.08” ID stainless steel liners
- 1 -4” X 1.08” ID sampler shoe
- Results in 330 cc/ 20.15 cu. in. of material
- 16.5 cu. in. in liners 3.65 cu. in. in shoe
- Using the average density of Hanford soils (1.8 g/cc) = 594 g sampled materials at 100% recovery

2 5/8” Driving and Sampling System

Multi-point 2 5/8" Sampling System

Dual Wall Sampler Shoe

Other Capabilities

- Mini-piezometers-Placed 8 piezometers to 20 and 30 ft bgs depths in 100 N Area in 5 working days using pre-built 2” constructions.
- At 3 locations on the US Ecology Site placed 9 vapor sampling installations- clusters of three (1-shallow 5-8 feet, 1 mid-range 30-35 feet, 1 deep 75-80 feet)
- System used to build moisture monitoring stations by placing HDU and capacitance sensors to various depths and building moisture logging placements in TY and T Farms

Other Capabilities Continued

- Routinely place resistivity tooling in exploration probe holes in the tank farm (two styles- single point and multi-depth)

Direct Push Support Services

- Safety field oversight- Trained and certified safety personnel familiar with the technology.
- All crew members have received 30 Hour OSHA Industry safety training as well as current with all entry and site requirements for Hanford.
- Logging support
- Specialty project designs

Appendix G

Push Probe Groundwater Sampling Information

Methods and Quantitation Limits for Analysis of Groundwater Push-Probe Samples, Horn Rapids Landfill

Parameters	Units	Groundwater Regulatory Standard MCL	Groundwater Regulatory Standard GWQS	Laboratory	PQL (mg/L)	Analytical Method
Volatile Organics						
1,1,1,2-Tetrachloroethane	µg/L			ENW	0.5	8260B
1,1,1-Trichloroethane	µg/L	200 *	200 *	ENW	0.5	8260B
1,1,2,2-Tetrachloroethane	µg/L			ENW	0.5	8260B
1,1,2-Trichloroethane	µg/L	5 *		ENW	0.5	8260B
1,1-Dichloroethane	µg/L		1 ***	ENW	0.5	8260B
1,1-Dichloroethene	µg/L	7 *		ENW	0.5	8260B
1,2,3-Trichloropropane	µg/L			ENW	0.5	8260B
l,2-Dibromo-3-chloropropane	µg/L	0.2 *		ENW	0.5	8260B
1,2-Dibromoethane	µg/L	0.05 *	0.001 ***	ENW	0.001	8260 SIM
1,2-Dichlorobenzene	µg/L	600 *		ENW	0.5	8260B
1,2-Dichloroethane (total)	µg/L	5 *	0.5 ***	ENW	0.5	8260B
1,2-Dichloropropane	µg/L	5 *	0.6 ***	ENW	0.5	8260B
1,4-Dichlorobenzene	µg/L	75 *	4 ***	ENW	0.5	8260B
2-Butanone	µg/L			ENW	4	8260B
2-Hexanone	µg/L			ENW	4	8260B
4-Methyl-2-pentanone	µg/L			ENW	4	8260B
Acetone	µg/L			ENW	4	8260B
Acrylonitrile	µg/L		0.07 ***	ENW	0.07	8260 SIM
Benzene	µg/L	5 *	1 ***	ENW	0.5	8260B
Bromochloromethane	µg/L			ENW	0.5	8260B
Bromodichloromethane	µg/L	80 *THM	0.3 ***	ENW	0.3	8260B
Bromoform	µg/L	80 *THM	5 ***	ENW	0.5	8260B
Bromomethane	µg/L			ENW	0.5	8260B
Carbon disulfide	µg/L			ENW	0.5	8260B
Carbon tetrachloride	µg/L	5 *	0.3 ***	ENW	0.3	8260B
Chlorobenzene	µg/L	100 *		ENW	0.5	8260B
Chloroethane	µg/L			ENW	0.5	8260B
Chloroform	µg/L	80 *THM	7 ***	ENW	0.5	8260B
Chloromethane	µg/L			ENW	0.5	8260B
cis-1,2-Dichloroethene	µg/L	70 *		ENW	0.5	8260B
cls-1,3-Dlchloropropene	µg/L			ENW	0.5	8260B
Dibromochloromethane	µg/L	80 *THM		ENW	0.5	8260B
Dibromomethane	µg/L			ENW	0.5	8260B
Ethylbenzene	µg/L	700 *		ENW	0.5	8260B
m,p-xylene	µg/L	10000 *XYL		ENW	1	8260B
Methyl Iodide	µg/L			ENW	NA	NA
Methylene chloride	µg/L	5 *	5 ***	ENW	0.5	8260B
o-xylene	µg/L	10000 *XYL		ENW	0.5	8260B
Styrene	µg/L	100 *		ENW	0.5	8260B
Tetrachloroethene	µg/L	5 *	0.8 ***	ENW	0.5	8260B
Toluene	µg/L	1000 *		ENW	0.5	8260B
trans-1,2-Dichloroethene	µg/L	100 *		ENW	0.5	8260B
trans-1,3-Dichloropropene	µg/L			ENW	0.5	8260B

Methods and Quantitation Limits for Analysis of Groundwater Push-Probe Samples, Horn Rapids Landfill

