King County Department of Natural Resources and Parks

Solid Waste Division

Phase 1 – Interim Actions

CONTRACT NO. E00286E12

Cedar Hills Regional Landfill – East Perched Zone Landfill Gas Optimization Assessment

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Solid Waste Division

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EAST PERCHED ZONE LANDFILL GAS OPTIMIZATION ASSESSMENT

Cedar Hills Regional Landfill

Prepared for: King County Solid Waste Division

Project No. 130088-820 • May 31, 2019 • Final

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1 Introduction

This Technical Memorandum (Memorandum) has been prepared to summarize assessment activities and recommendations for landfill gas (LFG) collection optimization at a portion of the Cedar Hills Regional Landfill (CHRLF), located in unincorporated King County, Washington (Figure 1). This Memorandum was prepared for King County Solid Waste Division (KCSWD) and addresses Task 820 – Optimize Existing LFG System under contract number E00286E12 for Engineering Services for Cedar Hills Regional Landfill Environmental Control System Modifications.

This Memorandum is considered a component of the Phase I Interim Actions focused on LFG collection optimization, which was recommended as an element of the preferred alternative (Alternative 2) presented in the agency draft East Perched Zone (EPZ) Remedial Investigation and Feasibility Study (EPZ RI/FS; Aspect, et al., 2016), and as agreed upon during discussions between the Washington State Department of Ecology and KCSWD. The one element of the preferred alternative (Alternative 2) that is addressed in this Memorandum consists of the following:

- Optimization of the LFG operations on portions of the CHRLF Main Hill including:
  - Changing operating conditions from relaxed/moderate to aggressive/very aggressive as defined in the Solid Waste Association of North America (SWANA) Landfill Gas Operation and Maintenance Manual (1997)
  - Adding selected flow-control devices on collection laterals tied in to the East and Central Header series

The focused area for the LFG optimization is near the EPZ, located east of the East Main Hill, where groundwater quality impacts are suspected to have resulted from interaction with LFG. The primary objective of LFG optimization is to reduce methane concentrations at gas probes GP-57 and GP-58 to zero percent – consistently over time – by methodically increasing LFG collection from locations within the waste extent. Achieving this objective should simultaneously address LFG migration at other locations and groundwater impacts in the EPZ, based on Aspect’s understanding of site conditions.

LFG is collected outside the EPZ, including other areas of the East Main Hill and the Southeast Pit Area, which affects the potential to optimize LFG collection related to the EPZ. The Migration Control Flare is used for treatment of LFG collected from the EPZ and these additional areas. Therefore, the recommendations provided herein may be considered for any LFG collected and sent to the Migration Control Flare for treatment. Figure 2 shows the focused area for this LFG optimization effort.

Note that most of the LFG collected at CHRLF is directed to the Bio Energy Washington (BEW) plant, which generates pipeline-quality gas from LFG. This Memorandum does not address LFG collected and sent to the BEW.

The remaining sections of this Memorandum include near-term recommendations for LFG optimization (Section 2), intermediate-term recommendations for assessing and maintaining existing LFG collection infrastructure (Section 3), long-term LFG system considerations (Section 4), and a summary of the LFG collection data assessment activities (Section 5). The long-term considerations depend on LFG system conditions following implementation of the near-term and intermediate-term recommendations.

2 Near-term Recommendations

This section describes the near-term procedures recommended for LFG optimization, some of which were implemented during the reporting process. Guidelines for implementing the data collection and LFG migration control adjustments are summarized in Attachment 1. The procedures recommended below reflect SWANA guidance for maximizing LFG migration control.

2.1 Precision Control Valves

Based on verbal recommendations, precision fine tune control valves were installed at LFG collection wells in December 2018 to better regulate gas flow from each wellhead and increase the balancing performance of LFG migration control across the well field. Prior to installation of the precision control valves, flow control valves at EPZ extraction wellheads were polyvinyl chloride (PVC) gate valves, which made small flow adjustments difficult.

Based on the assessment of LFG collection data described in Section 5, precision valves were installed according to a priority list included as Table 1 (on table, lightest shade indicates in-waste EPZ well most distant from the edge of waste; darkest shade indicates EPZ well located in native soils). Wells with high flow rates and low methane concentrations were identified as highest priority for receiving precision valves. Those wells with higher methane concentrations were identified as middle priority, and wells that were “shut in” or had little to no flow due to low methane concentrations were identified as lowest priority.

It is our understanding that orifice plates were not installed with the precision control valves. Therefore, optimized flows may be below the measurement range of the existing pitot tube assemblies. In this case, it is important to record the valve position (as percent open) to support an understanding of optimization progress. For example, if a valve is 100 percent open and no flow is measured, a followup inspection of the well and lateral is warranted (see Section 3.1).

2.2 Monitoring Data Collection

LFG collection monitoring and valve adjustments at CHRLF is performed by KCSWD staff and occurs approximately twice monthly. This operational frequency allows for steady optimization of the LFG collection system. Aspect recommends remaining on the current monitoring and valve adjustment schedule when implementing the near-term recommendations.

Data to be collected during each monitoring event will be the basis for determining if flow should be decreased or increased at each extraction well using valve adjustments. Monitoring data that should be collected are listed below and are referenced in the guidelines for near-term LFG optimization monitoring (Attachment 1).

At a minimum, the following parameters should be recorded and maintained in the operations logbook and site database when valve adjustments are made.

- LFG concentrations (initial)
- Flow (initial and adjusted)
- Pressure/vacuum (initial and adjusted)
- Control valve setting (percent open, initial and adjusted)

In addition to other LFG parameters, it is our understanding that KCSWD uses detector tubes to test for hydrogen sulfide or carbon monoxide based on field conditions, and that hydrogen sulfide has not been observed during monitoring in recent years in the EPZ.

Hydrogen sulfide is frequently associated with odors at landfills, and LFG collection optimization criteria may be modified to include hydrogen sulfide. If hydrogen sulfide is not detected above background at LFG collection locations, then alternative odor source investigation may be warranted.

Elevated oxygen concentrations (greater than 3 percent) are potential indicators of LFG collection conditions that may lead to subsurface fires. At this landfill, temperature is not a good indicator for conditions that may lead to subsurface fire because of the heating and cooling that occurs along the lateral between the wellhead and the monitoring location. Carbon monoxide concentrations above 100 ppm would indicate the potential for a subsurface fire and would warrant a change in LFG collection and further investigation. Carbon monoxide above 1000 ppm would indicate that a subsurface fire is likely and would trigger fire suppression activities.

2.3 Flow and Valve Adjustments

2.3.1 Criteria for Increasing Flow

If methane exceeds 35 percent by volume, then flow should be increased to provide optimal LFG migration control. If oxygen exceeds 1 percent by volume, then there may be a leak between the well and the monitoring port, and a measurement at the wellhead should be made.

2.3.2 Criteria for Decreasing Flow

If methane is less than 25 percent by volume, then flow should be decreased to allow for balancing LFG collection. To support LFG monitoring, a minimum flow should be allowed at each location within the waste extent by leaving the valve barely open (less than 5 percent open).

Following the flow and valve adjustment recommendations, LFG collection at GP-57 and the CHSE29-series wells will likely decrease over time as methane concentrations decrease to less than 25 percent by volume. A minimum flow at these locations should be allowed to support LFG monitoring.

An air leak is the likely explanation at locations where more than 3 percent oxygen and more than 25 percent methane are observed. If oxygen is greater than 3 percent by volume at the monitoring point, then the monitoring assembly, lateral, and wellhead should be inspected for atmospheric leaks. If wellhead monitoring confirms oxygen is greater than 3 percent by volume, and carbon monoxide is observed above 100 ppm and below 1000 ppm, then flow should be decreased to prevent conditions that could lead to subsurface fire. If carbon monoxide is observed above 1000 ppm, then the well should be shut-in and a focused subsurface fire investigation is warranted.

2.3.3 Valve Adjustments

After making initial LFG concentration measurements and evaluating criteria for flow adjustment, valves should be adjusted using relatively small increments. Valve adjustments should be limited to increasing or decreasing the valve position by no more than 10 percent, based on the demarcations on the valve stem. The examples below provide valve adjustment scenarios:

- If the initial valve position is 10 percent open, and the methane concentration is 42 percent by volume, then the valve should be adjusted to 20 percent open.
- If the initial valve position is 30 percent open, and the methane concentration is 24 percent by volume, then the valve should be slightly adjusted to 25 percent open.
- If small adjustments result in methane concentrations varying significantly between monitoring events, consider making valve adjustments every other monitoring event.

3 Intermediate-term Recommendations

This section provides intermediate-term recommendations related to assessment and potential rehabilitation of existing LFG collection infrastructure. The most recent assessment of LFG monitoring probes and collection wells was performed in 2008. As described in Section 5.4, additional assessment and extraction well rehabilitation is warranted to aid in improving effectiveness of LFG migration control in the EPZ area. Table 2 includes a summary of issues identified during the 2008 assessment.

3.1 Well and Lateral Inspection

There were several wells where issues were identified during the 2008 video inspection. It is uncertain if KCSWD addressed the observed water collected in wells, pinched well casings, clogged perforations, or other conditions that would limit the well-specific performance. Aspect recommends inspecting the integrity of the existing LFG collection and monitoring infrastructure to aid in LFG optimization efforts and prioritize rehabilitation efforts if warranted.

Initially, extraction wells and laterals should be assessed using manual measurements. Following a comparison of current manual measurements to as-built information, video inspection should be conducted where manual measurements warrant further evaluation for clogging, fully saturated well screens, silt build-up, and pinched or collapsed pipes. All visual observations made during the video inspection should be logged. Understanding where an extraction well is screened and drawing soil gas from is an important component of optimizing performance and controlling LFG migration.

3.2 Well Cleanout and Rehabilitation

Wells that exhibit clogging, saturated screens potentially due to clogging, and/or silt build-up can be cleaned out using one or a combination of the following techniques:

- Surging and/or brushing
- Air injection for wells with unsaturated screens
- Water flushing for wells with partially or submerged screens
- Pumping and/or vacuuming water/debris from the well

Depth measurements should be recorded prior to and following well and probe cleanout and rehabilitation efforts.

For wells or probes that are pinched, rehabilitation can be attempted using a tapered sleeve that is driven into the well or probe casing. If rehabilitation is not successful after driving a tapered sleeve, it may be necessary to replace the well or probe. For wells or probes that are collapsed, it’s likely that the well or probe will need to be replaced as described in Section 4.1.

3.3 Lateral Cleanout and Rehabilitation

Laterals that exhibit clogging, water build-up, or silt build-up can be cleaned out using one or a combination of the following techniques:

- Jetting and/or vacuuming out water/debris from the lateral

For laterals that are pinched or blocked, rehabilitation can be attempted using a tapered sleeve that is driven to expand the lateral pipe. Alternatively, the location of the blockage may be surveyed using a sonde, and the lateral may be excavated for repair. If differential settlement has resulted in a low point in the lateral, and water collects at that location reducing or preventing LFG collection, then the lateral may be excavated and pipe bedding material added to maintain a consistent slope toward the monitoring location.

4 Long-term Considerations

This section provides long-term considerations for the LFG collection system that depend on LFG system conditions following implementation of near-term and intermediate-term recommendations. The purpose of providing these long-term considerations is to inform KCSWD of potential system improvements to expand optimization efforts if needed in the future. The considerations provided below should be considered preliminary as they may be adjusted following implementation of the near- and intermediate-term actions.

