Bridgeton Landfill
13570 St. Charles Rock Road
Bridgeton, MO 63044

Data Evaluation of the Subsurface Smoldering Event at the Bridgeton Landfill

For The

Solid Waste Management Program
Division of Environmental Quality
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, MO 65102

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REPORT

As requested, the latest data set related to an ongoing subsurface smoldering event or SSE occurring at the Bridgeton Sanitary Landfill (Bridgeton Landfill) submitted on May 20, 2013 including update reports through June 11, 2013 by Republic Services to the Missouri Department of Natural Resources (DNR) along with other associated information provided by DNR was analyzed. This letter report provides comments, suggestions, and recommendations to DNR to assist the agency in overseeing and monitoring the SSE at this inactive sanitary landfill.

EVALUATION

The following evaluation is based on personal knowledge and experience gained from previous heating, smoldering, fire and “other” reported landfill events in the United States and abroad, DNR documents, Bridgeton Landfill documents, site visits, site photographs and videos, prior landfill fire investigations, fire science, suppression methodologies and tactics, state and federal regulatory codes and regulations, available landfill data, waste management practices, and twenty years of waste management oversight. This report and opinions are limited by time constraints and I reserve the right to modify my opinion if new information, additional data, research, transcripts, or publications become available. The accuracy and the validity of the landfill data are assumed.

Mr. Thalhamer’s observations and opinions concerning the Bridgeton Sanitary Landfill smoldering fire and/or heating event are provided to the DNR. Mr. Thalhamer prepared this report and his seal as a Registered Professional Civil Engineer in the State of California is affixed below.

Todd Thalhamer, P.E. No. C055197

PURPOSE

The purpose of this evaluation is to: (1) provide an analysis of the submitted reports, data, and information on the subsurface smoldering event at the Bridgeton Landfill; (2) render opinions and comments on data with regards to the facility's response; and (3) provide recommendations on the next set of actions.

TASKS

The following tasks were provided by DNR or identified by Mr. Thalhamer during his evaluation:

- Review the Bridgeton Landfill correspondence and data concerning the subsurface smoldering event at the Bridgeton Landfill;
- Provide an analysis and comments on data submitted by Bridgeton Landfill;
- Evaluate and provide comments on data gaps in the submitted information, if any;
- Develop a set of preliminary sentry criteria for a North Quarry Isolation Break;
- Provide technical assistance to DNR and the local fire service; and
- Provide conclusions and recommendations on the overall event.

In order to complete the above tasks, the following documents were provided by DNR to Mr. Thalhamer for review:

- Bridgeton Sanitary Landfill - Monthly Data Submittals - May 20, 2013
- Bridgeton Sanitary Landfill - Daily Flare Monitoring Data - Aug 2012 - April 2013
- Bridgeton Sanitary Landfill - Weekly Data Submittal - May 14, 2013
- Bridgeton Sanitary Landfill – Weekly Data Submittal – June 11, 2013
- Leachate Level in Leachate Collection Sump Raw Data – June 11, 2013.
- Temperature Monitoring Probe Raw Data – June 11, 2013.
- Gas Interceptor Well Reading Raw Data – June 11, 2013.
- Bridgeton Sanitary Landfill - Compiled Gas Well Data through April 30, 2013
- Bridgeton Sanitary Landfill - Compiled Leachate Levels through May 13, 2013
- Bridgeton Sanitary Landfill - Compiled Gas Interceptor Well Data through May 19, 2013
- Temporary Cap and Integrity System Plan, Bridgeton Landfill, Revised May 10, 2013
- New Source Performance Standards (NSPS) Semi-Annual Reports;
- Summary Report - Bridgeton Landfill Subsurface Oxidation Event, Dated April 3, 2012, by SCS Engineers;
- First Agreed Order of Preliminary Injunction (Order), Case No. 13SL-CC01088, Filed May 13, 2013;
- Site Visits on June 14, 2012 and August 22, 2012;
- DNR web site http://www.dnr.mo.gov/bridgeton/index.html; and
- General Correspondence and Other Documents, DNR, Various Dates.