Parameters	Units	Groundwater Regulatory Standard		Laboratory	PQL (mg/L)	Analytical Method
		MCL	GWQS			
trans-1,4-Dichloro-2-butene	µg/L			ENW	NA	NA
Trichloroethene	µg/L	5 *	3 ***	ENW	0.5	8260B
Trlchlorofluoromethane	µg/L			ENW	0.5	8260B
Vinyl Acetate	µg/L			ENW	NA	NA
Vinyl Chloride	µg/L	2 *	0.02 ***	ENW	0.02	8260 SIM
Dissolved Gases (RSK-175)						
Ethane	µg/L			TA	10	RSK-175
Ethylene	µg/L			TA	10	RSK-175
Methane	µg/L			TA	1.2	R5K-175

ENW = Energy Northwest
TA - TestAmerica
NA = ENW is not accredited to analyze these parameters

Bladder Pumps, Groundwater Sampling

Geotech Bladder Pumps

Together with the USGS, Geotech designed the original bladder pump for groundwater quality and pollution monitoring. They can pump to the surface from as deep as 1000 feet (305 meters) with minimal agitation for the best representative samples.

FEATURES

- **True low flow capability for less agitation**
- **Proprietary resin grade virgin PTFE bladder for long life**
- **Constructed of #316 SS for durability**
- **Dedicated or portable turnkey systems**
- **Screened intake extends bladder life**
- **Optional Drop-Tube assembly available for sampling from greater depths**
- **Limited lifetime warranty on dedicated stainless steel systems**
- **Compatible with the Geocontrol PRO and BP Controller units**

BLADDER PUMP MODELS

A. 1.66, 36" (4 cm, 91 cm)
Made from SS for maximum durability. Highest volume rate for a low flow pump. For 2" (5 cm) wells or larger.

B. 1.66, 18" (4 cm, 46 cm)
The same as above but for lower pump volume requirements.

C. .850, 18" (2.2 cm, 46 cm)
Made from high-grade SS for maximum durability.
Extra slim design provides excellent performance for its size.

D. .675, 18" (1.7 cm, 46 cm)
Our smallest bladder pump, fits in any well .75" (1.9 cm) or larger. Made with the same polished stainless steel as our other top-of-the-line pumps.

SPECIFICATIONS

	1.66, 36"	1.66, 18"	.850, 18"	.675, 18"
Pump Housing	316 SS	316 SS	316 SS	316 SS
Bladder Material	Virgin PTFE	Virgin PTFE	Virgin PTFE	Virgin PTFE
O.D.	1.66" (4.2 cm)	1.66" (4.2 cm)	.850" (2.2 cm)	.675" (1.7 cm)
Length w/Screen	38" (96.5 cm)	20" (51 cm)	18 5/8" (47.3 cm)	18 3/4" (47.6 cm)
Weight	5 lbs. (1.9 kg)	2.5 lbs. (0.93 kg)	1.1 lbs. (.5 kg)	.83 lbs. (.4 kg)
Volume / Cycle	21.1 oz. (625 ml)	10.5 oz. (313 ml)	.9 oz. (29 ml)	.5 oz. (15 ml)
Min. Well I.D.	2" (50 mm)	2" (50 mm)	1.00" (2.5 mm)	.75" (1.9 mm)
Operating Pressure	10-450 psi (.7-31 bar)	10-450 psi (.7-31 bar)	100 psi (6.9 bar)	100 psi (6.9 bar)
Min. Operating Pressure	5 psi (.34 bar) ash*	5 psi (.34 bar) ash*	5 psi (.3 bar) ash*	5 psi (.3 bar) ash*
Maximum Depth	1000' (305 m)	1000' (305 m)	200' (61 m)	200' (61 m)
Air Line (ID x OD)	.17" x .25" (4 mm x 6 mm)	.17" x .25" (4 mm x 6 mm)	.17" x .25" (4 mm x 6 mm)	.17" x .25" (4 mm x 6 mm)
Discharge Line (ID x OD)	.25" x .375" (6 mm x 10 mm)	.25" x .375" (6 mm x 10 mm)	.25" x .375" (6 mm x 10 mm)	.25" x .375" (6 mm x 10 mm)

*ash = above static head

A. B. C. D.

CALL GEOTECH TODAY (800) 833-7958

Geotech Environmental Equipment, Inc.
2650 East 40th Avenue • Denver, Colorado 80205
(303) 320-4764 • **(800) 833-7958** • FAX (303) 322-7242
email: sales@geotechenv.com website: www.geotechenv.com

GO TO GEOTECH

Sampling Pumps

geotech

Geotech Portable Bladder Pumps

Geotech's portable bladder pumps are designed with input from field technicians who actually do the sampling! Single turn release head and quick change bladders allow for quick, in-the-field bladder changes and easy decontamination. Custom hose barbs allow the pump to be secured to tubing without the need for tubing clamps.