4.1 Blower Replacement

Although the Migration Control Flare system is rated for up to 1,200 scfm, the average flow rate from 2015 through 2018 was approximately 850 scfm. If, after implementing near- and intermediate-term recommendations it is determined that additional flow will improve LFG migration control, a larger capacity blower may be needed. Based on the assessment described in Section 5, Aspect understands the existing blower is likely sufficient for controlling LFG migration in the EPZ area. However, following future optimization efforts and LFG system evaluations, the potential for blower replacement should be considered if additional flow capacity is needed or if blower conditions and performance characteristics are limiting LFG migration control.

4.2 Landfill Gas Collection Well Replacement/Installation

Following inspection and rehabilitation efforts, selected LFG collection wells should be considered for replacement in order to optimize the LFG system for the EPZ area. These wells may exhibit elevated methane concentrations and limited flow rates.

If the existing LFG collection infrastructure, following near- and intermediate- term recommendations, is not able to address deep LFG migration (to GP-57, for example), then new LFG collection wells may be warranted to collect LFG being generated at depth near the contact between waste and native soils.

4.3 In-Well Leachate Collection

Where more than 6 feet of water accumulates at the bottom of a LFG collection well, in-well leachate collection infrastructure should be considered to improve LFG collection efficiency and reliability. When leachate and condensate accumulate in LFG wells, especially over the long-term, screen openings can become blocked or clogged, thereby leading to reduction in gas flow from the well reflecting a smaller area of influence. Installing a dedicated pump system in-well following cleanout can prevent liquid accumulation and promote maximum gas flow.

4.4 Alternative LFG Control Locations

Historically, some LFG extraction points in the EPZ have been operated to control surface emissions based on surface emission monitoring data, or to collect leachate off-gas from the leachate collection system. If the aim of LFG collection is something other than optimizing subsurface LFG migration control, then it is considered alternative LFG control. Between 2015 and 2018, approximately one-quarter of the flow to the migration flare provided alternative LFG migration control was directed from LFG collection points with less than 5 percent methane. To maximize subsurface LFG migration control, it may be warranted to disconnect locations providing alternative LFG control from the migration flare. These alternative LFG control locations may then be connected to a separate blower and treatment system designed for low methane concentrations (such as a bioberm filter).

5 Landfill Gas Collection Data Assessment

This section describes the LFG migration monitoring, Migration Control Flare, and LFG collection system descriptions and data, which provide the basis for LFG collection optimization recommendations.

5.1 Landfill Gas Migration Monitoring Probes

5.1.1 Probe Network Description

The LFG monitoring network in the EPZ area includes 81 gas probe completions at 41 locations (see Table 3 and Figure 3). Typical gas probe completions consist of multiple probes completed at various depths to monitor LFG in both shallow and deep soil horizons. The LFG monitoring network consists of compliance probes along the property boundary as well as probes installed in native soils near the East Main Hill edge of refuse. Within the EPZ area, the compliance probes near the property boundary include GP-15 through GP-20 and GP-ATC-6 through GP-ATC-8. As required by LFG operation procedures, the perimeter probes are maintained and monitored monthly. Data from the perimeter probes are used to confirm that LFG is not migrating beyond the CHRLF property boundary.

The probes installed near the East Main Hill refuse boundary provide additional LFG characterization data and monitor the effectiveness of KCSWD's actions to control LFG migration into native soils. These probes include GP-1, GP-6 through GP-9, and GP-55 through GP-62. Probes GP-55 through GP-62 are shallow and deep gas probe pairs installed in native soils to investigate the LFG-to-groundwater contaminant migration pathway in the EPZ area (Aspect, 2010). The term "shallow gas probe" is used to define gas probes completed with the screen interval installed in weather till/glacio-lacustrine geologic units. The term "deep gas probe" is used to define gas probes completed with the screen interval installed in stratified drift geologic units. Additional monitoring network details can be found in the agency draft EPZ RI/FS (Aspect, et al., 2016).

5.1.2 Probe Monitoring Data

Observed LFG concentrations at 14 selected gas probes are shown in time-series graphs inserted on Figure 3. The graphs show observed concentrations of methane (red), carbon dioxide (green), and oxygen (blue) from July 23, 2010 through September 18, 2018.

Changes in LFG concentrations were observed at several probes during milestone changes in LFG collection. These milestones included connecting probe GP-57 for active

LFG collection in December 2011, installation of the Migration Control Flare in 2012, and periodic changes in LFG collection to maintain Migration Control Flare operation.

5.2 Migration Control Flare

5.2.1 Migration Control Flare System Description

LFG collection wells are connected to a network of gas conveyance pipes (headers and laterals) that direct collected gas to a condensate knockout pot located at the Migration Control Flare (see figures in Attachments 2 and 3). Vacuum is induced on the well field through a single 30 horse power (hp) blower. LFG is conveyed by the blower to the flare inlet where it is treated through combustion. The flare combusts LFG collected by the system when it consists of approximately 20 to 30 percent by volume (% vol.) methane. The flare and blower are rated for operation between 100 and 1,200 scfm of LFG and is able to operate with methane concentrations as low as 20% vol. within the fuel source. The flare typically operates around 850 to 900 scfm (KCSWD, 2015).

The Migration Control Flare is designed to operate continuously, except during downtime caused by unexpected shutdown or for maintenance. The flare will shut down and automatically attempt to restart when fault conditions occur for low temperature, flame failure, or pilot failure. If the number of restarts exceeds three attempts, the system will shut down and require operator intervention. System startup involves configuring the system to ensure normal operating conditions are present and then starting the system by activating the blower and flare, which are controlled from a single Programmable Logic Controller (PLC) touch screen control panel, located at the flare (KCSWD, 2015).

5.2.2 Migration Control Flare Monitoring Data

Observed operating conditions at the Migration Control Flare inlet are shown in time-series charts on Figure 4. The charts show data collected from January 1, 2015 through September 20, 2018. A stacked-area chart (top portion of Figure 4) shows observed methane, carbon dioxide, and oxygen, and a line chart (bottom portion of Figure 4) shows the observed flow rate and system pressure[1]. Average operating conditions based on the data included on Figure 4 charts are listed below:

- Methane: 28 percent by volume, 243 scfm[2]
- Carbon Dioxide: 23 percent by volume, 197 scfm
- Oxygen: 6 percent by volume, 53 scfm
- Balance Gas: 42 percent by volume, 359 scfm
- System Flow Rate: 851 scfm (total, not including moisture)
- System Pressure: 23 inches water column

[1] Negative pressure indicates vacuum.
[2] Flow rates reported by KCSWD are in units of “dry standard cubic feet per minute”, or “dscfm”. These flows rates have been calculated based on field measurements and may differ slightly from measurements made using field instruments. This detail does not affect recommendations in this technical memorandum.

5.3 Landfill Gas Collection Locations

5.3.1 Landfill Gas Collection System Description

LFG is collected from refuse through vertical gas extraction wells, horizontal gas collectors, and vertical dual-phase (LFG and leachate) extraction wells. LFG extraction wells for the Main Hill that are connected to the East Header have an "E" prefix identifier. LFG extraction wells and horizontal collectors for the Southeast Pit that are connected to the East Header have a "SEP" prefix. Dual-phase wells for the Main Hill have either a "GL" or "DPW" prefix. Attachment 2 shows the locations of LFG collection wells, laterals, and headers across the CHRLF (excerpted Figure 17, AECOM, 2015) Attachment 3 shows the monitoring points for LFG collection provided by KCSWD. The extraction wells typically consist of vertical pipe with a perforated section surrounded with a gravel pack. Vacuum is applied to the wells, creating overlapping zones of influence to collect LFG generated by the refuse. LFG that collects in the leachate system is withdrawn by the LFG system through lateral collectors with perforated sections of pipe buried in refuse and connected to a manifold through solid lateral pipes. LFG from the East Header and the southern portion of the Central Header is conveyed to the Migration Control Flare near the North Flare Station (AECOM, 2015).

Several LFG extraction wells are also located in native soils within the EPZ area, including the E-29 series wells and gas probe GP-57 (Figure 3). Probe GP-57 was connected to the extraction system in December 2011.

5.3.2 Landfill Gas Collection Monitoring Data

The average LFG collection parameters observed during monitoring from January 2015 through August 2018 are listed in Table 4 for all locations sending LFG to the Migration Control Flare, and on Table 5 for locations in the EPZ only. The Well ID is bold to identify those locations in the EPZ and shaded according to the distance from the edge of waste (lightest shade indicates in-waste EPZ well most distant from the edge of waste; darkest shade indicates EPZ well located in native soils). Average methane and oxygen concentrations are color coded according to SWANA guidelines for LFG collection providing very aggressive migration control. On Figure 3, LFG collection locations in the EPZ have been similarly color coded according to average methane concentrations. The valve adjustment recommendations provided in Section 2 are consistent with LFG collection providing very aggressive LFG migration control.

Figure 5 compares the average methane concentration with flow rate at each location and identifies those locations in the EPZ. There are a number of low-methane locations with disproportionately high flow rates, and substantial improvements in LFG optimization may be made by reducing flow rates at these locations. There are also a number of high-methane locations with relatively low flow rates. Ideally, the highest flow rates would correspond with the locations with highest methane for a system that has achieved LFG optimization.

Time-series data are graphed on Attachment 4 for selected LFG collection locations. Between 2015 and 2018, the selected locations had greater than 25 percent methane. The graphs include stacked-area charts of LFG concentrations and a line showing the flow rate. The variability in flow rates reflects the difficulty operators have had with controlling flow rates. With new precision valves, adjustments in flow rates, and subsequent changes in LFG concentrations, should be more gradual. Several locations appear to have been affected by atmospheric air intrusion, including E-31, E-40, E-40A, E-43A, and GL-61. It is unclear if these locations have been affected by leaks or if the reported values are representative of subsurface conditions.

6 References

AECOM Technical Services, Inc. (AECOM), 2015, Cedar Hills Regional Landfill Environmental Control Systems Modification Project, Landfill Gas Data Summary, Analysis, and Alternatives Report, Prepared for King County Department of Natural Resources, Solid Waste Division, November 2, 2015.

Aspect Consulting, LLC (Aspect), 2010, East Main Hill Perched Zones Technical Memorandum, prepared for King County Department of Natural Resources and Parks, Solid Waste Division, October 22, 2010.

Aspect Consulting, LLC (Aspect) et. al, 2016, East Perched Zones Remedial Investigation and Feasibility Study – Cedar Hills Regional Landfill, December 2016, Agency Review Draft.

King County Solid Waste Division (KCSWD), 2015, Page 2 from Cedar Hills Regional Landfill Migration Flare Commissioning Document, version 2.0, August 2015.Solid Waste Association of North America (SWANA), 1997, Landfill Gas Operation and Maintenance Manual of Practice, March 1997.

