Monthly Compliance Report

Solid Waste Permit #221
Bristol Integrated Solid Waste Management Facility
2655 Valley Drive
Bristol, VA 24201
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SCS ENGINEERS

02218208.05 | December 9, 2022

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EXECUTIVE SUMMARY

On behalf of the City of Bristol, Virginia (City), SCS Engineers has prepared this report to the Virginia Department of Environmental Quality (VDEQ) outlining steps taken towards the action items outlined in the Plan of Action submitted to VDEQ on July 6, 2022. This report covers the Solid Waste Permit #221 landfill during the month of November.

1.0 SURFACE EMISSIONS MONITORING

On October 12, 2022, SCS performed surface emissions monitoring on the landfill. The monitoring was performed in accordance with the site-specific GCCS Design Plan, the facility's Title V Permit, the requirements of 40 CFR 63.1960(c) and (d), 40 CFR 60.36f(c) and (d), and 40 CFR 60, Appendix A, Method 21. The landfill gas (LFG) collection system is required to operate such that the methane concentration is less than 500 ppm above background at the landfill surface. The frequency for performing surface emissions monitoring at the Closed Landfill is on an annual basis in accordance with the Facility's approved GCCS Design Plan.

The monitoring route included all applicable areas of the Permit No. 221 landfill. Sampling was conducted with a Thermo Scientific TVA-2020 Flame Ionization Detector (FID) at 30-meter intervals and where visual observations indicated the potential for elevated concentrations of LFG, such as distressed vegetation and surface cover cracks. In addition, in accordance with 40 CFR 63.1958(d)(ii)(2) and 40 CFR 60.34f(d), monitoring was conducted at all surface cover penetrations within the waste footprint outside of the active filling area.

VDEQ was copied on a letter outlining the results on October 28, 2022.

Table 1. Summary of October Surface Emissions Monitoring

Description	October 12, 2022
Number of Points Sampled	85
Number of Points in Serpentine Route	73
Number of Points at Surface Cover Penetrations	12
Number of Exceedances	0
Number of Serpentine Exceedances	0
Number of Pipe Penetration Exceedances	0

SCS understands that the Solid Waste Permit #221 landfill is subject to annual Surface Emissions Monitoring and therefore no additional monitoring was performed this month.

2.0 GAS COLLECTION

On October 3, 2022 and October 10, 2022, SCS Field Services (SCS-FS) visited the landfill and performed monitoring of the landfill gas wells. The results of that monitoring were submitted to VDEQ on November 7, 2022 and are included in Appendix A. This data will be used to optimize the wellfield and address oxygen intrusion along with the activities described in the rest of Section 2.

2.1 OPTIMIZATION PLAN

On December 1, 2022, on behalf of the City, SCS submitted a plan that provides for means and methods for optimizing the performance of the existing gas extraction system in the Solid Waste Permit #221 landfill. A copy of this plan is included in Appendix B. The plan proposes optimizing the landfill gas extraction system by performing the following activities:

- Reviewing and Evaluating the Existing LFG System Data
- LFG System Design and Construction Considerations
- LFG System Performance Field Activities

Specific action items identified in the report for future implementation include:

- An LFG wellfield balancing and tuning event
- A wellfield liquid level measurement and down-well camera event
- A voluntary SEM event
- A concept design for LFG system expansion and improvements

Appendix A

November Monthly Wellhead Monitoring Data

December 7, 2022
File No. 07220028.00 Task 6

MEMORANDUM

TO: Jonathan Chapman, VDEQ – SWRO

FROM: Mike Gibbons, SCS Field Services

SUBJECT: Monthly Landfill Gas System Wellhead Monitoring Data
for November, 2022 Landfill Permit Areas 221 and 498
Bristol Integrated Solid Waste Management Facility, Bristol, Virginia

SCS Field Services is submitting this data on behalf of the City of Bristol per DEQ request for monthly landfill gas (LFG) wellhead monitoring data for Solid Waste Permit Areas #221 and #498 for the month of November, 2022.

Area 221

There are currently 15 vertical extraction wells in the SWP #221 Landfill Area (Well Nos. 1 – 15). In waste disposal units where the age of the buried wastes is greater than 40 years, as is the case at SWP #221 landfill, the rate and quantity of decomposition gas production declines significantly compared to the rate and quantity of LFG generated in more recently buried wastes. Accordingly, the methane concentration tends to be substantially lower, the oxygen and nitrogen concentrations tend to be substantially greater, and the quantity of LFG collected declines substantially compared to the years immediately after waste placement. There is no historical evidence of elevated temperatures in SWP #221; however, the methane-to-carbon dioxide ratio measured in the wellheads can sometimes be less than 1 due to the fact that the wastes are becoming biochemically stabilized (meaning organic wastes have been more fully decomposed) and the rate of methanogenesis has declined. Also, the #221 Landfill Area is not believed to be a significant source of fugitive LFG emissions or odors.