FEATURES

- **Constructed of 316 stainless steel**
  For unsurpassed durability and truly representative samples
- **Portable turnkey systems available**
  Everything you need to quickly and efficiently sample your site
- **Easy-to-open housings**
  No special tools or training required to service the pump
- **Quick-change bladder configuration**
  Bladders are easily changed without tools by sliding back the PTFE collars
- **Drop tube intake option**
  Allows for deeper sampling
- **Extra bladders are readily available**
  Available in PTFE and Polyethylene for all models
- **Bonded tubing**
  In Polyethylene and FEP lined Polyethylene by the foot or by the roll
- **Compatible with the Geocontrol PRO & BP Controller units**
- **CE rated for quality**

1.66 Portable | .850 Portable | .675 Portable

SPECIFICATIONS

		1.66 Portable	.850 Portable	.675 Portable
Pump Housing		316 SS	316 SS	316 SS
Pump Ends		316 SS	316 SS	316 SS
Bladder Material		Virgin PTFE	Virgin PTFE	Virgin PTFE
Outer Diameter		1.66" (4.2 cm)	.850" (2.2 cm)	.675" (1.7 cm)
Length w/Screen		19" (48.3 cm)	18 5/8" (47.3 cm)	18 3/4" (47.6 cm)
Weight		3.0 lbs. (1.4 kg)	1.1 lbs. (.5 kg)	.83 lbs. (.4 kg)
Volume/Cycle		5 oz. (150 ml)	0.9 oz. (29 ml)	0.5 oz. (15 ml)
Min. Well I.D.		2" (5 cm)	1" (2.5 cm)	.75" (1.9 cm)
Max. Operating Pressure		100 psi (6.9 bar)	100 psi (6.9 bar)	100 psi (6.9 bar)
Min. Operating Pressure		5 psi (.3 bar) ash*	5 psi (.3 bar) ash*	5 psi (.3 bar) ash*
Max. Sampling Depth		200' (61 m)	200' (61 m)	200' (61 m)
Tubing Size	Air	.17" ID x .25" OD	.17" ID x .25" OD	.17" ID x .25" OD
	Discharge	.25" ID x .375" OD	.17" ID x .25" OD	.17" ID x .25" OD

*ash = above static head

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geotech

Geotech Portable Bladder Pump Optional Accessories

PORTABLE BLADDER PUMP DROP TUBE ASSEMBLY

Geotech's optional drop tube intake system allows you to easily relocate the bladder pump intake way beyond the depth limitations of the pump. As long as the pump remains submerged, you can effectively and economically low flow sample from the well's screened section.

- **Relocate pump intake to deeper well screen interval**
- **Keeps pump at optimum depth to maximize performance**
- **Drop tube length custom sized to each well**
- **Easily adaptable in the field**
- **Available for all three pump sizes**

PORTABLE BLADDER PUMP REEL

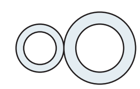
- Caddy stores pump when not in use
- Depth ranges to 175 feet (53 m)
- Quick-connect fittings at pump and reel

Portable Bladder Pump Reel System (shown with 1.66 Pump)

BONDED TUBING

Bonded Polyethylene x Polyethylene

[.170" x .25", .170 x .25"] 

[.170" x .25", .25" x .375"] 

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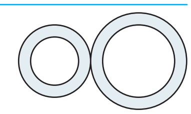
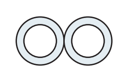
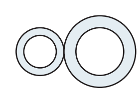
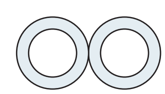
[.25" x .375", .375" x .50"] 

Bonded FEP Lined Polyethylene x Polyethylene

[.170" x .25", .170 x .25"] 

[.170" x .25", .25" x .375"] 

[.25" x .375", .25" x .375"] 

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Appendix H

Monitoring Well Specification

7-10 Groundwater Monitoring Well (New Section)

7-10.1 Drilling

The appropriate safety precautions apply and shall be addressed in the CONTRACTOR'S Health and Safety Plan, Section 1-07.28. Health and safety training in compliance with 29CRF 1919.120 and Chapter 296-62-300 WAC is required of the CONTRACTOR for this job. In response to this bid, the CONTRACTOR acknowledges that he/she is familiar with conditions at the project site and has ascertained any Health and Safety Plan requirements of applicable laws and regulations pertinent to the specific project site conditions.

The CONTRACTOR shall be required to have a well driller licensed to drill and install monitoring wells in Washington State and a competent driller's assistant on-site during all drilling and well construction activities. The drilling CONTRACTOR shall have successfully completed a minimum of 10,000 linear feet using the same procedures described above. The CONTRACTOR shall provide a rig large enough and capable of reaching the desired depths. The driller's assistant may perform well development alone.

Prior to the commencement of field operations, the CONTRACTOR shall designate the representative who will be the only individual authorized to discuss performance of the work and related matters with the County. The CONTRACTOR shall procure all permits, licenses, and certificates that may be required by law for the execution of the work described in this document. The CONTRACTOR shall comply with all federal, state, and local laws, ordinances, rules, and regulations relating to the performance of the work described in this document.

The CONTRACTOR shall submit start cards to Ecology prior to mobilization as specified in Chapter 173-160-055 WAC, Well Construction Notification (Start Card). At the completion of the project, the CONTRACTOR shall be required to complete and submit to Ecology all necessary reports and forms relating to the completion of the each boring (Chapter 173-160-050 WAC, Records).

The CONTRACTOR shall be required to have at least two qualified persons on-site through the duration of drilling and well installation, and at least one qualified person on-site during well development. In addition, the CONTRACTOR shall:

1. Provide electric power at each drill site (if needed to complete the drilling and well installation).
2. Restore site to pre-drilling condition.
3. Provide water and sanitary facilities at each drill site.
4. Review and sign the County daily log of construction activities.

All work, materials, and construction shall conform to the requirements of Chapter 173-160 WAC, Minimum Standards for the Construction of Wells. In the event of a conflict between these specifications and Chapter 173-160 WAC, and in the absence of a variance from Chapter 173-160 WAC, Chapter 173-160 WAC shall govern.