TABLES

Table 1. Flow Precision Valve Installation Priority

Project No. 130088, Cedar Hills Regional Landfill

King County, Washington

Well ID	Overall Flow Precision Valve Priority	EPZ Flow Precision Valve Priority	Flow:Methane Ratio	Average Flow (SCFM)	Average Methane (% by vol)
CHSEP64D	1		2532	51	0
CHSEP64M	2		196	7	0
CHSEP63D	3		158	7	0
CHSEP0B4	4		115	21	0
CHSEPE11	5		96	16	0
CHSEP63S	6		91	6	0
CHSEP58S	7		48	2	0
CHSEPE14	8		42	15	0
CHE0036A	9	1	41	10	0
CHSE29BS	10	2	36	14	0
CHSEP065	11		35	6	0
CHSEP62D	12		10	5	1
CHSEP59S	13		10	0	0
CHSE29AS	14	3	9	8	1
CHSEPVLT	15		9	21	2
CHSEP64S	16		9	5	1
CHE0046A	17	4	4	0	0
CHE0001C	18		3	1	0
CHE0049A	19		3	0	0
CHE00016	20		3	16	6
CHSEP63M	21		3	7	2
CHSE29AD	22	5	2	5	2
CHSEP62S	23		2	6	3
CHSE29CS	24	6	2	8	5
CHE00069	25	7	1	15	11
CHE00009	26		1	27	23
CHE00013	27		1	23	22
CHE00004	28		1	47	46
CHE00010	29		1	22	22
CHSEP60S	30		1	6	7
CHE00034	31	8	1	40	49
CHSEP59D	32		1	7	10
CHSEP58D	33		1	6	10
CHE00043	34	9	1	28	46
CHEGL059	35	10	1	24	43
CHSEP0E8	36		1	22	39
CHSE29BD	37	11	1	7	13
CHE00040	38	12	0	15	30
CHSEP60D	39		0	6	12
CHE00071	40	13	0	22	46
CHE00032	41	14	0	23	56
CHEGL061	42	15	0	15	40
CHSE29CD	43	16	0	2	5
CHE00035	44	17	0	17	46
CHE00024	45	18	0	15	42
CHE00038	46	19	0	2	4
CHE00019	47	20	0	21	63
CHE00023	48	21	0	8	23
CHE00068	49	22	0	10	32
CHE0042A	50	23	0	0	1
CHE00022	51	24	0	11	39
CHE0043A	52	25	0	7	26
CHSEP61S	53		0	7	27
CHE00030	54	26	0	15	57
CHE00037	55	27	0	2	6
CHE00050	56		0	12	49
CHE00036	57	28	0	11	48
CHSE29DD	58	29	0	7	29
CHEGL060	59	30	0	5	22
CHE00048	60		0	8	37
CHE00070	61	31	0	9	41
CHE00049	62		0	9	43
CHE00018	63	32	0	8	40
CHE00027	64	33	0	10	50
CHE0040A	65	34	0	10	49
CHSEP61D	66		0	7	36
CHE00031	67	35	0	7	36

Table 1. Flow Precision Valve Installation Priority

Project No. 130088, Cedar Hills Regional Landfill

King County, Washington

Well ID	Overall Flow Precision Valve Priority	EPZ Flow Precision Valve Priority	Flow:Methane Ratio	Average Flow (SCFM)	Average Methane (% by vol)
CHE00033	68	36	0	11	59
CHE0056A	69		0	13	69
CHE0047A	70		0	11	59
CHE00042	71	37	0	3	15
CHE00021	72	38	0	9	59
CHE00017	73	39	0	4	23
CHE00055	74		0	2	16
CHE00E1A	75		0	2	17
CHE00026	76	40	0	8	54
CHE00008	77		0	4	29
CHGL0010	78		0	5	39
CHEGLSE3	79		0	2	36
CHEGLSE8	80		0	2	43
CHE0001D	81		0	0	9
CHE00006	82		0	0	10
CHEGLSE7	83		0	1	27
CHE00054	84		0	0	18
CHEGLSE6	85		0	0	20
CHE00067	86		0	0	11
CHEMHFC1	87		0	0	2
CHE00028	88	41	0	0	3
CHE00047	89		0	0	4
CHE00066	90		0	0	16
CHE0032A	91	42	0	0	11
CHE00039	92	43	0	0	2
CHEGLSE4	93		0	0	22
CHE0001B	94		0	0	3
CHEGLSE5	95		0	0	9
CHSE29DS	96	44	0	0	0
CHE0048A	97		0	0	12
CHE0035A	98	45	0	0	0
CHGL0016	99		0	0	9
CHEGLSE2	100		0	0	9
CHEGLSE1	101		0	0	7
CHE00052	102		0	0	3
CHE00044	103	46	0	0	3
CHE00014	104		0	0	3
CHE00053	105		0	0	2
CHE0038A	106	47	0	0	1
CHE00057	107		0	0	0
CHE00056	108		0	0	0
CHE0056B	109		0	0	0
CHGL0015	110		0	0	4
CHGL0009	111		0	0	29
CHGL0014	112		0	0	6
CHGL0011	113		0	0	25
				Total Flow	
				888	29.3

Bold = EPZ	General description:
Native Soil	Beyond edge of waste
Near Edge	Bottom of slope - East Main Hill
Bottom Tier	
Middle Tier	
Top Tier	Top of slope - East Main Hill

Table 2. 2008 Observed Conditions during Video Inspection

Project No. 130088, Cedar Hills Regional Landfill
King County, Washington

WELL ID	Disc #	Boring Log Depth (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Depth to Perf. Pipe (feet)	Stick up (inches)	Comments
CHE00004	1	75	40	37		50	Lowered well stick up 26 inches. Blockage at 39ft. Camera not able to pass. Used slope indicator for depth to bottom.
CHE00006	1	60	64	47	28	70	Screws at 36ft.
CHE00008	1	60	61			69	Broken pipe at 27ft. Camera not able to pass. Heavy buildup at 22ft. Used slope indicator for depth to bottom.
CHE00009	1	70	34			16	Pipe shifted. Broken at 26ft. Camera not able to pass. Used slope indicator for depth to bottom.
CHE00010	1	50	43	28	22	59	
CHE00013	1	87	35			71	Broken pipe at 35ft. Camera not able to pass.
CHE00014	1	57	63		24	58	
CHE00016							
CHE00017	1	90	35			53	Broken pipe at 35ft. Camera not able to pass.
CHE00018	1	30	31	20	18	54	Lots of sediment at the bottom of the well.
CHE00019	1	78	44			62	Break in pipe at 44ft. Camera not able to pass. Gas present- hard to see.
CHE0001B	1	50	53	33	27	67	
CHE0001C							
CHE0001D	1	55	48	45	23	58	
CHE00021	1	35	37	33	22	60	
CHE00022	1	94	44			49	Broken pipe at 44ft. Camera not able to pass. Gas present- hard to see.
CHE00023	1	40	32		17	43	Broken pipe at 32ft. Camera not able to pass.
CHE00024		90	47			50	Broken pipe at 44ft. Camera not able to pass. Used slope indicator for depth to bottom.
CHE00026	2	101	53			42	Broken pipe at 46ft. Camera not able to pass. Used slope indicator for depth to bottom.
CHE00027	2	35	36	31	20	48	
CHE00028							
CHE00030	2	63	10			58	Broken pipe at 10ft. Camera not able to pass.
CHE00031	2	41	39	36	25	59	
CHE00032							
CHE00033	2	80	51	50	36	71	
CHE00034							
CHE00035	2	31	32	32	14	39	
CHE00036							
CHE00037	2	37	28		17	54	
CHE00038							
CHE00039							
CHE00040	2	81	40		20	44	Broken pipe at 39ft. Camera not able to pass.
CHE00042							
CHE00043	2	57	59	49	17	49	Cloudy water. No view
CHE00044	2	32	37	37	18	60	
CHE00047							
CHE00048	2	34	32		14	57	
CHE00049							
CHE00050	2	34	41	40	21	44	
CHE00052	2	37	42	39	20	49	
CHE00053							
CHE00054	2	18	26		18	55	
CHE00055							
CHE00056							
CHE00057	2	12	20	10	11	53	Cloudy water.
CHE00066							
CHE00067							
CHE00068							
CHE00069							
CHE00070							
CHE00071							
CHE0032A							
CHE0035A							
CHE0036A							
CHE0038A							
CHE0040A							
CHE0042A							
CHE0043A							
CHE0046A							
CHE0047A							
CHE0048A							
CHE0049A							
CHE0056A							
CHE0056B							
CHE00E1A	1	54	53	36	23	60	
CHEGL059	5		41		32	26	
CHEGL060	5		36	34	26	29	
CHEGL061	5		42		32	22	
CHEGLSE1	4		45	28	35	41	
CHEGLSE2	4		40		30	42	
CHEGLSE3	4		44	43	34	43	

Table 2. 2008 Observed Conditions during Video Inspection

Project No. 130088, Cedar Hills Regional Landfill
King County, Washington

WELL ID	Disc #	Boring Log Depth (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Depth to Perf. Pipe (feet)	Stick up (inches)	Comments
CHEGLSE4	4		42		33	41	Build up on side walls @ 33 ft.
CHEGLSE5	5		44		34	48	
CHEGLSE6	5		42		32	38	
CHEGLSE7	5		45	44	35	45	
CHEGLSE8	5		44		34	45	Low visibility due to gas.
CHEMHFC1							
CHGL0009	5	92	34		29	42	
CHGL0010	5	89	34		30	53	
CHGL0011	5		34		33	42	
CHGL0014	5		43		34	48	
CHGL0015							
CHGL0016							
CHSE29AD	2	79	77	74	74	59	
CHSE29AS	2	64	60	55	20	56	Cloudy water.
CHSE29BD	2	86	81	79	70	48	
CHSE29BS	2	71	43	35	18	45	Foam build up at 35ft. Cloudy water.
CHSE29CD	2	81	84	83	69	51	Screws at 48ft. Foam buildup near bottom of well.
CHSE29CS	2	66	52	48	22	48	Very dark, murky water. Sludge like.
CHSE29DD	2	84	79	79	61	36	
CHSE29DS	2	69	54	9	20	33	Clear in water.
CHSEP065	3		108		89	47	
CHSEP0B4	2	150	145		119	37	Thick build up on side walls @ 120 ft.
CHSEP0E8	1	102	105	97	92	62	
CHSEP58D	2	87	86		74	43	
CHSEP58S	2	51	54	45	34	26	Clear in water.
CHSEP59D	2	80	80	79	62	49	
CHSEP59S	2	44	48	40	28	42	
CHSEP60D	3	95	98		78	45	
CHSEP60S	3	56	58		38	35	
CHSEP61D	3	94	96	93	77	39	
CHSEP61S	3	78	81	80	60	37	
CHSEP62D	3	95	93		60	46	Thick build up on side walls. Had to locate perf. pipe.
CHSEP62S	3	65	67	66	47	42	
CHSEP63D	3		139	131	47	47	Thick build up @ 47 ft. No visibilty in water.
CHSEP63M	3		108	107	49	36	Thick build up on side walls most of the way.
CHSEP63S	3		61	48	24	56	Visibility is low in water.
CHSEP64D	3		150		132	50	
CHSEP64M	3		101	99	86	44	
CHSEP64S	3		57	56	36	52	Thick build up on side walls @ 36 ft.
CHSEPE11	1	73	70		104	55	
CHSEPE14	1	86	91			47	Screws at 32ft. Camera not able to pass. Used side slope indicator for depth to bottom.
CHSEPVLT							