Adjustments are made during wellhead monitoring to optimize gas quality and applied vacuum on the Area 221 wells. All Area 221 are under vacuum. During the November monitoring, vacuum was increased at EW-03, -06, and -07 in response to high methane at the wellhead. The average gas composition in the Area 221 wells is shown in Table 1. Methane and carbon dioxide concentrations increased over the previous month while oxygen concentration decreased, which is likely attributed to the corresponding reduction in applied vacuum.

Table 1. Monthly Average Wellhead LFG Composition – Area 221 Wells

Month	Average CH_4 (% Vol)	Average CO_2 (% Vol)	Average O_2 (% Vol)	Average Pressure (inches w.c.)
October '22	40.0	29.2	6.4	-14.9
November '22	47.4	33.7	3.3	-11.9

Area 498

The SWP #498 Landfill is approximately 12.0 acres and is located south of the SWP #221 Landfill and east of the SWP #588 Landfill. As of September 2022, mining in Permit #498 has concluded. The majority of the SWP #498 Landfill does not have an active LFG collection system, due to mining operations which have occurred since waste placement was completed. The current system includes four vertical wells (GW-19, GW-20, GW-21, and GW-22) and a condensate trap (CT-1) at the low point. Field reconnaissance efforts in September/October 2022 identified that the header pipe serving the four wells had been severed, blocked, or otherwise compromised, such that no distribution of vacuum and no gas collection was occurring. Site personnel successfully established vacuum at GW-19 during November 2022, and plan to continue repairs to the vacuum supply line to allow gas collection from the other three gas wells. The buried wastes in SWP #498 Landfill Area are greater than 25 years old, thus, the rate and quantity of decomposition gas production has declined significantly compared to the rate and quantity of LFG generated in more recently buried wastes. Accordingly, the methane concentration tends to be substantially lower, the oxygen and nitrogen concentrations tend to be substantially greater, and the quantity of LFG collected declines substantially compared to the years immediately after waste placement. Furthermore, much of the organic wastes in the upper layer have likely decomposed aerobically (i.e., were composted) because of the mining operations. There is no historical evidence of elevated temperatures in SWP #498; however, the methane-to-carbon dioxide ratio measured in the wellheads can sometimes be less than 1 due to the fact that the wastes are becoming biochemically stabilized (meaning organic wastes have been more fully decomposed) and the rate of methanogenesis has declined. Also, the #498 Landfill Area is not believed to be a significant source of odors.

Vacuum was restored to EW-19 in Area 498 by re-aligning the header to allow liquids to drain and restore gas flow. Work is in progress to restore vacuum to the remaining wells.

Bristol Virginia Landfill - Permit 221 and498 Extraction Well Data - 11/01/2022 to 11/30/2022

Point Name	Record Date	CH4 (% by vol)	CO2 (% by vol)	O2 (% by vol)	Bal Gas (% by vol)	Init Static Pressure ("H2O)	Adj Static Pressure ("H20)	Temp (F)	System Pressure ("H20)	Comments
01	11/3/2022 11:09	56.2	39.1	1.0	3.7	-22.8	-22.9	65.1	-22.5	
02	11/3/2022 11:00	31.3	20.2	11.0	37.5	-15.3	-15.3	79.0	-23.3	
03	11/3/2022 10:56	59.4	40.3	0.2	0.1	0.5	-0.3	76.3	-23.4	Adjusted open
03	11/10/2022 10:22	59.1	40.9	0.0	0.0	-0.1	0.0	71.2	-10.6	Rececked, Adjusted open
03	11/17/2022 10:38	31.0	23.0	9.6	36.4	-2.6	-2.6	49.6	-13.4	
04	11/3/2022 10:40	49.9	37.1	2.6	10.4	-6.2	-6.2	74.1	-23.3	
05	11/3/2022 10:36	55.3	40.8	0.9	3.0	-23.1	-22.7	69.5	-23.2	
06	11/3/2022 11:56	61.5	37.5	0.0	1.0	1.3	-1.9	89.8	-23.3	
06	11/3/2022 11:58	54.5	34.3	2.1	9.1	-5.9	-6.4	66.3	-23.3	Adjusted open
07	11/3/2022 11:45	56.1	39.0	0.5	4.4	-10.2	-10.1	74.5	-23.4	
07	11/3/2022 11:50	56.2	39.5	0.4	3.9	-11.7	-11.7	87.8	-23.4	Adjusted open
08	11/3/2022 11:41	31.2	20.7	10.0	38.1	-0.1	-0.1	84.2	-23.5	
09	11/3/2022 11:31	53.0	36.9	1.7	8.4	-22.7	-22.7	85.4	-23.6	
10	11/3/2022 11:27	56.4	42.0	0.4	1.2	-6.1	-6.1	82.9	-23.4	
11	11/3/2022 11:22	22.3	15.8	12.9	49.0	-23.2	-23.2	77.5	-23.3	
12	11/3/2022 11:13	32.7	23.3	9.1	34.9	-23.7	-23.6	71.6	-23.5	
13	11/3/2022 10:49	54.2	38.6	0.9	6.3	-23.4	-23.3	65.1	-23.4	
14	11/3/2022 11:36	42.3	25.7	6.3	25.7	-2.4	-2.4	77.4	-23.4	
15	11/3/2022 11:04	57.8	39.3	0.7	2.2	-23.4	-23.5	73.7	-23.4	
16	11/3/2022 12:14	33.6	35.0	0.6	30.8	-11.9	-11.9	80.4	-23.4	
17	11/3/2022 12:17	44.2	36.2	0.7	18.9	-18.0	-17.9	77.0	-23.3	
18	11/3/2022 13:26	44.9	37.0	1.1	17.0	-12.0	-11.9	79.7	-23.3	
19	11/29/2022 10:43	3.0	11.7	6.2	79.1	-13.9	-13.8	70.0	n/a	Needs system pressure port
23	11/3/2022 12:05	0.2	0.3	20.6	78.9	-2.1	-2.0	65.1	-23.5	
23	11/3/2022 12:10	0.1	0.3	20.8	78.8	-2.7	-2.7	61.1	-23.4	Adjusted open