The work will be performed using air rotary drilling methods. All the drilling locations are outside the limits of refuse. No refuse material will be encountered during well installation. The well will be completed with a protective steel casing, locking lid, and guard posts.

No bit lubrication other than filtered air and potable water shall be allowed. Compressed air shall be filtered to eliminate contamination of the air by oil from the compressor. The CONTRACTOR shall prevent contamination of soil or groundwater at the drilling site from hydrocarbons or other chemicals used by the CONTRACTOR on or around the drilling equipment. Drilling muds, foams, and petroleum- or soap-based products shall not be allowed. The use of petroleum-based joint compounds, which are normally used to prevent binding, shall not be allowed.

During air rotary drilling, drill cuttings from the cyclone will be collected at 5-foot intervals using a 5-gallon bucket.

The CONTRACTOR shall conduct all operations in such a way as to prevent any destruction, scarring, or defacing of the work site. Every effort shall be made to present an orderly appearance at the work site while drilling operations take place. At the completion of the field activities, the CONTRACTOR shall restore each drilling site to its pre-drilling condition.

In the event that any damages to the site property occur because of the CONTRACTOR'S activities, the CONTRACTOR shall, at his own expense, repair the damages or reclaim the land to the extent deemed suitable by the ENGINEER.

7-10.2 Decontamination Procedures

All large drilling equipment (rods, bits, drill rig, etc.) will be steam cleaned with a high-pressure washer prior to drilling the groundwater monitoring well. The area designated for steam cleaning activities will be located at least 50 feet south from the well or as designated by the ENGINEER.

7-10.3 Borehole Logging

Borehole logging shall be conducted by the ENGINEER for the purpose of this project and must also be done by the CONTRACTOR for fulfillment of state requirements. The CONTRACTOR shall endeavor to provide information on drilling conditions that will assist the ENGINEER in making determinations of subsurface material character.

7-10.4 Alignment

Alignment requirements during drilling are that any casing, liner, or drill tools can be run freely through the boring. At a minimum, the alignment shall conform to Chapter 173-160-215(4) WAC, Design and Construction—Well Completion—General (Alignment).

7-10.5 Abandonment

7-10.5(1) New Wells Installation

If the groundwater monitoring well does not meet the alignment or other requirements, or which is contaminated by the CONTRACTOR, or the well on which the CONTRACTOR stops work will be considered abandoned. Once a well installed by the CONTRACTOR has been designated as abandoned, the CONTRACTOR shall initiate installation of a new well in the immediate vicinity at a location designated by the ENGINEER. The CONTRACTOR may, at his own expense, remove any ungrouted casing. At a minimum, all borings and well shall be abandoned in accordance with Chapter 173-160-560 WAC, Abandonment of Resource Protection Wells.

7-10.5(2) Existing Well Abandonment

The existing groundwater monitoring well (MW-7) is 105 feet deep and screened between depths of 87.5 feet and 102.5 feet below ground surface. It is installed in a 6-inch diameter borehole and is constructed with 2-inch Schedule 40 PVC pipe with an 8-inch diameter steel monument at the surface.

No well log is available for existing gas probe (GP-6), but the probe has two ½ inch PVC completions within one borehole and an 8-inch diameter PVC monument at the surface. The borehole is approximately 6 to 8 inches in diameter

The well and probe shall be abandoned in accordance with Chapter 173-160-560 WAC, Abandonment of Resource Protection Wells.

The existing gas probe shall be decommissioned by withdrawing the casings and filling the borehole with neat cement grout, neat cement, bentonite, or bentonite slurry as the casing is being withdrawn or by overdrilling and filling the bore hole with neat cement grout, neat cement, bentonite, or bentonite slurry.

The existing monitoring well shall be decommissioned by filling the casing from bottom to land surface with bentonite, bentonite slurry, neat cement grout, or neat cement.

Existing steel casing and locks shall be stockpiled as directed by the Owner. The Owner shall remove existing fence.

7-10.6 Well Installation

All well casing pipes shall be PVC in accordance with Section 9-05.21(2), and as shown on the Plans. The top of the screen shall be set approximately 5 feet above the top of the groundwater table. Centralizers will be placed at several positions along the upper portion of the solid riser pipe, and above and below the screen.

The well casing will then be lowered into the boring and shall be suspended at the required depth for the remainder of the installation. The casing shall be pulled back a few inches prior to pack material installation to insure that the completion is not caught in the drill casing.

The design dimensions for the monitoring well completion is shown on the Plans. The monitoring well shall be constructed in accordance with Chapter 173-160 WAC, Minimum Standards for Construction and Maintenance of Wells. Specific construction procedures are described in the following sections.

The annular space between the borehole wall and well screen shall be filled with a 20 to 40 mesh silica sand filter pack to approximately 2 feet above the top of the screen. The depth to the top of the filter pack shall be probed using the tremie pipe, verifying the thickness of the sand pack. A 2-foot layer of finer silica sand (100 mesh) shall be placed on top of the sand pack material.

A five-foot seal of bentonite pellets shall be placed above the sand pack and hydrated by pouring clean potable water through a separate tremie pipe placed in the annual space of the well. The completed annular seal shall fully surround the permanent casing, be evenly distributed, free of voids, and extend from the permanent casing to undisturbed or recompacted soil.