BOLD = EPZ

Table 3 - Gas Probe Construction Information

Project No. 130088, Cedar Hills Regional Landfill
King County, Washington

Well ID	Stick-up (ft)	Well Diameter (in)	Top of PVC Elevation (ft MSL)	Boring Depth (ft bgs)	2015 Measured Total Depth of Probe (ft btoc)	Screened Interval (ft bgs)	Screened Geologic Unit	Notes
GP-1A	2.41	0.5	639.93	22.5	14	8 - 12	Weathered Till / Glacio-Lacustrine	
GP-1B	2.3	0.5	639.82	22.5	24.8	18.5 - 22.5	Weathered Till / Glacio-Lacustrine	Bottom of screen elevation from boring log above measured elevation.
GP-2A	2.76	0.5	627.03	22.5	12.8	6 - 10	Weathered Till / Glacio-Lacustrine	
GP-2B	2.76	0.5	627.03	22.5	25.2	18 - 22	Weathered Till / Glacio-Lacustrine	
GP-3	0.3	0.5	594.21	63	---	15.5 - 19.5	Weathered Till / Glacio-Lacustrine	Obstructed at 11 feet.
GP-4A	2.43	0.5	605.72	24	11.79	5 - 9	Weathered Till / Glacio-Lacustrine	
GP-4B	2.56	0.5	605.85	24	22.26	15.5 - 19.5	Weathered Till / Glacio-Lacustrine	
GP-5A	1.24	0.5	617.47	75	9.9	6 - 7	Weathered Till / Glacio-Lacustrine	Measured dry (likely obstructed).
GP-5Ba	1.56	0.5	619.33	75	9.5	6 - 7	Weathered Till / Glacio-Lacustrine	
GP-5Bb	1.59	0.5	619.3	75	23.1	22 - 23	Weathered Till / Glacio-Lacustrine	Bottom of screen elevation from boring log above measured elevation.
GP-5Bc	1.58	0.5	619.31	75	32.5	51 - 52	Stratified Drift	Obstructed.
GP-5Bd	1.58	0.5	619.31	75	5.3	63 - 64	Stratified Drift	Bottom of screen elevation from boring log above measured elevation.
GP-6A	1.72	0.5	634.81	203	56	54 - 55	Stratified Drift	Bottom of screen elevation from boring log is above measured elevation. Boring logs just have 4 probes in GP-6A and 4 in GP-6B. Matched boring log depths up with closest field measured depth.
GP-6B	1.6	0.5	634.53	203	116.9	84 - 85	Stratified Drift	Likely obstructed. Boring logs just have 4 probes in GP-6A and 4 in GP-6B. Matched boring log depths up with closest field measured depth.
GP-6C	1.62	0.5	634.75	203	148.7	94 - 95	Stratified Drift	Bottom of screen elevation from boring log above measured elevation. Total depth measured indicates well was mislabeled in field. Boring logs just have 4 probes in GP-6A and 4 in GP-6B. Matched boring log depths up with closest field measured depth. 2007 report suggests the well was mislabeled in the field.
GP-6D	1.66	0.5	634.69	203	98.2	113 - 114	Stratified Drift	Bottom of screen elevation from boring log above measured elevation. Total depth measured indicates well was mislabeled in the field. Boring logs just have 4 probes in GP-6A and 4 in GP-6B. Matched boring log depths up with closest field measured depth. 2007 report identified boring log bottom above measured bottom.
GP-6E	1.53	0.5	634.62	203	72.8	134 - 135	Stratified Drift	Bottom of screen elevation from boring log above measured elevation. Boring logs just have 4 probes in GP-6A and 4 in GP-6B. Matched boring log depths up with closest field measured depth. 2007 report identified boring log bottom above measured bottom.
GP-6F	1.72	0.5	634.81	203	133.1	148 - 149	Stratified Drift	Bottom of screen elevation from boring log above measured elevation. Boring logs just have 4 probes in GP-6A and 4 in GP-6B. Matched boring log depths up with closest field measured depth. 2007 report identified boring log bottom above measured bottom.
GP-6G	1.59	0.5	634.68	203	166.7	163 - 164	Stratified Drift	Bottom of screen elevation from boring log above measured elevation. Boring logs just have 4 probes in GP-6A and 4 in GP-6B. Matched boring log depths up with closest field measured depth. 2007 report identified boring log bottom above measured bottom.
GP-6H	1.44	0.5	634.71	203	89.2	178 - 179	Stratified Drift	Bottom of screen elevation from boring log above measured elevation. Total depth measured indicates well was mislabeled in the field. Boring logs just have 4 probes in GP-6A and 4 in GP-6B. Matched boring log depths up with closest field measured depth. 2007 report identified boring log bottom above measured bottom.
GP-7	1.88	0.5	640.24	58	51.6	48 - 50	Weathered Till / Glacio-Lacustrine	Bottom of screen elevation from boring log above measured elevation.
GP-8	1.46	0.5	642.23	60	46	44.5 - 46.5	Stratified Drift?	Bottom of screen elevation from boring log above measured elevation. 2007 report identified boring log bottom above measured bottom. Screen fully silted? Obstruction at about 6 ft down initially that was broken through during second measurement. Something on the bottom of well.
GP-9	1.42	0.5	644.99	70	39.7	58 - 60	Stratified Drift	Bottom of screen elevation from boring log above measured elevation.

Table 3 - Gas Probe Construction Information

Project No. 130088, Cedar Hills Regional Landfill
King County, Washington

Well ID	Stick-up (ft)	Well Diameter (in)	Top of PVC Elevation (ft MSL)	Boring Depth (ft bgs)	2015 Measured Total Depth of Probe (ft btoc)	Screened Interval (ft bgs)	Screened Geologic Unit	Notes
GP-11A	2.3	0.5	566.69	100	7.1	6.5 - 7.5	Weathered Till / Glacio-Lacustrine	Full screen silted.
GP-11B	2.32	0.5	566.71	100	NA	23.5 - 25	Weathered Till / Glacio-Lacustrine	Potentially obstructed. Likely mislabeled in the field. Could not get probe down past 3.4 ft btoc.
GP-11C	2.35	0.5	566.74	100	35.2	54.5 - 60	Stratified Drift	Field measurments of well bottom much shallower than boring log indicates. Full screen silted?
GP-11D	2.33	0.5	566.72	100	26.2	91.5 - 93	Stratified Drift	Likely mislabeled in the field. Field measurments of well bottom much shallower than boring log indicates. Full screen silted?
GP-12A	1.71	0.5	567.79	90	8.4	6.5 - 8	Weathered Till / Glacio-Lacustrine	
GP-12B	1.72	0.5	567.8	90	23.4	20.5 - 22	Weathered Till / Glacio-Lacustrine	
GP-12C	1.61	0.5	567.69	90	46.8	44.5 - 469	Stratified Drift	Half screen silted.
GP-12D	1.65	0.5	567.73	90	76.4	73 - 75	Stratified Drift	Bottom of screen elevation from boring log above measured elevation.
GP-13A	0.82	0.5	587.87	89	8.6	6.5 - 8	Weathered Till / Glacio-Lacustrine	Bottom of screen elevation from boring log above measured elevation.
GP-13B	0.8	0.5	587.85	89	22.4	20.5 - 22	Weathered Till / Glacio-Lacustrine	
GP-13C	0.71	0.5	587.76	89	37.8	35.5 - 37	Stratified Drift	Bottom of screen elevation from boring log above measured elevation.
GP-13D	0.69	0.5	587.74	89	78.7	78.5 - 80	Stratified Drift	Full screen silted.
GP-14A	1.93	0.5	613.05	100	69.4	68.5 - 70	Stratified Drift	Full screen silted.
GP-14B	1.91	0.5	613.03	100	88.2	86.5 - 88	Stratified Drift	Full screen silted.
GP-15A	1.1	0.5	618.35	89	8	6.5 - 8	Weathered Till / Glacio-Lacustrine	Possibly obstructed. Bottom not solid. Hitting a rubber stopper?
GP-15C	1.13	0.5	618.38	89	37.6	34.5 - 36	Stratified Drift	Bottom of screen elevation from boring log above measured elevation. Possibly obstructed as bottom does not feel solid. Possibly hitting a rubber stopper?
GP-15D	1.06	0.5	618.31	89	2.8	82.5 - 84	Stratified Drift	Likely mislabeled in the field. Possibly obstructed as bottom does not feel solid. Possibly hitting a rubber stopper?
GP-16A	1.33	0.5	629.8	70	8.1	6.5 - 8	Weathered Till / Glacio-Lacustrine	Possibly obstructed as bottom does not feel solid. Possibly hitting a rubber stopper?
GP-16B	1.36	0.5	629.83	70	20.3	18.5 - 20	Weathered Till / Glacio-Lacustrine	Bottom of screen elevation from boring log above measured elevation. Possibly obstructed as bottom does not feel solid. Possibly hitting a rubber stopper?
GP-16C	1.29	0.5	629.76	70	59.6	58.5 - 60	Stratified Drift	Bottom of screen elevation from boring log above measured elevation. Possibly obstructed as bottom does not feel solid. Possibly hitting a rubber stopper?
GP-17A	1.26	0.5	632.12	43	NA	6.5 - 8	Weathered Till / Glacio-Lacustrine	Tygon tubing in probe--cannot insert water level meter. TOC elevation derived from LiDAR ground surface data plus casing stick-up.
GP-17B	1.28	0.5	632.14	43	NA	15 - 16.5	Weathered Till / Glacio-Lacustrine	Tygon tubing in probe--cannot insert water level meter. TOC elevation derived from LiDAR ground surface data plus casing stick-up.
GP-17C	1.24	0.5	632.1	43	NA	35.5 - 37	Stratified Drift	Tygon tubing in probe--cannot insert water level meter. TOC elevation derived from LiDAR ground surface data plus casing stick-up.
GP-18A	1.49	0.5	603.76	58	NA	6.5 - 8	Weathered Till / Glacio-Lacustrine	Tygon tubing blocking probe--cannot insert water level meter.
GP-18B	1.51	0.5	603.78	58	NA	24.5 - 26	Weathered Till / Glacio-Lacustrine	Tygon tubing in pipe--cannot insert water level meter.
GP-18C	1.38	0.5	603.65	58	NA	43.5 - 45	Stratified Drift	Tygon tubing in probe--cannot insert water level meter.
GP-19A	1.06	0.5	547.3	40	NA	6.5 - 8	Weathered Till / Glacio-Lacustrine	Tygon tubing blocking--cannot insert water level meter
GP-19B	0.9	0.5	547.14	40	NA	14.5 - 16	Weathered Till / Glacio-Lacustrine	Tygon tubing attached to screen blocking--cannot insert water level meter.
GP-19C	1.04	0.5	547.28	40	NA	29.5 - 31	Stratified Drift	Tygon tubing attached to screen blocking--cannot insert water level meter.
GP-20A	1.56	0.5	496.6	95	NA	6.5 - 8	Weathered Till / Glacio-Lacustrine	Tygon tubing blocking well.
GP-20B	1.53	0.5	496.6	95	NA	30.5 - 32	Weathered Till / Glacio-Lacustrine	Tygon tubing blocking well.
GP-20C	1.55	0.5	496.6	95	NA	86.5 - 88	Stratified Drift	Tygon tubing blocking well.
GP45d	1.6	1	566.57	113	115.4	93 - 113	Stratified Drift	

Table 3 - Gas Probe Construction Information
Project No. 130088, Cedar Hills Regional Landfill
King County, Washington