Appendix B

Landfill Gas Collection and Control System Optimization Plan

Landfill Gas Collection and Control System Optimization Plan

Bristol Integrated Solid Waste Management Facility

Solid Waste Permit #221 and 498

2655 Valley Drive
Bristol, VA 24201

SCS ENGINEERS

02218208.05 | December 1, 2022

15521 Midlothian Turnpike, Suite 305
Midlothian, VA 23113
804-378-7440

Signature/Certification Sheet

We certify that we have prepared this Plan, that it has been prepared in accordance with industry standards and practices, and that the information contained herein is truthful and accurate to the best of our knowledge.

Name: Robert E. Dick, PE, BCEE Senior Vice President

Signature: _____

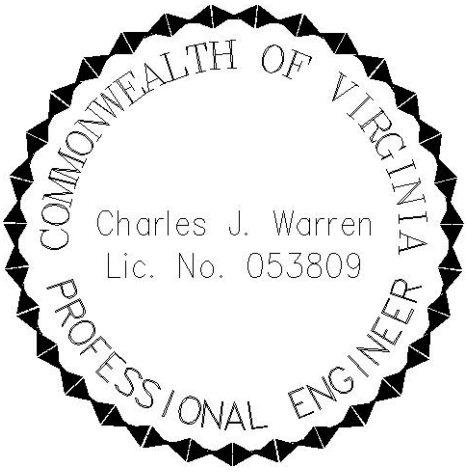
Date: December 1, 2022

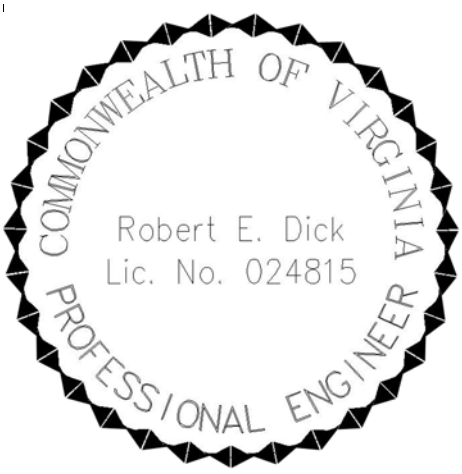
Name: Charles J. Warren, PE, Project Manager

Signature: _____

Date: December 1, 2022

Virginia Professional Engineer's Certification:





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1.0 INTRODUCTION

The Bristol Integrated Solid Waste Management Facility (ISWMF) is an active solid waste management facility owned and operated by the City of Bristol, Virginia (City).

The ISWMF has three landfill units within its property boundary. The first landfill unit (Solid Waste Permit #221) received waste from 1977 to 1986 and is closed and capped. The second landfill unit (Solid Waste Permit #498) received waste from 1986 to 1998 and was mined for airspace recovery up until recently, while plans are being made for capping and closure. The third landfill unit (Solid Waste Permit #588) is an in-active landfill that commenced operation in March 1998 and ceased waste acceptance in September of 2022.

The landfill gas collection and control system (GCCS) at the ISWMF has been installed in phases by several contractors beginning in July 2000, primarily in the Permit #588 and #221 landfills. The objectives of the current GCCS are to control subsurface landfill gas (LFG) migration, control odors and fugitive emissions, provide LFG as fuel to the LFGE facility, and to maintain compliance with the EG Subpart Cf and NESHAP Subpart AAAA requirements referenced in the Facility's Title V Permit.

Per a request by the Virginia Department of Environmental Quality (VDEQ or Department), SCS has prepared this LFG Collection and Control System Optimization Plan to assess and improve the LFG collection in the Solid Waste Permit (SWP) #221 and 498 landfills and mitigate potential for subsurface LFG migration. The Optimization Plan is divided into the following tasks for Each Landfill:

- Review and Evaluation of Existing LFG System Data
- LFG System Design and Construction Considerations
- LFG System Performance Field Activities

The City will be implementing select items discussed herein and providing a report of the results by February 1, 2023 (see Section 4.0 for a summary of action items and deliverables). Subsequent action items, if any, will be accomplished according to milestone dates established by the City and communicated to VDEQ in the Facility's Monthly Progress Reports.