The remaining annular space shall be filled to two feet below land surface in a continuous operation with Portland Type I cement/bentonite slurry with a tremie tube. Potable water shall be used to hydrate the mixture.

Well-site safeguards should include keeping all materials covered with plastic sheeting, off the ground, and ensuring that they are touched only with clean tools and gloves. Equipment or materials to be inserted into the bore hole must not be allowed to touch the ground.

7-10.7 Completion

The monitoring well shall be completed at the surface with an above grade locking steel stovepipe monument to protect the well casing. The steel monument shall be 6 feet in length, extend at least six inches above the top of the well casing, and be cemented at least two feet into the ground. Three protective posts at least three inches in diameter will be installed in a triangular array around the casing and at least two feet from it with at three feet above and below the land surface. The top of the well casing shall be fitted with an expandable-gasket lockable cap, and the well will be locked.

The monitoring well steel casing and the protective posts shall be painted with a highly visible paint as indicated on the Plans and in accordance with Section 9-05.21(2)C.

7.10.8 Well Development

The objective of monitoring well development shall be to remove sediment that may have accumulated in the well during well installation, to consolidate the filter pack around the well screen, and to enhance the hydraulic connection between the formation and the filter pack. Monitoring well development shall be performed after well installation but not sooner than 48 hours following placement of the grout seal. Prior to development, the water level and total depth of the well shall be measured. The monitoring well shall initially be surged with a surge block in five-foot intervals, beginning at the bottom of the well and working upward. After surging, the monitoring well shall be bailed of coarse sediment using a stainless steel bailer or similar type.

7-10.9 Site Restoration

At the conclusion of all work activity at a boring, all drilling work, extra casing, trash, disposal of materials used for decontamination, and other materials shall be removed from the site. No work shall begin on subsequent borings until the previous boring site has been cleaned up and approved by the ENGINEER. All boring and miscellaneous trash materials such as bentonite bags will be properly disposed of in the landfill as directed by the ENGINEER. These costs shall be included with unit price.

7-10.10 Well Construction Records

The CONTRACTOR shall keep a daily written log of operations, including size and length of the casing placed, character, depth and thickness of all formations penetrated, causes of delays, and screen locations. Duplicate copies of this log shall be furnished to the ENGINEER at the end of each work day.

7-10.11 Waste Soil

The investigation-derived waste soil will be disposed of on the ground surface.

7-10.12 Measurement

Measurement shall be as follows:

1. “Groundwater Monitoring Well,” by the unit price per linear vertical foot. The well shall be measured by vertical measure over the length of the installed from existing grade to bottom of boring as shown on the Plans.

2. “Existing Well Abandonment,” by the unit price per linear vertical foot. The well shall be measured by vertical measure over the length of the existing well depth from existing grade to bottom of boring.

7-10.13 Payment

Payment shall be as follows:

1. “Groundwater Monitoring Well,” per vertical linear foot:

   The unit price bid per vertical linear foot shall be full compensation for all labor, tools, equipment, and materials necessary to drill, furnish materials and install the wells, complete in place. Work will include but not limited to, drilling, installation of well casing and screened intervals and installation of all well backfill materials as described in the specifications and on the Plans.

   Costs for mobilization to and from the well location including all costs for temporary access (e.g., crushed rock, wood timber supports, etc.), if required, are to be incidental with the unit price bid for this item.

   Cost for all well materials (e.g., PVC pipe, bentonite, sand backfill, etc.) are to be included in the unit price bid for this item. No payment for materials used in well installation will be made under any other bid item.

   In the event abandonment of an incomplete well is necessary due to unforeseen conditions and not the result of poor CONTRACTOR workmanship or materials, the cost of abandonment will be paid at the unit price bid for this item. Prior approval by the ENGINEER will be required.

2. “Existing Well Abandonment,” per vertical linear foot.

   The unit price bid per vertical linear foot shall be full compensation for all labor, tools, equipment, and materials necessary to abandon wells in place. Work will include but not limited to, removal of surface monument, casing removal or overdrilling, and installation of grout as described in the specifications.

   Costs for mobilization to and from the well location including all costs for temporary access, if required, are to be incidental with the unit price bid for this item.

   Cost for all well abandonment materials are to be included in the unit price bid for this item. No payment for materials used in well abandonment will be made under any other bid item.

END OF DIVISION 7

DIVISION 9

MATERIALS

9-05 DRAINAGE STRUCTURES, CULVERTS, AND CONDUITS

9-05.21 HDPE Pipe and Fittings (New Section)

9-05.21(1) HDPE Material

High-density polyethylene pipe and fittings shall be made from polyethylene resin compound qualified as Type III, Category 5, Class C, Grade P34 in ASTM D1248. The HDPE pipe and fittings shall conform to Cell Classification 345464C or 355434C (ASTM D3350). Diameter shall be as shown on the Plans. This material shall have compressive yield strength of 1,600 psi when tested and analyzed by ASTM D695. This material shall have a Tensile Yield Strength of 3,200 psi when tested and analyzed by ASTM D638.

The polyethylene compound shall be suitably protected against degradation by ultraviolet light by means of carbon black, well dispersed by precompounding in a concentration of not less than 2 percent.

The manufacturer shall be listed with the Plastic Pipe Institute as meeting the recipe and mixing requirements of the resin manufacturer for the resin used to manufacture the pipe and fittings for this project.