Well ID	Stick-up (ft)	Well Diameter (in)	Top of PVC Elevation (ft MSL)	Boring Depth (ft bgs)	2015 Measured Total Depth of Probe (ft btoc)	Screened Interval (ft bgs)	Screened Geologic Unit	Notes
GP-45I	1.62	1	566.59	76	77.6	56 - 76	Stratified Drift	
GP-45s	1.6	1	566.57	40	41.5	20 - 40	Weathered Till / Glacio-Lacustrine	
GP-55	2.1	1	643.09	70	NA	60 70	Stratified Drift	
GP-56	2.5	1	643.57	20	18.9	6 - 16	Weathered Till / Glacio-Lacustrine	
GP-57	1.98	1	639	66.5	NA	53.5 - 63.5	Stratified Drift	
GP-58	2.25	1	639.81	20	18.8	6 - 16	Weathered Till / Glacio-Lacustrine	
GP-59	2	1	635.45	65.5	NA	53.5 - 63.5	Stratified Drift	
GP-60	4.12	1	635.84	20	20.7	8 - 18	Weathered Till / Glacio-Lacustrine	
GP-61	1.76	1	563.18	65.4	NA	53 - 63	Stratified Drift	
GP-62	1.85	1	565.28	20	18.9	8 - 18	Weathered Till / Glacio-Lacustrine	
GP-ATC-1D	-0.28	0.5	591.01	21	20	15 - 20.5	Weathered Till / Glacio-Lacustrine	
GP-ATC-1S	-0.26	0.5	591.03	21	5.2	4 - 5.5	Weathered Till / Glacio-Lacustrine	
GP-ATC-2	---	---	---	21	2.5	- - -	- - -	Gas probe not installed at this location due to the shallow saturated condition of the gravel backfill in the sewer line trench.
GP-ATC-3D	-0.23	0.5	615.99	21	5.1	15 - 20.5	Weathered Till / Glacio-Lacustrine	Bottom of screen elevation from boring log above measured elevation. 2007 report indicated well might be silted. Suspect well label switched with GP-ATC-3S.
GP-ATC-3S	-0.26	0.5	616.02	21	18.8	4 - 5.5	Weathered Till / Glacio-Lacustrine	Suspect well label switched with GP-ATC-3D.
GP-ATC-4	---	---	---	21	---	4 - 5.5	Weathered Till / Glacio-Lacustrine	Location unknown.
GP-ATC-4	---	---	---	21	---	15 - 20.5	Weathered Till / Glacio-Lacustrine	Location unknown.
GP-ATC-5D	-0.36	6	625.29	21	21	15 - 20.5	Weathered Till / Glacio-Lacustrine	Location unknown.
GP-ATC-5S	-0.33	0.5	625.32	21	5.5	4 - 5.5	Weathered Till / Glacio-Lacustrine	Location unknown.
GP-ATC-6D	-0.38	0.5	619.78	21	19.5	15 - 20.5	Weathered Till / Glacio-Lacustrine	
GP-ATC-6S	-0.38	0.5	619.78	21	4.6	4 - 5.5	Weathered Till / Glacio-Lacustrine	Slight siltation at the bottom of the screen.
GP-ATC-7	---	---	---	22	---	4 - 5.5	Weathered Till / Glacio-Lacustrine	Location unknown.
GP-ATC-7	---	---	---	22	---	15 - 20.5	Weathered Till / Glacio-Lacustrine	Location unknown.
GP-ATC-8D	-0.49	0.5	629.79	22	19.5	15 - 20.5	Weathered Till / Glacio-Lacustrine	Bottom of screen elevation from boring log above measured elevation. 2007 report identified boring log bottom below measured bottom. Slight siltation at bottom of screen.
GP-ATC-8S	-0.35	0.5	629.65	22	4.2	4 - 5.5	Weathered Till / Glacio-Lacustrine	Slight siltation at bottom of screen.

Notes:
ft = feet, ft MSL = feet above mean sea level, ft bgs = feet below ground suface, ft btoc = feet below top of casing, in = inches

Sources of data:
Historical notes obtained from: *Technical Memorandum Phase I Investigations Groundwater Monitoring Well System Enhancements* (October 12, 2007).
CH2M Hill and Udaloy, 1985, Phase 2 -- Site Development Plan, Task 13.0 Geotechnical and Water Quality Field Work, August 1985.
CH2M Hill, 1987, Technical Memorandum: Task 51 - Additional Monitoring Wells and Task 52 - Landfill Gas Migration Investigation, January 1987.
EMCON Northwest, 1993, Operations and Maintenance Manual for Landfill Gas Collection Systems at Cedar Hills Regional Landfill, May 1993.
Hong West & Associates, 1995, Revised Gasprobe and Gas Extraction Well Logs - Landfill Gas Extraction System - SE Perimeter, June 1995.
CH2M Hill, 2004, Cedar Hills Regional Landfill Main Hill Saturated Perched Zone Report, May 2004.
Geomatrix Consultants and Herrera Environmental Consultants, 2006, Dual-Phase Well Facility Evaluation Focus Work Plan, August 29, 2006.

Table 4. 2015 - 2018 Observed Conditions by Location

Project No. 130088, Cedar Hills Regional Landfill
King County, Washington

Well ID	Average Flow (SCFM)	Average Methane (% by vol)	Avergage Oxygen (% by vol)	Average Carbon Dioxide (% by vol)	Average Static Pressure (inches H2O)	Average Differential Pressure (inches H2O)	Max Temperature (F)
CHE00004	47	46	1.5	28	-25	0.17	96
CHE00006	0	10	15.5	4	-32	0.08	102
CHE00008	4	29	8.8	17	-13	0.03	113
CHE00009	27	23	1.5	21	-4	0.09	102
CHE00010	22	22	1.3	20	-23	0.06	99
CHE00013	23	22	4.4	19	-2	0.08	112
CHE00014	0	3	18.1	3	-1	0.00	114
CHE00016	16	6	16.6	5	0	0.16	97
CHE00017	4	23	9.6	15	0	0.06	102
CHE00018	8	40	1.2	28	-21	0.05	108
CHE00019	21	63	0.7	34	-26	1.16	111
CHE0001B	0	3	16.3	3	0	0.00	118
CHE0001C	1	0	19.4	1	0	0.00	118
CHE0001D	0	9	8.6	10	-2	0.04	117
CHE00021	9	59	2.1	28	-26	0.07	114
CHE00022	11	39	0.2	29	-8	0.08	114
CHE00023	8	23	7.3	18	-1	0.07	116
CHE00024	15	42	0.5	32	-9	0.11	99
CHE00026	8	54	0.3	34	-34	0.05	97
CHE00027	10	50	0.1	32	-24	0.06	100
CHE00028	0	3	17.7	3	0	0.00	92
CHE00030	15	57	0.2	39	-33	0.07	96
CHE00031	7	36	8.3	21	-3	0.08	102
CHE00032	23	56	1.4	37	-29	1.03	105
CHE00033	11	59	0.0	40	-34	0.06	93
CHE00034	40	49	0.1	35	-10	0.39	86
CHE00035	17	46	0.7	34	-13	0.10	93
CHE00036	11	48	0.3	31	-3	0.07	102
CHE00037	2	6	15.2	6	0	0.02	103
CHE00038	2	4	16.8	5	0	0.16	99
CHE00039	0	2	18.1	3	-1	0.00	98
CHE00040	15	30	8.0	21	-2	0.27	91
CHE00042	3	15	10.3	16	-1	0.15	99
CHE00043	28	46	0.0	34	-3	0.29	95
CHE00044	0	3	19.7	2	-1	0.00	99
CHE00047	0	4	18.4	3	-9	0.00	97
CHE00048	8	37	0.6	27	-3	0.15	94
CHE00049	9	43	0.0	31	-7	0.06	94
CHE00050	12	49	0.8	28	-21	0.07	97
CHE00052	0	3	19.9	2	-2	0.00	95
CHE00053	0	2	20.1	1	-1	0.00	96
CHE00054	0	18	11.7	11	-1	0.05	101
CHE00055	2	16	7.3	16	0	0.36	98
CHE00056	0	0	18.6	2	0	0.00	99
CHE00057	0	0	17.5	3	-1	0.00	99
CHE00066	0	16	12.6	8	-3	0.00	104
CHE00067	0	11	13.7	9	-18	0.04	104
CHE00068	10	32	0.1	24	-4	0.14	114
CHE00069	15	11	13.3	10	-1	0.42	103
CHE00070	9	41	3.1	32	-3	0.06	98
CHE00071	22	46	1.7	36	-2	0.26	98
CHE0032A	0	11	15.0	8	-18	0.03	99
CHE0035A	0	0	17.2	3	-1	0.00	105
CHE0036A	10	0	20.5	1	0	0.16	103
CHE0038A	0	1	19.5	2	0	0.00	96
CHE0040A	10	49	3.2	32	-26	0.07	94
CHE0042A	0	1	20.6	1	-1	0.00	103
CHE0043A	7	26	7.2	21	-1	0.16	101
CHE0046A	0	0	20.8	1	0	0.00	98
CHE0047A	11	59	1.2	34	-37	0.10	97
CHE0048A	0	12	13.7	9	-1	0.00	105
CHE0049A	0	0	20.6	1	0	0.00	98
CHE0056A	13	69	0.8	27	-33	0.08	99
CHE0056B	0	0	20.8	1	0	0.00	97
CHE00E1A	2	17	5.0	15	-5	0.03	102
CHEGL059	24	43	1.4	34	-5	0.23	97
CHEGL060	5	22	10.0	15	-1	0.06	102
CHEGL061	15	40	5.7	28	-2	0.23	88

Table 4. 2015 - 2018 Observed Conditions by Location

Project No. 130088, Cedar Hills Regional Landfill
King County, Washington

Well ID	Average Flow (SCFM)	Average Methane (% by vol)	Average Oxygen (% by vol)	Average Carbon Dioxide (% by vol)	Average Static Pressure (inches H2O)	Average Differential Pressure (inches H2O)	Max Temperature (F)
CHEGLSE1	0	7	17.7	4	0	0.00	106
CHEGLSE2	0	9	17.3	4	-15	0.00	99
CHEGLSE3	2	36	7.6	15	-17	0.05	105
CHEGLSE4	0	22	12.0	8	-16	0.02	101
CHEGLSE5	0	9	17.3	4	-10	0.00	101
CHEGLSE6	0	20	12.1	7	-12	0.00	100
CHEGLSE7	1	27	10.9	15	-5	0.02	98
CHEGLSE8	2	43	6.5	21	-23	0.05	105
CHEMHFC1	0	2	17.4	4	-1	0.00	100
CHGL0009	0	29	9.5	15	-2	0.02	100
CHGL0010	5	39	0.3	26	-35	0.03	96
CHGL0011	0	25	5.2	19	-9	0.08	90
CHGL0014	0	6	10.5	11	-6	0.05	96
CHGL0015	0	4	17.9	3	-1	0.06	101
CHGL0016	0	9	4.6	15	-1	0.05	104
CHSE29AD	5	2	17.1	3	-10	0.04	97
CHSE29AS	8	1	19.2	1	-1	0.05	85
CHSE29BD	7	13	3.8	17	-14	0.04	92
CHSE29BS	14	0	19.9	1	-2	0.11	70
CHSE29CD	2	5	16.4	6	-1	0.01	98
CHSE29CS	8	5	17.3	4	-2	0.05	86
CHSE29DD	7	29	1.3	27	-10	0.04	81
CHSE29DS	0	0	16.9	2	-1	0.00	97
CHSEP065	6	0	3.4	5	-5	0.04	94
CHSEP0B4	21	0	13.8	7	-14	0.05	116
CHSEP0E8	22	39	4.3	25	-15	0.04	117
CHSEP58D	6	10	2.8	12	-14	0.05	99
CHSEP58S	2	0	19.2	1	0	0.02	107
CHSEP59D	7	10	15.3	6	-14	0.05	97
CHSEP59S	0	0	17.4	1	0	0.00	104
CHSEP60D	6	12	4.1	13	-14	0.05	104
CHSEP60S	6	7	13.6	4	-14	0.05	95
CHSEP61D	7	36	4.6	19	-14	0.05	96
CHSEP61S	7	27	4.2	15	-14	0.05	100
CHSEP62D	5	1	13.4	3	-14	0.04	100
CHSEP62S	6	3	18.3	2	-14	0.05	93
CHSEP63D	7	0	20.1	0	-14	0.05	86
CHSEP63M	7	2	8.0	10	-15	0.05	92
CHSEP63S	6	0	20.0	0	-15	0.04	95
CHSEP64D	51	0	10.8	3	-6	0.69	69
CHSEP64M	7	0	15.8	2	-4	0.05	96
CHSEP64S	5	1	16.9	1	-14	0.04	97
CHSEPE11	16	0	19.5	1	-14	0.03	105
CHSEPE14	15	0	8.9	4	-14	0.03	108
CHSEPVLT	21	2	12.0	7	-1	0.07	105
	Total Flow	**Total Flow-weighted Concentrations**					
	888	29.3	5.9	20.7			