2.0 SOLID WASTE PERMIT #221 LANDFILL

The primary components of LFG system optimization efforts at the Permit #221 Landfill will consist of:

- A review and evaluation of operational data (from historical wellhead monitoring and surface emissions monitoring events);
- A field investigation, including wellfield liquid level measurements, down-well camera investigations, and voluntary surface emissions monitoring; and,
- LFG design considerations and planning.

The following sections elaborate upon the specific action items anticipated for these tasks.

2.1 REVIEW AND EVALUATION OF EXISTING LFG SYSTEM DATA

There are currently 15 vertical extraction wells in the SWP #221 Landfill area. The City will analyze the LFG system operational data that is measured and recorded on a routine basis at these components to identify performance trends and indicators. The data includes the LFG collection system (wellfield) monitoring data that is stored in the SCS e-Tools database, and the surface emissions monitoring (SEM) data recorded during routine monitoring events. The purpose of the data review exercise is to identify opportunities to modify or adjust the system operations to improve LFG collection.

2.1.1 Wellfield Monitoring Data Review

The wellfield data review will be comprised of the analyses and actions described below. The results of these analyses will be presented to technicians to guide ongoing monthly wellfield balancing and tuning events.

Wells with High Methane and Low Vacuum

The production of methane gas (a principal component of LFG) by methanogenic bacteria usually begins after oxygen contained in the refuse is depleted. The LFG which results from anaerobic decomposition is predominantly methane (CH_4) and carbon dioxide (CO_2). For typical sanitary landfill waste disposal units, the methane content of LFG produced within the established (greater than 1 year) waste mass is typically in the range of approximately 55 to 60 percent. The remainder is mostly CO_2 with trace constituents typically comprising less than 1 percent of the total gas volume. The presence of oxygen and nitrogen in LFG is attributed to infiltration of ambient air into the LFG extraction components through the surface of the landfill since the microbial decomposition of organic waste under anaerobic conditions does not produce oxygen and nitrogen directly.

However, in waste disposal units where the age of the buried wastes is greater than 40 years, as is the case at SWP #221 landfill, the rate and quantity of decomposition gas production declines significantly compared to the rate and quantity of LFG generated in more recently buried wastes. Accordingly, the methane concentration tends to be substantially lower, the oxygen and nitrogen concentrations tend to be substantially greater, and the quantity of LFG collected declines substantially compared to the years immediately after waste placement.

Accordingly, methane concentrations (along with other parameters such as oxygen and nitrogen concentrations, CH_4:CO_2 ratio, etc.) will be evaluated as an indication of whether the applied vacuum at the wellhead and the extraction rate is sufficient to achieve “comprehensive control” of LFG

emissions from the waste mass. A slight reduction in the methane concentration along with introduction of slight oxygen and nitrogen concentrations due to dilution from air intrusion, is generally accepted as an industry best management practice to demonstrate that the wellfield is balanced or "tuned" to establish a zone-of-influence that extends throughout the waste mass without creating excessive "over-pulling" (which can result in subsurface oxidation). The term "over-pulling" refers to the condition of applying too much vacuum such that the flowrate into the well exceeds the LFG generation rate and results in air intrusion into the waste mass, which is problematic because the landfill is an anaerobic environment. Inversely, high methane concentrations (and little to no oxygen and nitrogen) can be indicative that the vacuum applied at the wellfield is insufficient to extend as far as practicable and may reflect a condition of "under-pulling", which results in greater fugitive LFG emissions. The term "under-pulling" refers to the condition of applying too little vacuum such that the flowrate into the well is less than the LFG generation rate.

High Methane and High Vacuum

The methane content of LFG produced within the waste mass is typically in the range of approximately 55 to 60 percent. However, it is common that methane content is less in older waste disposal units, such as SWP #221. According to typical industry best management practices, proper tuning and balancing of the wellfield causes a slight decrease in the "as-produced" methane concentration at each wellhead, thus, establishing the maximum zone-of-influence coverage while preventing over-pulling that can result in subsurface oxidation. Wellheads that exhibit high methane concentration can indicate that LFG is not being optimally collected and may indicate that under-pulling is occurring. However, when these wellheads exhibit high vacuum that should correlate with increased LFG flowrates, there is a possibility that these extraction components have a partial or total blockage of perforated piping, reducing the zone-of-influence.

Fluctuations in Vacuum

Adjustments in applied vacuum at the individual wellhead induced by the LFG system operator during routine wellfield monitoring and balancing are intended to improve LFG system performance and effectiveness. If gas composition at a wellhead indicates low methane concentrations and high oxygen/nitrogen concentrations, the LFG system operator generally will perform fine tune adjustments to lower the applied vacuum in order to introduce less air into the waste mass, which typically (although not always) reduces the flow and increases the methane concentrations of the LFG being collected at the well. Conversely, if methane concentrations are high and oxygen/nitrogen concentrations are low, the LFG system operator will usually perform fine tune adjustments to increase the applied vacuum, which typically (although not always) increases flow and decreases the methane content of the LFG (due to slight introduction of air into the waste mass). As noted in Section 2.1.1, this balancing or "tuning" of the wellfield is an industry best management practice.