The HDPE products shall contain no recycled compound except that generated in the manufacturer's own plant from resin of the same specifications from the same raw material supplier.

The CONTRACTOR shall submit, at the preconstruction meeting, a description of the pipe to be used which includes materials specifications provided by the manufacturer. The CONTRACTOR shall supply the manufacturer's certificate of compliance in accordance with Section 1-06.3 of the Standard Specifications prior to installing any HDPE piping.

9-05.21(1)A High Density Polyethylene (HDPE) Pipe

HDPE pipe meeting the requirements of this section shall be used for the landfill gas and condensate systems, and all other piping unless specified or otherwise shown on the Plans.

The same manufacturer shall supply polyethylene pipe and fittings. Pipe and fittings from different manufacturer's shall not be interchanged.

Pipe and fittings shall be of the nominal diameter shown on the Plans. All pipe sizes, either solid or perforated, shall conform to ASTM F 714.

The maximum allowable hoop stress shall be 1000 psi at 140 degrees F.

The polyethylene pipe shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or their injurious defects. Any pipe with nicks, scrapes, or gouges deeper than 5 percent of the nominal wall thickness shall be rejected. The pipe shall be uniform in color, opacity, density, and other physical properties.

The pipe and fittings used for the landfill gas system, unless otherwise designated on the Plans, shall conform to the following:

1. All vertical gas well pipe shall (solid and slotted) shall have a minimum SDR 11. The slotted pipe sections shall be shop fabricated and supplied in nominal diameter as shown in the Plans. The slots shall be uniformly placed perpendicular to the axis of the pipe in straight rows. The slots shall be 0.25-inch wide, 1-inch long inside length and 2 3/4 inches long outside length, and shall be 1-inch apart on-center in four places equidistant around the pipe. Slotted pipe shall be free of cutting debris, and other physical properties.

The following information shall be continuously marked on the pipe or spaced at intervals not exceeding 5 feet:

1. Name and/or trademark of the pipe manufacturer
2. Nominal pipe size
3. Standard Dimensional Ratio (SDR)
4. PE 3408
5. Manufacturing Standard Reference
6. A production code from which the date and place of manufacture can be determined

Joints and pipe connections shall be thermal butt-fusion. No mechanical couplings shall be used unless shown on the Plans or approved by the ENGINEER.

9-05.21(1)B HDPE Fittings

Fittings shall be manufactured in accordance with ASTM D3261, and shall be manufactured by injection molding, a combination of extrusion and machining, or fabrication from HDPE pipe conforming to these specifications. Fittings shall be from the same manufacturer as the pipe and shall have the same or numerically smaller SDR than pipe connecting to the fitting. Fittings shall be molded, for sizes 6-inch and smaller.

All reducing tees shall be factory-molded if available as a standard item by any manufacturer having pipe and meeting these specifications. If not available as a standard item, branch saddle reducing tees shall be used. Reducers shall be shop-fabricated. Field fabricated branch saddle connections will not be allowed.

All molded fittings shall have the same or higher pressure rating as the pipe when installed in accordance with the latest technical specifications. All fabricated fittings shall have the same or higher pressure rating as the adjoining pipe when installed in accordance with the manufacturer's recommendations.

9-05.21(1)C Pipe Connections

Joints and pipe connections shall be thermal butt-fusion. No mechanical couplings shall be used unless shown on the Plans or approved by the ENGINEER.

9-05.21(1)D Seal Material

The bentonite seal shall be Volclay Chip medium, Enviroplug medium, CETCO medium bentonite chips, or approved equal. A high-solid content non-shrink cement slurry shall be used to seal the remaining annular space to the ground surface.

9-05.21(2) Groundwater Monitoring Well Materials

Groundwater monitoring well shall be constructed using new, commercially manufactured materials.

9-05.21(2)A PVC Pipe

The riser pipe and fittings shall be 2-inch Schedule 40 PVC pipe that is flushed threaded. A flush thread end plug shall be fitted to the bottom of the well. The well screens shall have 0.010-inch factory machine-cut horizontal slots and shall be spaced approximately 0.375 inches apart. All joints shall be flush threaded.

9-05.21(2)B Seal Material

All bentonite used for the well shall be certified by NSF/ANSI approval standards for use in potable water supply wells, or equivalent standards as approved by the department. The product shall be clearly labeled as meeting these standards. A high-solid content non-shrink cement slurry shall be used to seal the remaining annular space to the ground surface. The neat concrete shall be Class 3000, and shall consists of either Portland cement types I, II, III, or high-alumina cement mixed with not more than six gallons of potable water pre sack of cement (ninety-four pounds per sack).

Unhydrated bentonite--pelletized, granulated, powder, or chip bentonite may be used in the construction of seals or in decommissioning of wells. The bentonite material shall be specifically designed for sealing or decommissioning and be within the industry tolerances for dry western sodium bentonite. Placement of bentonite shall conform to the manufacturer's specifications and result in a seal free of voids or bridges.

9-05.21(2)C Protective Casing

The protective casing shall be a new Schedule 40 Grade B, seamless, rust-free, carbon steel pipe per ASTM A53 standard, and shall complete with a lockable steel cap and casing, which should be approved by the Engineer. The protective casing shall be painted with a high visible paint, in accordance with the manufacturers recommendations, which matches the existing casing as the site or recommended by the Owner. The top of the well casing will be fitted with an expandable-gasket lockable cap, and the well will be locked.