Bold: EPZ
Native Soil
Near Edge
Bottom Tier
Middle Tier
Top Tier

Methane	Oxygen	
>50%	<0.1%	Relaxed
>45% and <50%	>0.1% and <0.5%	Moderate
>35% and <45%	>0.5% and <1%	Aggressive
>25% and <35%	>1% and <3%	Very Aggressive
<25%	>3%	

Table 5. 2015 - 2018 Observed Conditions by Location - EPZ Only

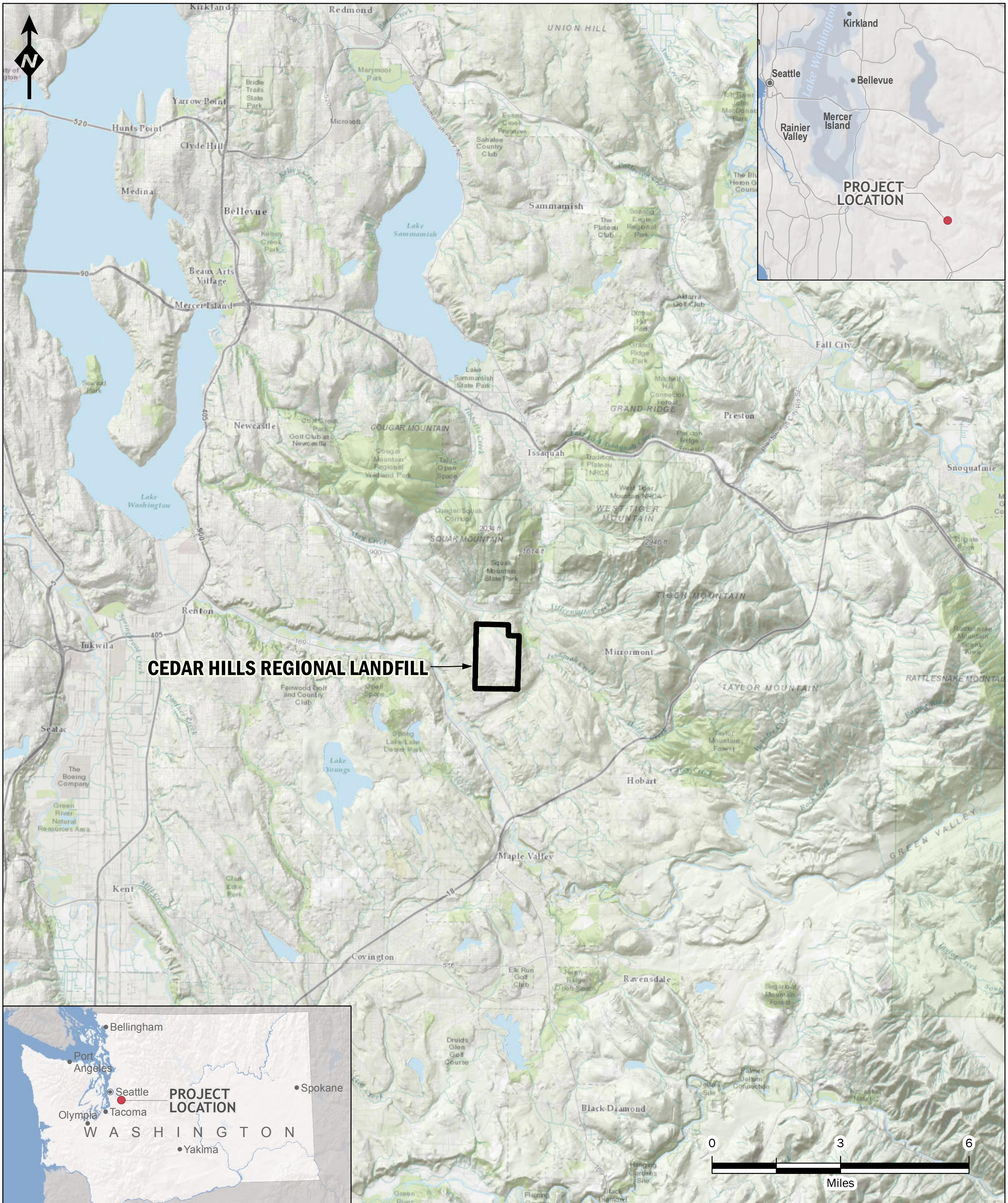
Project No. 130088, Cedar Hills Regional Landfill
King County, Washington

Well ID	Average Flow (SCFM)	Average Methane (% by vol)	Average Oxygen (% by vol)	Average Carbon Dioxide (% by vol)	Average Static Pressure (inches H2O)	Average Differential Pressure (inches H2O)	Max Temperature (F)
CHE00019	21	63	0.7	34	-26	1.16	111
CHE00021	9	59	2.1	28	-26	0.07	114
CHE00033	11	59	0.0	40	-34	0.06	93
CHE00030	15	57	0.2	39	-33	0.07	96
CHE00032	23	56	1.4	37	-29	1.03	105
CHE00026	8	54	0.3	34	-34	0.05	97
CHE00027	10	50	0.1	32	-24	0.06	100
CHE0040A	10	49	3.2	32	-26	0.07	94
CHE00034	40	49	0.1	35	-10	0.39	86
CHE00036	11	48	0.3	31	-3	0.07	102
CHE00071	22	46	1.7	36	-2	0.26	98
CHE00035	17	46	0.7	34	-13	0.10	93
CHE00043	28	46	0.0	34	-3	0.29	95
CHEGL059	24	43	1.4	34	-5	0.23	97
CHE00024	15	42	0.5	32	-9	0.11	99
CHE00070	9	41	3.1	32	-3	0.06	98
CHE00018	8	40	1.2	28	-21	0.05	108
CHEGL061	15	40	5.7	28	-2	0.23	88
CHE00022	11	39	0.2	29	-8	0.08	114
CHE00031	7	36	8.3	21	-3	0.08	102
CHE00068	10	32	0.1	24	-4	0.14	114
CHE00040	15	30	8.0	21	-2	0.27	91
CHSE29DD	7	29	1.3	27	-10	0.04	81
CHE0043A	7	26	7.2	21	-1	0.16	101
CHE00023	8	23	7.3	18	-1	0.07	116
CHE00017	4	23	9.6	15	0	0.06	102
CHEGL060	5	22	10.0	15	-1	0.06	102
CHE00042	3	15	10.3	16	-1	0.15	99
CHSE29BD	7	13	3.8	17	-14	0.04	92
CHE0032A	0	11	15.0	8	-18	0.03	99
CHE00069	15	11	13.3	10	-1	0.42	103
CHE00037	2	6	15.2	6	0	0.02	103
CHSE29CD	2	5	16.4	6	-1	0.01	98
CHSE29CS	8	5	17.3	4	-2	0.05	86
CHE00038	2	4	16.8	5	0	0.16	99
CHE00028	0	3	17.7	3	0	0.00	92
CHE00044	0	3	19.7	2	-1	0.00	99
CHSE29AD	5	2	17.1	3	-10	0.04	97
CHE00039	0	2	18.1	3	-1	0.00	98
CHE0038A	0	1	19.5	2	0	0.00	96
CHSE29AS	8	1	19.2	1	-1	0.05	85
CHE0042A	0	1	20.6	1	-1	0.00	103
CHSE29BS	14	0	19.9	1	-2	0.11	70
CHE0036A	10	0	20.5	1	0	0.16	103
CHE0035A	0	0	17.2	3	-1	0.00	105
CHE0046A	0	0	20.8	1	0	0.00	98
CHSE29DS	0	0	16.9	2	-1	0.00	97

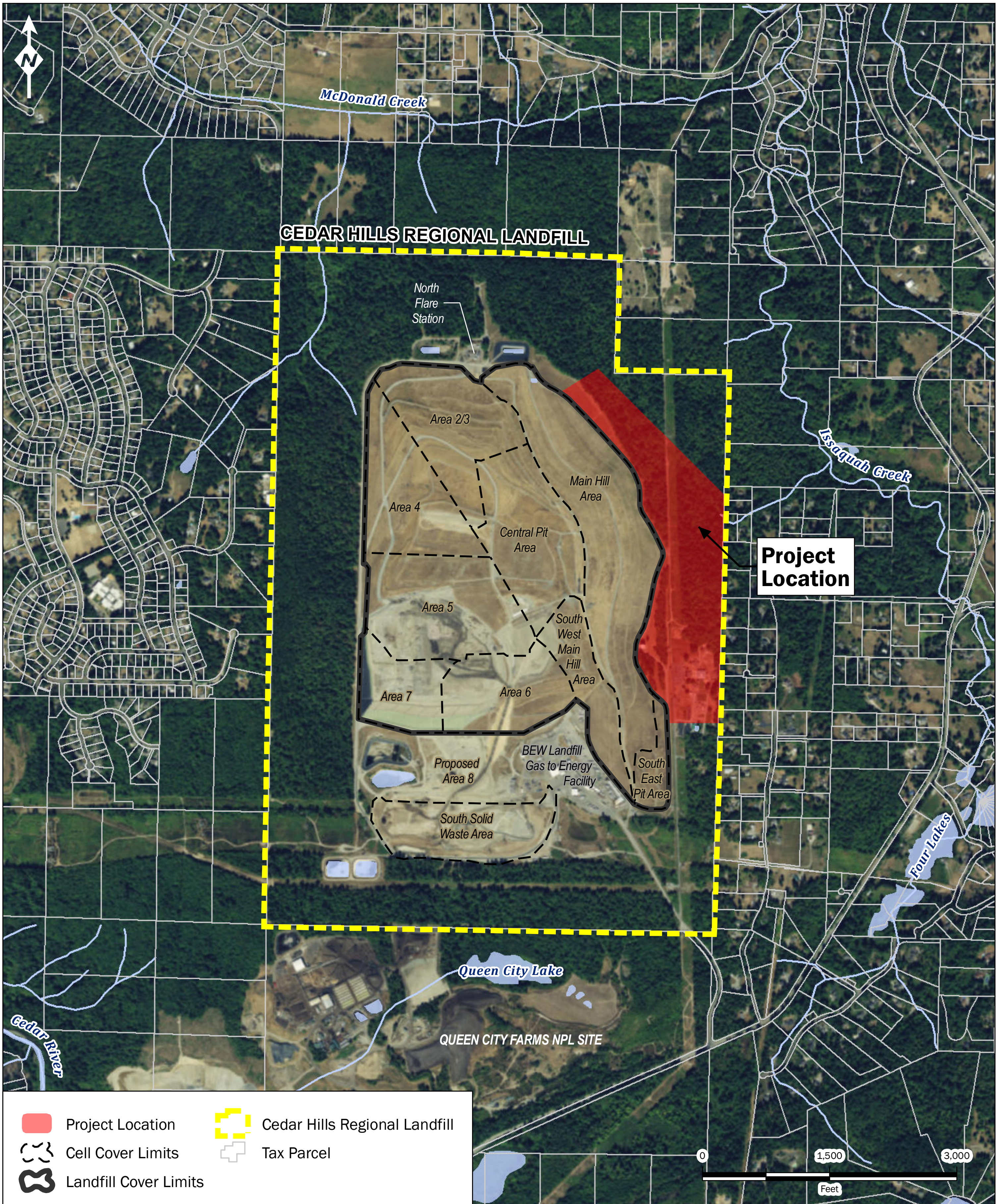
Bold: EPZ
Native Soil
Near Edge
Bottom Tier
Middle Tier
Top Tier