Variations and fluctuations in the vacuum that unintentionally occur to large portions of the system often have detrimental impacts to wellfield operations because these instances result in changes in the gas composition and flowrates. The frequency and magnitude of these fluctuations have an effect on the extent of the zone-of-influence at each LFG extraction components and potentially impose undesirable "over-pulling" and/or "under-pulling." Because the control valve at each well is adjusted according to the vacuum measured in the lateral piping that is connected to the wellhead (referred to as the "available system pressure" or "available vacuum") at the time of the monitoring event, frequent and/or large variations and fluctuations in the vacuum can cause marginal or ineffective wellfield performance and result in a low collection efficiency by either escalating too high (and introducing excessive air intrusion and potential subsurface oxidation) or by decreasing too low (and allowing excessive fugitive emissions while not optimizing the collection efficiency).

Methane-to-Carbon Dioxide Ratios

For typical sanitary landfill waste disposal units the methane content of LFG produced within the waste mass is typically in the range of approximately 55 to 60 percent. Approximately 40 to 45 percent is CO_2 with trace constituents typically comprising less than 1 percent of the total gas volume. For typical sanitary landfill waste disposal units, wells recording LFG content with greater carbon dioxide than methane can be an indication of high subsurface temperatures, which can inhibit methanogenesis (the microbial formation of methane). However, in waste disposal units where the age of the buried wastes is greater than 40 years, such as SWP #221 landfill, the methane-to-carbon dioxide ratio can sometimes be less than 1 due to the fact that the wastes are becoming biochemically stabilized (meaning organic wastes have been more fully decomposed) and the rate of methanogenesis has declined.

Well Failure and Elevated Liquid Levels

The presence of solids and/or liquids within vertical and horizontal LFG extraction components can inhibit and impede the distribution of vacuum into the waste mass and restrict the flow of LFG into the well/collector piping. This results in a smaller zone-of-influence, and the presence of solids or elevated liquids can impair LFG system performance and effectiveness. If solids/liquids completely block the entire length of perforated piping within an individual well, there is typically no flow and the well vacuum will usually immediately equal the available system vacuum. For this exercise, the term "well failure" refers to situations in which the well riser pipe is blocked by solids or semi-solid materials (e.g., siltation or sludge) or the riser pipe has been crimped or sheared. Since liquids can be removed from the well via pumping, elevated liquids within the riser pipe are generally not referred to as "well failure."

The City will review the results of the liquid level measurement event (see Section 2.2.1) and down-well camera investigations (Section 2.2.2), to identify well failure and/or liquid blockages. From there, dewatering pumps may be installed strategically to increase production at wells where it is most needed.

2.1.2 Review of Surface Emissions Monitoring Events

Surface Emission Monitoring (SEM) events are performed at the SWP #221 Landfill on an annual basis. This monitoring is performed in accordance with the site-specific GCCS Design Plan and the facility's air quality Permit. SEM events are required to be conducted in all areas of the Landfill where waste has been placed for a period greater than 5 years. The LFG collection system is required to operate such that the methane concentration is less than 500 ppm above background at the landfill surface. This is the performance standard under the Emissions Guidelines (EG) and the National Emissions Standards for Hazardous Air Pollutants (NESHAP) Subpart AAAA regulations for MSW landfills that indicates conformance with "comprehensive control" of surface LFG emissions. During the SEM events, sampling is performed at approximate 30-meter intervals and where visual observations indicate a potential for elevated concentrations of LFG, such as distressed vegetation, leachate seeps, and surface cover cracks.

The methane concentrations measured at the landfill surface during SEM events serve as the EG/AAAA performance standard because EPA believes they provide a direct correlation to fugitive LFG emissions. These methane concentrations can serve as a good indicator of LFG system performance and effectiveness (although other factors, such as integrity of cover materials, heavily influence the surface methane concentrations). While an isolated instance of elevated methane concentration may not indicate marginal LFG system performance, areas of the landfill surface which

exhibit high methane concentrations on a frequent basis are likely to correlate with areas in which the LFG system is less efficient in collecting the LFG being produced within the waste mass.

The City will review historical SEM reports to identify potential problem-areas where additional LFG wells could be installed to increase LFG collection efficiency.

2.2 LANDFILL GAS SYSTEM DESIGN CONSIDERATIONS

This task focuses on the LFG system design criteria and construction practices to identify potential improvements or alternate procedures. The City will develop a concept drawing for a wellfield expansion based on the following exercises, in addition to the results of historical monitoring data analyses and field observations in Sections 2.1 and 2.2.