9-36 SOILS (NEW SECTION)

9-36.1 Gas Well Pack Material

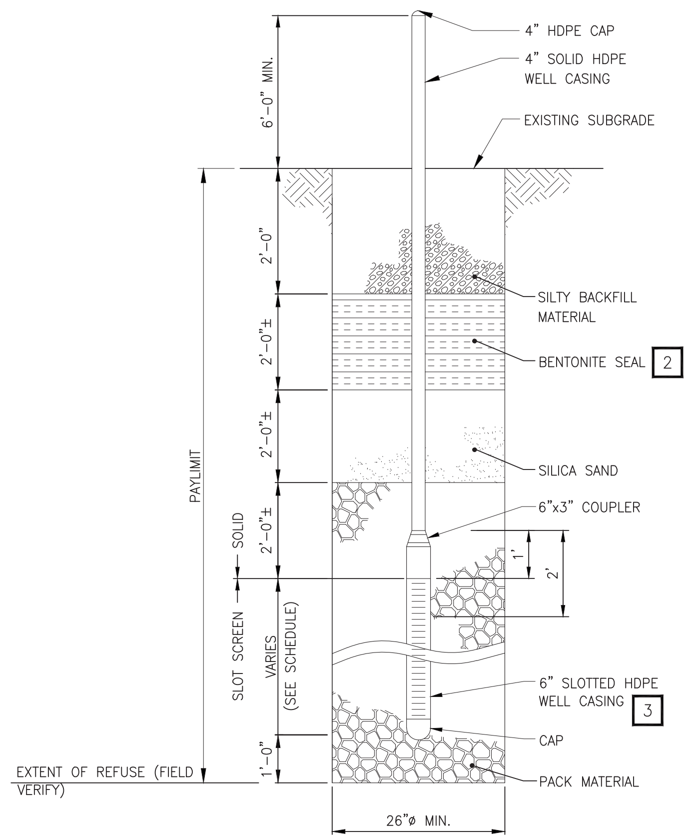
The pack material for the landfill gas wells shall be clean, 1 1/4”- or 1 1/2”-diameter round well-graded drain rock, or as approved by the Engineer.

9.36.2 Groundwater Monitoring Well Pack Material

The pack material for the groundwater monitoring well shall be clean, round drain rock, or as approved by the Engineer.

Artificial filter pack will be of 20-40 Colorado silica sand or equivalent. Finer grained sand (100 mesh Colorado silica sand) will be placed above the filter pack to prevent slurry infiltration.

END OF DIVISION 9



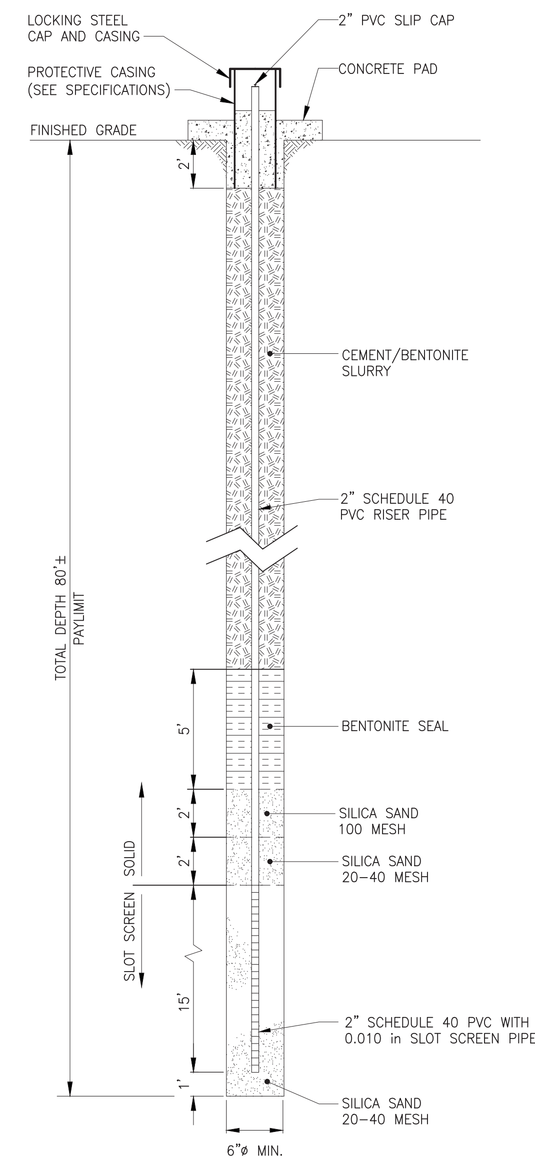
TYPICAL IN-REFUSE GAS VERTICAL LANDFILL GAS WELL

DETAIL 1 (C2, C3)

NO SCALE

NOTE:

1. EXCAVATED MATERIAL SHALL BE DISPOSED OF BY THE CONTRACTOR IN THE LANDFILL ACTIVE AREA, SEE SHEET C2
2. BENTONITE TO BE HYDRATED WITH CLEAN WATER.
3. SLOTTED PIPE, SEE DETAIL 2/C3



GROUNDWATER MONITORING WELL (MW-11)

DETAIL 3 (C2)