Methane	Oxygen	
>50%	<0.1%	**Relaxed**
>45% and <50%	>0.1% and <0.5%	**Moderate**
>35% and <45%	>0.5% and <1%	**Aggressive**
>25% and <35%	>1% and <3%	**Very Aggressive**
<25%	>3%	

FIGURES



King County / Aspect CONSULTING	**Project Location Map** **Cedar Hills Regional Landfill** King County, Washington	DATE: Sep-2016 DESIGNED BY: KSL/RAP DRAWN BY: KSL/RAP REVISED BY: - - -	PROJECT NO. **130088** FIGURE NO. **1**



King County

Aspect CONSULTING

Cedar Hills Regional Landfill Site Features

Cedar Hills Regional Landfill

King County, Washington

DATE: Sep-2016	PROJECT NO. 130088
DESIGNED BY: KSL/RAP	
DRAWN BY: KSL/RAP	FIGURE NO. 2
REVISED BY: PPW	

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Methane: >50%
Oxygen: <0.1%

Methane: >45% & <50%
Oxygen: <0.1% & <0.5%

Methane: >35% & <45%
Oxygen: <0.5% & <1%

Methane: >25% & <35%
Oxygen: <1% & <3%

Methane: <25%
Oxygen: >3%

Groundwater Extraction Well
Gas Extraction/Dual-Phase/Leachate Well
Gas Probe
Leachate Sampling Manhole
Manhole
Perched Zone Monitoring Well
Perched Zone Piezometer
Regional Aquifer Monitoring Well
Staff Gauge
Surface Water Monitoring Station
Non-Potable Water Well
Borehole/Geoprobe (Decommissioned)
East Shallow Perched Zone[1]
Northeast Shallow Perched Zone[1]

[1]Uncertainty in zone boundary indicated by dashed line
[2]Gas probe locations could not be field verified

Stream
Approximate Extent of Wetland Area
Project Location
Landfill Cover Limits
Property Boundary

Aspect CONSULTING

King County

EPZ Features and Monitoring Locations
Cedar Hills Regional Landfill
King County, Washington

DATE: Dec-2018	PROJECT NO. 130088
DESIGNED BY: KSL/RAP	
DRAWN BY: KSL/RAP	FIGURE NO. 3
REVISED BY: SDM / RAP	

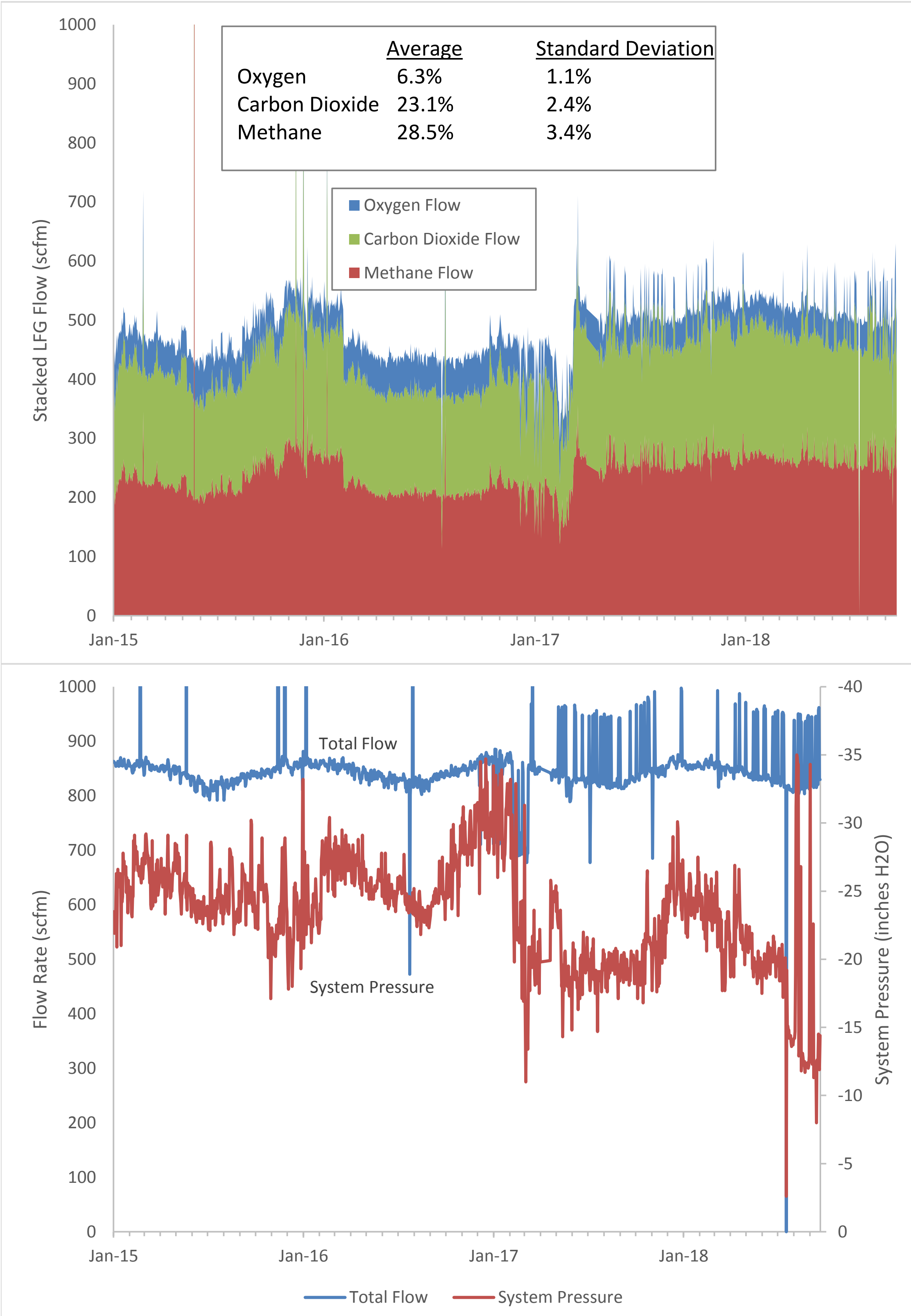


Figure 4

2015-2018 Observed Conditions at Migration Control Flare

EPZ LFG Optimization Memo

P:\AECOM Cedar Hills Env Controls E00286E12\Data\Analyses\LFG\Migration Flare 2015-2017_Aspect.xlsx

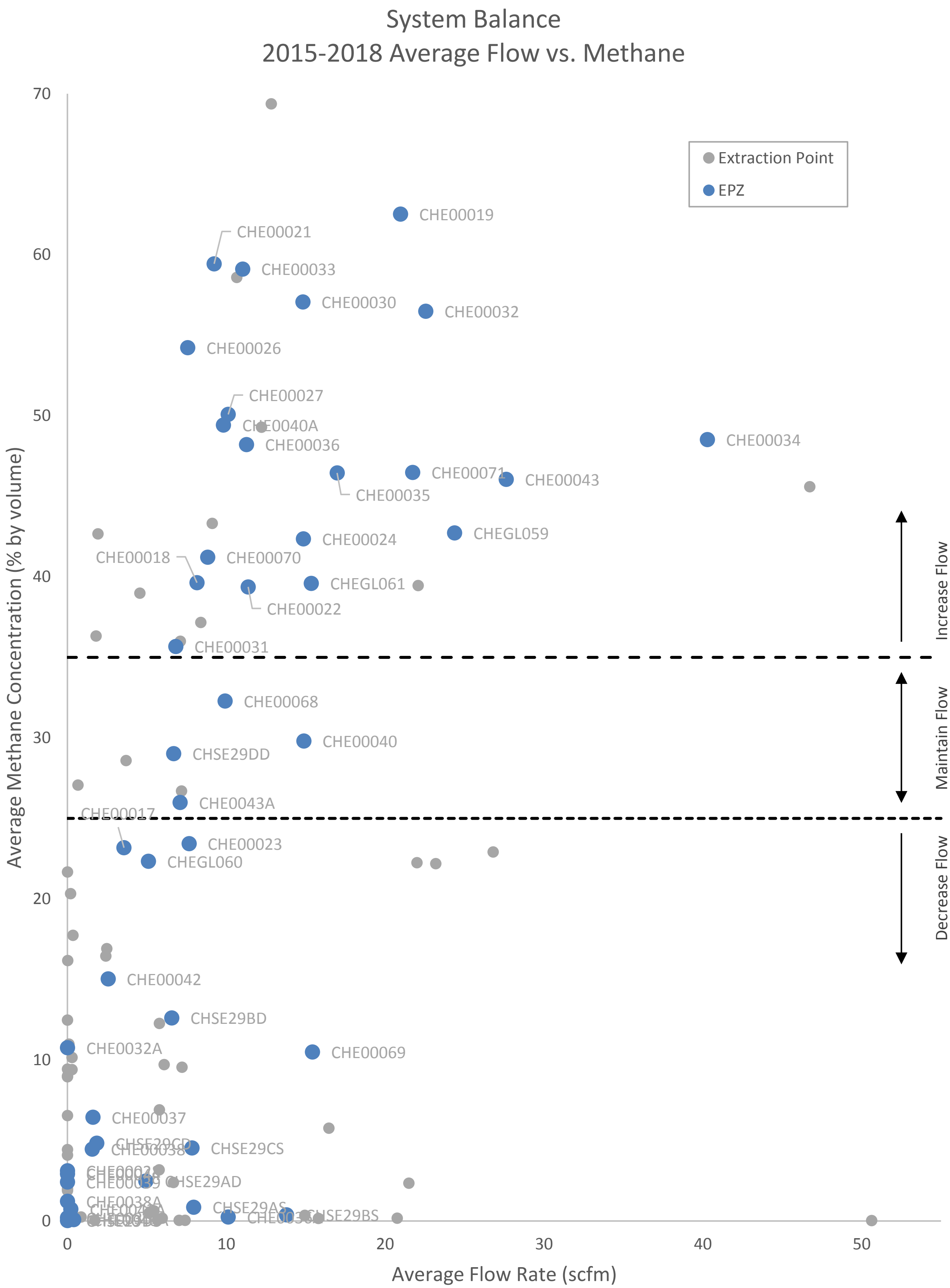


Figure 5
Methane vs. Flow Rate
EPZ LFG Optimization Memo

ATTACHMENT 1

Near-term LFG Optimization Monitoring Guidelines

Attachment 1

Guidelines for Landfill Gas Migration Control Optimization – EPZ

These guidelines summarize the monitoring data collection and flow and valve adjustments recommended for optimizing LFG migration control. Refer to Section 2.3 in the Memorandum for additional details.

Step 1: Initial Readings: Measure and record stabilized LFG concentrations, pressure readings, calculated flow, and valve position.

Step 2: Evaluate initial readings for basis of determining valve adjustments, as described below.