2.2.1 Theoretical Zone-of-Influence Representations

Landfill gas vertical extraction well spacing is designed based on the theoretical zone-of-influence, which assumes a maximum radius that each well is capable of exerting a vacuum and extracting landfill gas. The actual zone-of-influence of a well is likely not a perfect circle as there is variability in subsurface conditions, which are unknown. Therefore, the theoretical zone-of-influence is an ideal circular shape dictated by the radius extending from the well as the center point, with the radius governed by certain factors, such as total well depth or depth to liquids. The design theoretical zone-of-influence is derived from the total boring depth (or solid/slotted pipe length) of the well multiplied by an assumed value to calculate the radius-of-influence (ROI). The theoretical zone-of-influence is used for planning and engineering design. It is used to determine the locations and spacing of the vertical LFG extraction wells. Wells are located and spaced to maximize LFG collection efficiency. However, once installed, the theoretical zone-of-influence should be adjusted to reflect subsurface conditions, such as loss of well depth and the depth to liquid level.

One of the most important design considerations is the overlapping of adjacent wells' corresponding zones-of-influence. The key is to design and install wells that minimize uncollected areas between wells whose actual zones-of-influence fail to extract LFG in regions between the wells. Additionally, the design engineering should minimize the amount of overlap of their theoretical zones-of-influence in order to prevent the wells from over-pulling one another and pulling oxygen into the landfill. The City will produce both a theoretical and adjusted zone-of-influence map of the Permit #221 Landfill to assess current coverage, and identify areas that may need additional wells.

2.2.2 Inventory of Wells

Inventory of Raised Wells

The City will review the down-well camera investigation results to identify previously raised wells that may need replacements.

Temporary Removal from Service Practices

In accordance with the provisions of the Facility's Landfill Gas Collection and Control System Design Plan, the Facility temporarily disconnects select wells/collectors for safety reasons. The City will identify the reasoning and timeline for any wells currently removed from service, and either take action to put the wells back online or make a plan to replace them.

2.2.3 Landfill Gas Collection Pipe Configuration and Connections

During the life of a LFG collection system, a discrete section of the LFG collection piping network may develop a leak resulting in loss of vacuum, or incur a restriction due to condensate blockage or debris, or become damaged and need to be isolated and repaired. A standard design criteria is to provide redundant pathways for LFG to be conveyed from the LFG extraction components to the blower/flare station. By configuring "loops" in the LFG collection piping, LFG will continue to be collected from substantial portions of the wellfield and delivered to the blower/flare station during times when a critical section of the piping network is being investigated and repaired/replaced. This design strategy of configuring the LFG collection piping to form a looped circuit allows LFG recovered at points along the circuit to be transported in two or more directions within the piping network. These redundant pathways prevent major flow loss in the case of a single pipe being damaged.

The City will audit the current pipe layout of the LFG collection system using these principles, and decide whether or not it is effective as-is, or if sections should be replaced to better service extraction components. This activity will also involve measurements at sample ports in the header, if available.

2.3 LANDFILL GAS SYSTEM PERFORMANCE FIELD ACTIVITIES

This task will include several field monitoring events to supplement routine wellfield monitoring efforts to enhance the optimization of the LFG system. The field activities that will be conducted as part of this Plan are summarized below:

2.3.1 Liquid Levels at Vertical Landfill Gas Extraction Wells

The City will conduct a liquid level measurement event at the Permit #221 Landfill, establishing total well depth and the depth to liquid in each well.

2.3.2 Down-well Camera Investigations

The City will use a pipe inspection camera to find the depth of the slotted part of the well casing where it transitions to the solid casing visible at the surface, as well as any places where the casing may be damaged or crimped.

2.3.3 Landfill Gas Flowrates

Wellhead flow indicates how much gas can move through the wellhead and into header piping in a certain amount of time. The greater the flowrate, the more productive the wellhead. In cases where wellhead flow is low, the LFG collection system is underperforming. In addition, low flowrates can be indicative of further problems at certain wellheads. Liquid blockages or well failures will result in poor gas flow at the wellheads and indicate that the well is not performing to its full potential.

In some instances, flowrates can be high at the same time that LFG is not fully collected. This can occur when wellhead piping is not large enough to allow for all the LFG extracted by the well to travel through the wellhead and into the header system. This creates a bottleneck and infringes on the well's full capacity, lowering its theoretical zone of influence. This is common in wells that have high flowrates, high methane, and high applied vacuum.

Field technicians will first make sure that all wellhead sample ports are configured such that flow can be measured, then make note of wells with little to no flow and wells with the most flow, in order to identify what areas are the most productive of LFG.

2.3.4 Voluntary Surface Emissions Monitoring Event

Surface Emission Monitoring (SEM) events are conducted yearly over the portion of the landfill footprint that is subject to the EG/AAAA operational provisions. As part of this Plan, the City will conduct a one-time voluntary SEM event specifically looking for rills, areas with visibly limited cover soil, and odorous areas to find "hot spots" of fugitive LFG emissions. As with routine SEM events, the City will use a Flame Ionization Detector (FID) to record methane concentrations at approximately 30 meter intervals. Points at which the methane concentration exceeds the regulatory threshold of 500 ppm are marked in the field with flags before landfill personnel perform corrective actions, however the City will consider areas with elevated methane concentrations that do not exceed this threshold for purposes of designing LFG collection system improvements.