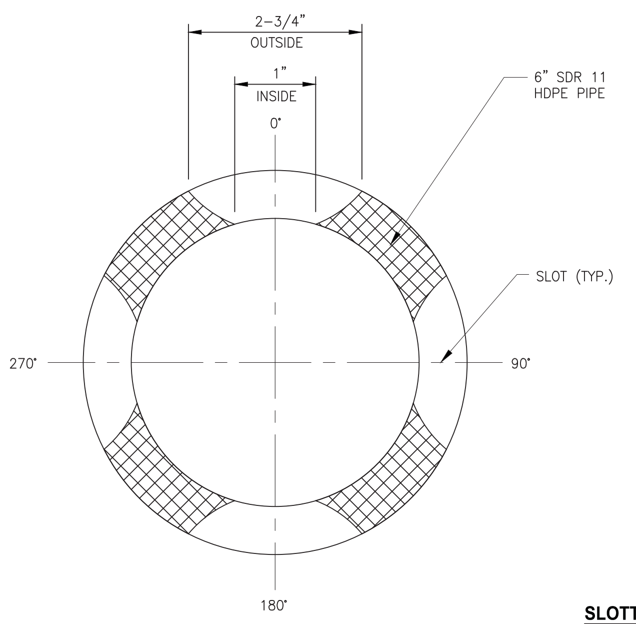
NO SCALE

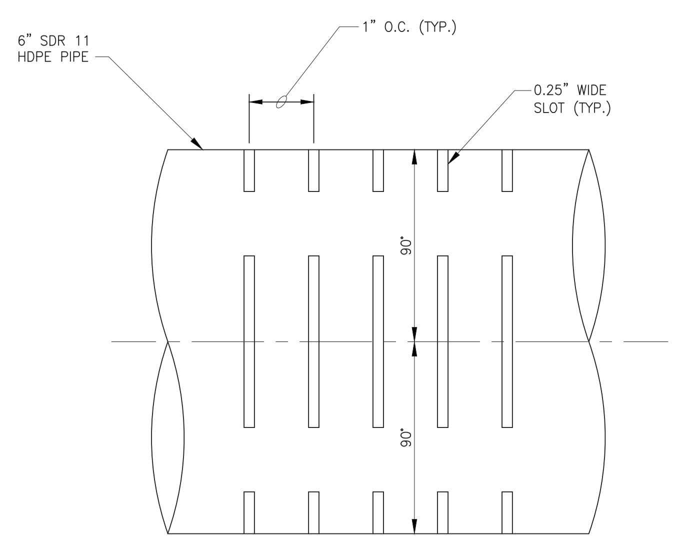
WELL SCHEDULE

NUMBER	NORTHING	EASTING	EXISTING GRADE	BOTTOM BORING ELEVATION	TOP OF SCREEN ELEVATION
EXTRACTION WELLS					
GW-5	372390.66	2291954.81	512.90	468.00	504.90
GW-6	372240.63	2291954.46	514.70	468.00	506.70
GW-7	372090.52	2291954.25	515.70	468.00	507.70
GW-8	371940.66	2291954.40	516.80	468.00	508.80
GW-9	371790.84	2291954.50	516.60	468.00	508.60
GW-10	371640.01	2291955.17	515.00	468.00	507.00
GW-11	371490.79	2291954.10	513.90	468.00	505.90
GW-12	371340.44	2291953.94	514.50	468.00	506.50
GW-13	371190.00	2291954.83	515.40	468.00	507.40
GW-14	371040.70	2291954.49	510.40	468.00	502.40
GW-15	372380.77	2292092.47	514.60	454.00	506.60
GW-16	371078.39	2292100.27	519.50	454.00	511.50
GW-17	372363.24	2292229.23	519.00	455.00	511.00
GW-18	371351.05	2292177.70	528.80	455.00	520.80
GW-19	371085.43	2292249.96	529.90	455.00	521.90
GW-20	372343.76	2292376.40	519.00	455.00	511.00
GW-21	372143.80	2292384.48	529.70	455.00	521.70
GW-22	371944.55	2292377.54	531.80	455.00	523.80
GW-23	371748.86	2292341.31	535.50	455.00	527.50
GW-24	371549.98	2292339.94	535.20	455.00	527.20
GW-25	371353.81	2292378.15	532.80	455.00	524.80
GW-26	371155.11	2292385.19	532.80	455.00	524.80
GW-27	371003.77	2292375.44	532.40	455.00	524.40

NOTE:

1. BOTTOM BORING ELEVATION SHALL BE FIELD VERIFIED BASED ON ACTUAL REFUSE LIMITS.
2. OWNER SHALL SURVEY WELL LOCATION AND LABEL EXISTING GROUND SURFACE AND WELL NUMBER.





SLOTTED PIPE

DETAIL 2 (C3)

NO SCALE

REVISIONS	DATE	BY	
			DESIGNED S.EMGE
			DRAWN S. SIRES
			CADD CHECKED
			CHECKED
			APPROVED

ONE INCH AT FULL SCALE. IF NOT, SCALE ACCORDINGLY

FILE NAME BL3820001P2AT03-C01

JOB No. 555-3820-001

DATE FEBRUARY 2010

STEPHEN M. EMGE STATE OF WASHINGTON 34389 REGISTERED PROFESSIONAL ENGINEER

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PROJECT NAME

HORN RAPIDS LANDFILL GAS and GROUNDWATER WELLS INSTALLATION PROJECT

RICHLAND, WA

DETAILS and WELL SCHEDULE

DRAWING NO. 3 OF 4

C4

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