LIMITATIONS

This report has been prepared for the DNR. Mr. Thalhamer bases the following discussions and opinions concerning this event on information supplied by DNR and prior smoldering and heating events. The accuracy and the validity of the data and reports provided to Mr. Thalhamer are assumed. This report is intended for the sole use of DNR's staff who is familiar with the site operations, permits, and state policy concerning the landfill.

DISCLAIMER

This report to DNR was produced under a contract between Mr. Thalhamer and DNR. The statements and conclusions contained in this report are those of Mr. Thalhamer and not necessarily those of CalRecycle, its employees, or the State of California and should not be cited or quoted as official policy or direction. The State of California makes no warranty, expressed or implied, and assumes no liability for the information contained in the succeeding text. Any mention of commercial products or processes shall not be construed as an endorsement of such products or processes.

BACKGROUND

The West Lake Landfill site is located in Bridgeton, Missouri. The site is listed on the U.S. Environmental Protection Agency's (EPA), Superfund National Priorities List due to the disposal of radiological wastes. The Bridgton Sanitary Landfill site sits within the West Lake Landfill site and is inactive and no longer accepting waste for disposal. The West Lake Landfill site has four distinct units

- Operable Unit 1 – Radiologically contaminated wastes
- Operable Unit 2 – Mixture of debris
- Bridgeton Sanitary Landfill
- Demolition Landfill

The U.S. EPA oversees the first two units. The Bridgeton Sanitary Landfill, owned by Bridgeton Landfill LLC whose parent company is Republic Services, Inc., is overseen by DNR. The Bridgeton Sanitary Landfill has two distinct areas known as the North and South Quarries which are separated by a narrow area referred to as the "neck". This neck area lies between and joins the two quarries.

Republic Services, Inc., the parent company of Bridgeton Sanitary Landfill, LLC, has experience in managing subsurface smoldering or heating events within the past five years. As disclosed in the company's U.S. Securities and Exchange Commission filing for the 12 months ended December 31, 2012, they note that in September 2009, Republic Services II, LLC entered into Final Findings and Orders with the Ohio Environmental Protection Agency that require the company to implement a comprehensive operation and maintenance program to manage the remediation area at the Countywide Recycling and Disposal Facility. In August 2010, Congress Development Company agreed with the State of Illinois to have a Final Consent Order entered by the Circuit Court of Illinois, Cook County. Pursuant to the Final Order, the company agreed to continue to implement certain remedial activities at the Congress Landfill. The report states that during 2012, the company encountered certain environmental issues at a closed Missouri landfill. The financial filing indicates they believe the reasonably possible range of loss for remediation costs is $50 million to $240 million. Additionally, the Middle Point Landfill near Murfreesboro, Tennessee has experienced a subsurface smoldering or heating event as this facility is cited by the company as the source for the gas interceptor well plan, and has settled a case with the US Environmental Protection Agency and the local air district on a number of smoldering events that occurred at the Forward Landfill near Stockton, California in 2008.

SITE VISITS

On June 6, 2012, and on August 22, 2012, I was requested by DNR to observe the site conditions at the Bridgeton Landfill. Upon my arrival on June 6, 2012, DNR staff, Timothy D. Stark, PhD, P.E., another DNR landfill fire and slope stability consultant and I met with the landfill operators and their consultants. The operator provided a brief update on the issues and current conditions. The operator noted the odor issues and explained the facility was upgrading its flare capacity and installing a heat exchanger. The landfill manager also noted the flame arrestor was experiencing weekly maintenance issues due to a "tar-soot" like substance that was impacting the flame arrestor.