3.0 SOLID WASTE PERMIT #498 LANDFILL

The SWP #498 Landfill is approximately 12.0 acres and is located south of the SWP #221 Landfill and east of the SWP #588 Landfill. At this time, mining in Permit #498 has concluded, and additional LFG system infrastructure to establish a more comprehensive LFGCCS will be installed concurrently with closure activities, in accordance with the Solid Waste Permit. Considerations to be used in the design and execution of the LFGCCS are documented below.

3.1 REVIEW AND EVALUATION OF EXISTING LFG SYSTEM DATA

The majority of the SWP #498 Landfill does not have an active GCCS, due to mining operations which have occurred since waste placement was completed. The current system includes four vertical wells (GW-19, GW-20, GW-21, and GW-22) and a condensate trap (CT-1) at the low point. GW-19, GW-20, and GW-21 are located along the southern slope of the landfill while GW-22 is located along the eastern slope. One 6-inch header line connects these four wells to the main 6-inch header, which is connected to the facility's existing blower/flare station.

Recent field reconnaissance efforts identified that the header pipe serving the four wells had been severed, blocked, or otherwise compromised, such that no distribution of vacuum and no gas collection was occurring. Site personnel have successfully established vacuum at GW-19, and plan to continue repairs to the vacuum supply line to allow gas collection from the other three gas wells. When designing the permanent system these wells will be evaluated to determine if they will be included in the upgraded system or if they will need to be replaced/redrilled.

3.2 LANDFILL GAS SYSTEM DESIGN CONSIDERATIONS

The LFGCCS for the SWP #498 Landfill will be designed to reduce fugitive gas emissions and prevent gas migration offsite. The design criteria are outlined below:

3.2.1 Well Density and Coverage

There are no quantitative criteria contained in the EG regulations for positioning LFG extraction components within a certain distance of each other, either in the vertical plane or the horizontal plane. An industry rule-of-thumb is to achieve a spacing of at least one well per acre within the waste footprint, which works out to be approximately 200-foot spacing (often referred to as 200-foot on-center). This rule-of-thumb, which has existed in the industry for approximately 30 years, assumed that wells were drilled to approximately 75 percent of the waste depth and were not impacted by restrictions, such as pipe deflection and/or elevated liquid levels. Other design considerations related to well spacing and coverage at the Permit 498 Landfill include:

- Spacing shallower wells closer together due to variations of the zone-of-influence based on well depth.
- The general historical practice is avoiding placement of vertical wells in areas where the waste depth is less than approximately 50 feet (i.e., establishing a minimum well depth of approximately 40 feet).
- Providing adequate coverage without placing wells too close together to prevent significant overlap from the zone-of-influence of adjacent wells. This overlap also creates competition for the same LFG, which creates difficulties during wellfield balancing and tuning exercises.

- Considering proposed final closure grades, which will affect waste depth and well depth. In some locations of shallow waste, horizontal collectors may be more appropriate then vertical wells.

- Evaluate the existing infrastructure to determine if it is functional and optimized. Well sounding at the four existing wells will be completed to determine the integrity of each well and the approximate liquid levels within the wells.

- Design the wellfield in accordance with the Theoretical Zone of Influence (see section below)

3.2.2 Theoretical Zone-of-Influence

Per the description in Section 2.2.1, Landfill gas vertical extraction well spacing is designed based on the theoretical zone-of-influence, which assumes a maximum radius that each well is capable of exerting a vacuum and extracting landfill gas. These principles will be used to design vertical well locations in the SWP #498 LFGCCS.

3.2.3 Landfill Gas Collection Pipe Sizing and Evaluation

The LFG collection system header piping provides vacuum to the LFG wellfield components on site. This vacuum is generated at the blower station and then applied throughout the LFG collection system through a network of main header circuits. Applied vacuum incurs head loss over the distance LFG travels through the LFG collection system. Each header pipe diameter incurs a drop in pressure calculated per 100 feet, but generally the smaller the pipe diameter, the greater the head loss. Therefore, LFG collection system header circuits should be sized to allow sufficient available vacuum throughout the system. Other factors that increase head loss include partial liquids blockages, friction loss through 90 degree elbows, air intrusion through cracked headers or broken welds on the header, damaged sample ports, and disconnected flexible piping on an active wellhead.

Site personnel will perform routine inspection of the header infrastructure and note any damage to the LFG collection system piping or wells has occurred. Increasing the diameter of LFG collection piping provides greater flow capacity and reduces the head loss. In designing the LFG infrastructure for an upcoming expansion to yield a more comprehensive system, the appropriate header size will be selected to allow for maximum vacuum collection.

3.2.4 Wellheads

The Permit #498 Landfill has not accepted waste since 2002. Because the waste in the Permit #498 Landfill is older, fine tuning of wellheads is likely necessary to maximize LFG collection. Therefore, a wellhead equipped with a globe valve, such as a 2-inch QED Precision wellhead would improve collection without over-pulling.

3.2.5 Installation of Cover Material

In conjunction with the installation of a LFGCCS, additional cover material will be installed at the Permit #498 Landfill to decrease opportunities for fugitive LFG emissions.