Flow and Valve Adjustment Guidelines

Methane (% vol)	Action	Conditions
> 35%	Increase Flow	Valve adjustment should be 10% or less based on valve stem demarcations.
25–35%	Maintain Flow	
< 25%	Decrease Flow	

Additional Monitoring Parameters and Criteria

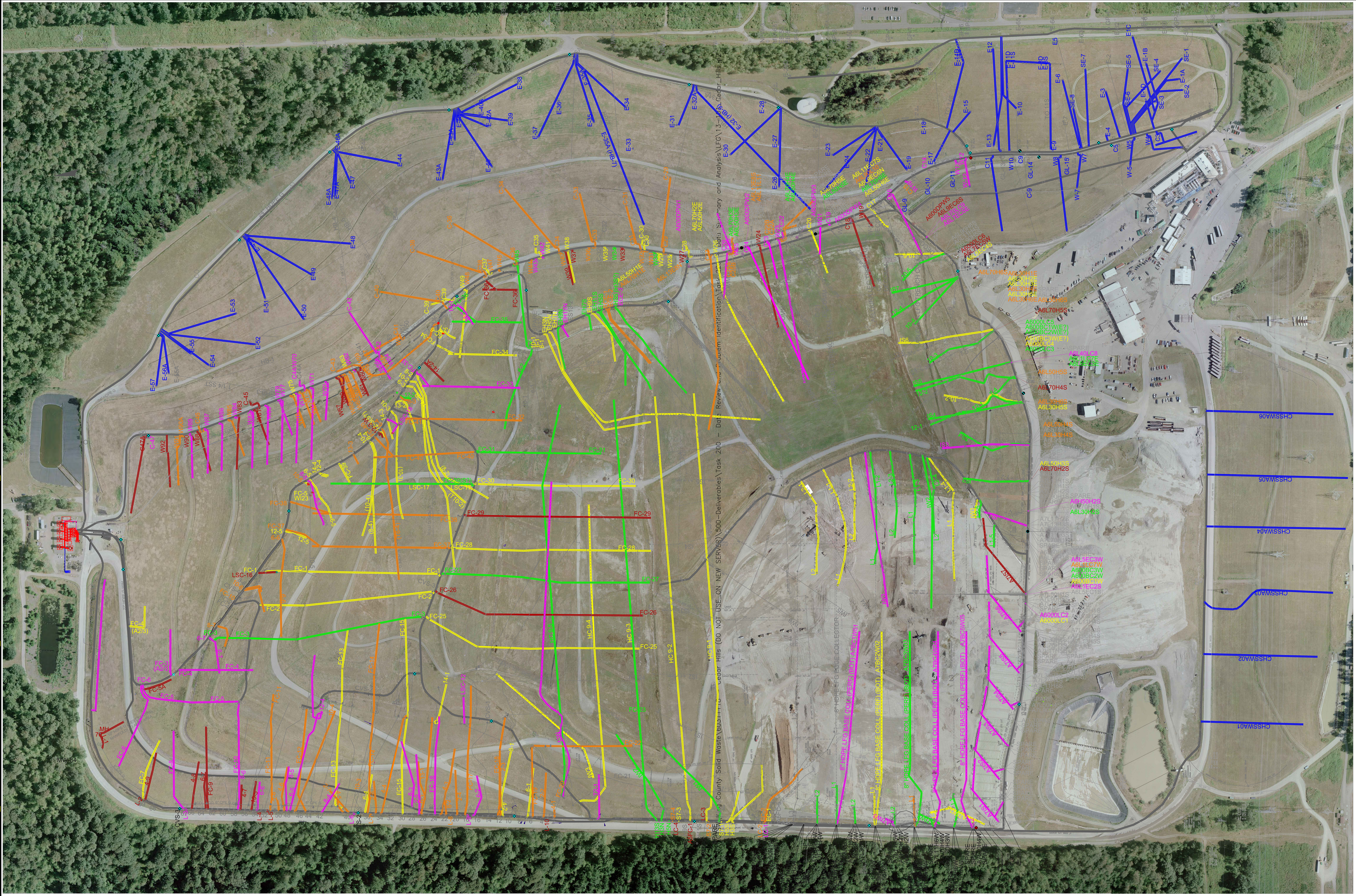
LFG Parameter	Primary Potential Concern(s)	Condition	Action(s)
Hydrogen sulfide (H_2S)	Odor control	Is odor present?	If odor observed, monitor for H_2S to confirm source. If H_2S is not present in LFG, inspect wellhead for damage to boot or cover.
Oxygen (O_2)	Air leaks, subsurface fires	If O_2 > 3%, this could indicate potential air leak	Inspect monitoring assembly, lateral, and wellhead for atmospheric leaks. Address leaks.
Carbon monoxide (CO)	Subsurface fire	If CO is less than 100 ppm, subsurface fire is unlikely	Adjust valve according to methane concentration.
		If CO is between 100 ppm and 1,000 ppm, there is potential for subsurface fire	Decrease flow to reduce potential for subsurface fire, notify manager.
		If CO_2 > 1000 ppm, subsurface fire is likely	Close valve to minimize potential for subsurface fire, notify manager.

Step 3: Adjust valve at extraction well based on valve adjustment criteria described above.

Step 4: Adjusted Readings: Measure and record pressure readings, calculated flow, and valve position.

ATTACHMENT 2

Reproduced Figure 17 from 2015 AECOM Report



NOTE: SOME LANDFILL GAS BASE MAP UTILITIES COULD NOT BE ASSOCIATED WITH THE COLLECTOR IDS LISTED IN CHRLF MONITORED DATA. THEREFORE, THIS FIGURE IS A WORKING DRAFT AND REQUIRES OPERATION'S ASSISTANCE IN IDENTIFYING OR CONFIRMING THE LOCATION OF THE COLLECTOR IDS LISTED IN TABLE 11.

0 150 300 Feet

No.	REVISION	BY	APP'D	DATE

COLOR CODE / LEGEND

- HEADERS
- BASE MAP UTILITIES
- BLUE - MIGRATION CONTROL WELLS (E.G. FLARES METHANE AT SKID-MOUNTED FLARE)
- RED - CLOSED 100% OF MONITORED DURATION OR OXYGEN > 2%
- PINK - METHANE < 46% AND/OR NITROGEN > 10%
- ORANGE - METHANE > 46%, OXYGEN < 2%, AND NITROGEN < 10% WITH <1/2 TPD METHANE PRODUCTION
- YELLOW - METHANE > 46%, OXYGEN < 2%, AND NITROGEN < 10% WITH < 1 TPD AND > 1/2 TPD METHANE PRODUCTION
- GREEN - METHANE > 46%, OXYGEN < 2%, AND NITROGEN < 10% WITH > 1 TPD METHANE PRODUCTION
- CLOSED ISOLATION BUTTERFLY VALVE
- OPEN ISOLATION BUTTERFLY VALVE

DESIGNED:

DRAWN:

RECOMMENDED:

APPROVED:

CHECKED:

SCALE: AS NOTED

CONTRACT NO:

King County DNRP

SOLID WASTE DIVISION
CEDAR HILLS REGIONAL LANDFILL

FIGURE 17
PERFORMANCE DATA RESULTS COLOR CODED COLLECTOR LAYOUT

DATE: November 2, 2015

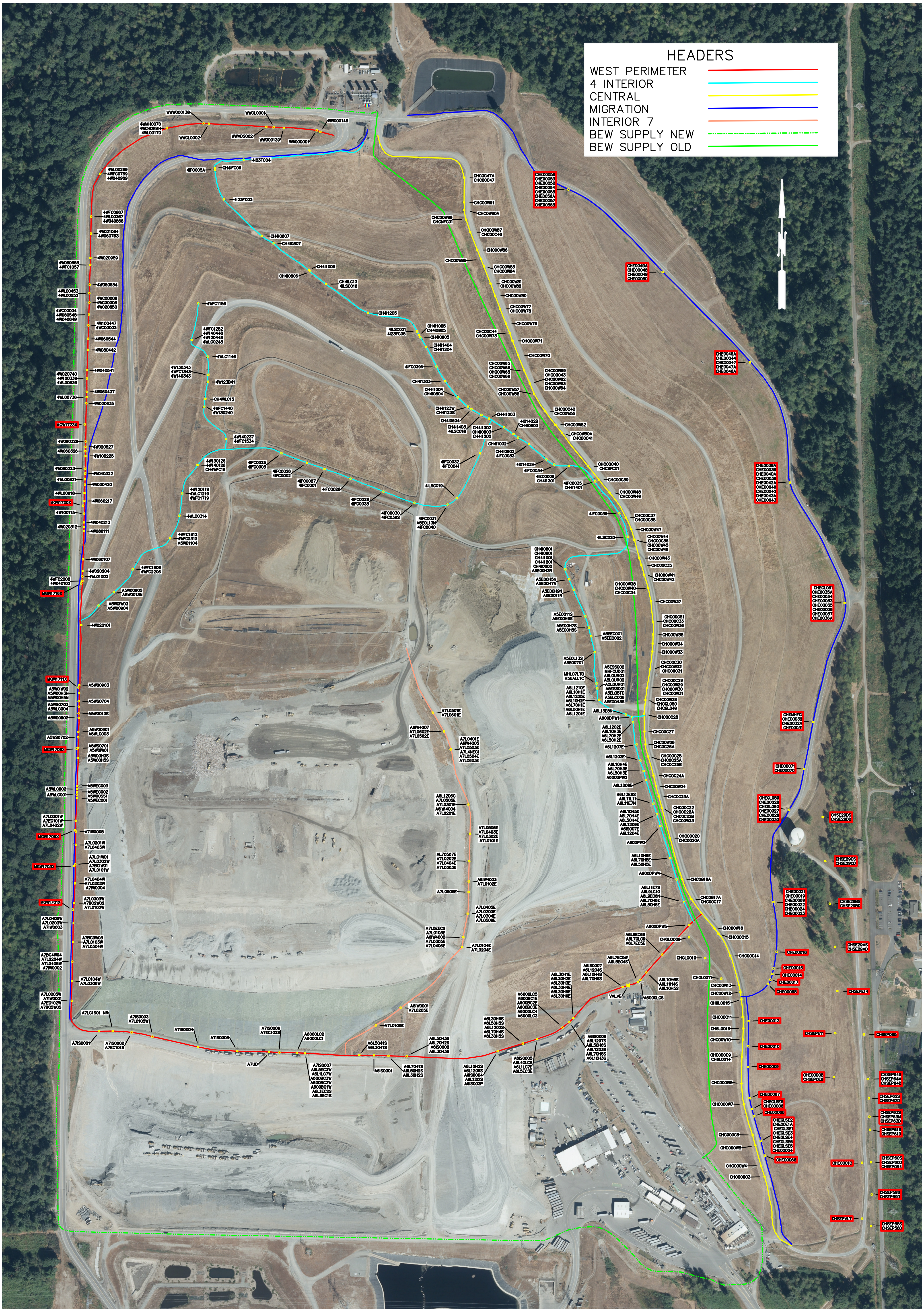
PROJECT NO:

DRAWING NO:

SHEET NO: 1 OF 1

ATTACHMENT 3

Map Provided by KCSWD Showing Monitoring Locations


HEADERS
WEST PERIMETER
4 INTERIOR
CENTRAL
MIGRATION
INTERIOR 7
BEW SUPPLY NEW
BEW SUPPLY OLD
N

ATTACHMENT 4

2015-2018 Observed LFG Collection at Selected Locations

Attachment 4
LFG Collection Assessment By Location
CHRLF LFG Optimization

P:\AECOM Cedar Hills Env Controls E00286E12\Data\Analyses\LFG\East Header Gas Collection System Data 2015-2017_Aspect.xlsx