From the field observations, I determined the facility was experiencing two distinct areas of subsidence, the west bowl and east bowl. A geomembrane cover had been installed in both areas in an attempt to control the odors; however the geomembrane liners were being inflated by excessive landfill gas. During my site visit, I observed two strong, distinct odors. During the visit I also noted a number of fissures in the soil cover and observed bubbling leachate in the west bowl area. Witnessing the inflated geomembrane and fissures and personally experiencing the rancid, putrid odors, I concluded the current landfill gas collection and control system was not capable of meeting its design goal. I provided the following guidance and recommendations:

- Repair and cover all fissures in the areas around settlement;
- Evaluate settlement daily, look for fissures;
- Hydrate the soil cover to repair and prevent fissures;
- Relocate the two power poles in the west bowl;
- Implement an incident command system and develop an incident action plan;
- Collect air samples of the odor;
    - Evaluate the odors for toxic and/or hazardous gases;

  - o Collect a minimum of three air samples in a summa canister from each odor location;
  - o Implement an air sampling plan as designed by an industrial hygienist; and
- Reduce oxygen to less than 1% on all interior gas extraction wells.

On August 22, 2012, Dr. Stark and I again met with DNR and the landfill operators to assess the current situation. The operators discussed the odor issues and stated they had expended a significant amount of resources to control off-site emissions. The facility also stated they made significant upgrades to the landfill engineering control systems and cover. Based on the field observations, the facility was still experiencing two distinct areas of subsidence. Both settlement areas had increased and some of the gas temperatures had increased to over 200°F. While the odors and fissures were noticeably reduced from the June site visit, the smoldering subsurface event had expanded in all directions and most concerning was the movement north towards the narrow portion (i.e., "neck") between the North and South Quarries and then potentially on to the Operable Unit 1. Appendix A contains both Observation Reports.

GENERAL DISCUSSION

Landfill Fires

Based on personal experience, most municipal solid waste (MSW) landfills at some time during their operational span, experience a surface and/or subsurface fire. Some landfills may experience working face fires while others may have subsurface smoldering event(s) or some may have both. Although smoldering events are more common during late spring and fall in the United States with the barometric changes (Thalhamer 2011), an uncovered working face can be ignited by arson, a hot load, chemical reaction, or equipment at any time. Most of the incidents are small and are considered "operational fires." These fires are usually handled by the operating facility and are noted in the facility log, if required by regulations. Other fires may need support from the local fire department and may be evaluated by the local or state regulatory agencies. Seldom do these operational fires draw much attention besides a short news article in the local newspaper. Only about one to two percent of the reported landfill fires require specialized response, expertise, additional environmental oversight, and/or repair of the landfill's engineering control systems. Of this subset only about 10% become a large-scale environmental problem (Thalhamer 2011).

Types of Landfill Fires

The most common types of fires occur at the surface, where fuel and oxygen are abundant. These fires can burn between the surface and up to five feet below ground surface. The other event develops below ground and can extend down past 100 feet depending on geological and site conditions.

Understanding fire types is paramount to prevention. Most people have a defined concept of fire. However, when one examines how a landfill fire starts, you need to evaluate the environmental circumstances and have a clear definition of combustion (or fire). Combustion is an exothermic oxidation reaction that generates detectable heat and light (DeHann 2007). One should note that the definition of light is not limited to our visible spectrum. For example, when they burn both hydrogen and methanol fires are not visible to the human eye. In order for combustion to occur the following conditions must be present:

- A combustible fuel;
- An oxidizer (such as oxygen in air) must be available in sufficient quantity;
- Energy as some means of ignition (e.g., heat) must be applied; and
- The fuel and oxidizer must interact in a self-sustaining chain reaction.

The first three can be described as the fire triangle but the fourth must be present if the fire is to be self-sustaining (DeHann 2007). In the landfill environment, combustion can be broken down into two types: 1) flaming and 2) smoldering (DeHann 2007 and Martin et al. 2011). While the first type of combustion is usually obvious, except for the visible light spectrum circumstances, the second type of combustion can cause investigative errors or lead to creative terminology to avoid using the term fire (Thalhamer 2011). Unless one excavates a smoldering fire, the signs of a smoldering fire may be obscured by the environmental conditions of a landfill (Martin et al. 2011). As depicted in Photo 1, the signs of a smoldering fire are not always readily apparent to the human eye. During a San Francisco landfill fire investigation, a vent temperature of 480°F was measured with no visible signs of smoke. Landfill operations can either increase or decrease the potential for a smoldering event based upon how the waste is covered, compacted, and controlled. These operational decisions will determine whether or not a smoldering fire will ignite and through control of the available oxygen, through compaction, adequate cover, waste profiling, and gas control, the likelihood of having a smoldering fire will diminish. The most common causes of a smoldering fire are the overdrawing of a gas collection system (LandTec 2005a, LandTech 2005b). Smoldering fires can also start from actions that allow oxygen to enter the waste prism such as fissures, rapid settlement, an abandoned gravel access road, poorly compacted or inadequate interim covers, uncapped borings, passive venting systems, or other poorly installed environmental