3.3 LANDFILL GAS SYSTEM PERFORMANCE FIELD ACTIVITIES

Once a more comprehensive LFGCCS has been installed, monthly data analysis will be performed to confirm ongoing optimization. Wellhead monitoring in accordance with the EG/AAAA requirements

will be performed on a monthly basis and temperature or pressure exceedances will be noted and addressed via appropriate corrective actions. In addition, data analysis to identify wells with high oxygen, high methane, low flow and various other metrics as described in Section 2.1.1 of this report, will be performed to identify opportunities for improvement.

In addition, surface emissions monitoring will be performed on a quarterly basis throughout the footprint of the Permit 498 Landfill. Results of the surface emissions monitoring can help identify areas of the landfill where there may be poor surface conditions, or where there may be a lack of gas collection coverage.

The landfill will perform routine operations and maintenance activities on the GCCS. The routine and non-routine maintenance and repair activities for the LFG collection and control system should be prioritized to ensure that the system is providing sufficient and consistent vacuum throughout the collection piping network and is eliminate obstructions or restrictions that inhibit LFG flow from the waste mass into the LFG wells/collectors and throughout the conveyance piping network.

3.3.1 Solid Waste Permit #498 Requirements

In accordance with the Solid Waste Permit 498, inspections, maintenance, and monitoring are required at the landfill. Following each of these procedures will help reduce excess gas from areas of the landfill. A summary of these activities is included below:

Cover Inspections

Part of the Facility's inspection program evaluates physical aspects of the site. Inspections include:

- As-needed site inspections following major storm events to determine if excessive erosion or other damage has occurred.

- Quarterly site inspection including; security control devices, erosion damage, cover settlement, subsidence and displacement, vegetative cover, runoff and runoff control measures, leachate collection and removal systems, landfill gas monitoring system, and groundwater monitoring wells.

If deficiencies are noted, the Facility should perform corrective actions including repairs to erosion, reseeding, and any necessary repairs to the leachate and landfill gas systems.

Maintenance

Maintenance of the SWP #498 Landfill is also essential to minimizing fugitive gas emissions. Preventative and corrective maintenance activities to be performed are listed below:

- Maintain cover integrity, including vegetative cover conditions;
- Maintain runoff control structures;
- Maintain leachate collection system including flow meters, valves, pump stations, manholes, seeps, and treatment and disposal; and,
- Maintain Groundwater and LFG Monitoring Systems.

Monitoring

Monitoring of the SWP #498 Landfill includes, or will include, quarterly monitoring of the perimeter boundary probes, monthly monitoring of the landfill gas collection wells, and monitoring of groundwater wells. The frequencies for such monitoring may be modified in accordance with applicable regulatory requirements and/or Permit provisions.

4.0 OBJECTIVES/ACTION ITEMS

In summary, the following objectives and action items should be completed by the Facility by February 1, 2023.

4.1 PERMIT #221 LANDFILL

- A dedicated LFG wellfield balancing and tuning event by an experienced field technician to optimize the performance at each individual wellhead for the quality and quantity of LFG removal;
- A wellfield liquid level measurement and down-well camera event;
- A voluntary SEM event to identify fugitive emissions "hot spots";
- Development of a theoretical and an adjusted ROI map of the current state of the LFGCCS;
- A concept design for a LFG system infrastructure expansion and vertical well replacement ("redrills") based on the data collected and reviewed;

After these initial efforts are completed, the City will continue to perform ongoing LFGCCS analysis via Surface Emissions Monitoring, Wellhead Monitoring, Wellfield Sounding, and various other inspections of the GCCS system. When issues are identified, the City will make repairs and improvements to the system.

4.2 PERMIT #498 LANDFILL

- Wells GW-18, GW-19, and GW-20 have wellheads and should be capable to function in a manner to enable LFG extraction, once vacuum is applied upon connection to the LFG collection piping network. Site personnel or designated contractor should make repairs to the existing main header pipe that connects these three wells to the main system header. Once connected, monthly wellhead monitoring in accordance with the EG/AAAA standards should be implemented.
- Wells GW-18, GW-19, and GW-20 should be inspected and "sounded" (i.e., record total depth and liquid level measurements) to determine if they should be utilized in the design of an LFG system expansion within this waste disposal unit;
- Complete design drawings for a permanent GCCS throughout the entire footprint of the 498 landfill. These drawings will take into account the design considerations outlined above in order to optimize gas collection and control for the 498 landfill

Once design plans are completed for the LFG expansion project, these action items can proceed as an extension of this Optimization Plan (***after*** the February 1, 2023 deadline).

- Construction and installation of a more comprehensive permanent LFGCCS based on the design completed.
- Perform inspections, maintenance, and monitoring in accordance with the Solid Waste Permit Conditions.

- Perform ongoing LFGCCS analysis via Surface Emissions Monitoring, Wellhead Monitoring, Wellfield Sounding, and various other inspections of the GCCS system. When issues are identified, the City will make repairs and improvements to the system.