Photo 1. Smoldering Landfill Fire at Candlestick State Park (Source Todd Thalhamer, 2006).

controls. The events usually occur on slopes, at changes in slopes, areas with poor interim cover and/or areas within the influence of the gas extraction system.

The waste mass tends to oxidize around or near a surface feature that allows oxygen to enter the waste mass. Most subsurface fires in gas collection systems are detected by elevated temperatures at the well head or by the detection of carbon monoxide (CO) or soot in the gas collection system (LandTech 2005a). These fires are more likely to burn slowly without visible flame or large quantities of smoke and are characterized by rapid oxidation of organic waste. At times, this combustion/oxidation will go undetected until a sinkhole or smoke appears. Normally, an individual will not see actual flame or dark, black smoke during smoldering events unless the subsurface fire is excavated or exposed to the atmosphere.

Based on several of my training seminars and other discussions with landfill operators and consultants, there are several misconceptions about smoldering combustion. Over the years, the general belief in the industry has been that smoldering fires need oxygen above 15% by volume and temperatures above 450°F to 480°F to propagate. While the ignition temperature of wood is around 480°F (Babaruskas 2003a), it has been documented that temperatures as low as 170° F for time periods of several months to several years have ignited wood (Babaruskas 2003b; Babaruskas 2003c). Additionally, smoldering fires will propagate at oxygen concentrations below 3% (DeHann 2007) and have been documented to persist within a solid waste landfill between 212°F and 250°F (Ettala et al. 1996). Recognition of these facts is critical to understanding the potential consequences of overdrawing a landfill gas extraction system and the need to operate a gas extraction system in compliance with state and federal regulations.

Detecting Landfill Fires

To understand how a landfill fire occurs, one must understand that both chemical and biological reactions occur in the typical landfill environment from the first day the waste is disposed. Normally, landfills produce gas that is composed of a mixture of hundreds of different gases. By volume, landfill gas typically contains 45% to 60% methane (CH_4) and 40% to 60% carbon dioxide (CO_2). Landfill gas also includes small amounts of nitrogen, oxygen, ammonia, sulfides, hydrogen, carbon monoxide, and nonmethane organic compounds (NMOCs), such as trichloroethylene, benzene, and vinyl chloride (ATSDR 2001).

The bacteria, both aerobic and anaerobic, present in organic matter require water to biologically breakdown organic matter. As anaerobic bacteria biodegrades the organic material, heat (Δt) is produced along with degraded organic matter, methane (CH_4), carbon dioxide (CO_2) and other gases as shown by the following equation.

$$\text{Organic Matter (solid waste)} + H_20 \xrightarrow[\Delta t]{\text{Bacteria}} \text{Biodegraded organic matter} + CH_4 + CO_2 + \text{Other gases}$$

In spontaneous combustion, waste material is heated by biological decomposition which in turn causes chemical oxidation of organic matter. The spontaneous combustion in waste is analogous to chemical self-heating of hay piles and similar to fires in oxygen-limiting silos. This process involves three separate reactions: (1) decomposition; (2) chemical oxidation; (3) Maillard Reaction (US Fire Administration 1998; Ontario Ministry of Agriculture, Food, and Rural Affairs 1993). The Maillard Reaction is a nonenzymatic reaction between sugars and proteins that occurs upon heating and that produces browning. The resulting heat from these three reactions causes the material to reach the point of ignition. This rapid oxidation in a municipal or construction/wood waste facility is directly related to the type of bacteria and amount of moisture and oxygen present in the fill. With the correct conditions present, spontaneous combustion can occur in household trash and construction debris. This type of smoldering combustion will produce excessive amounts of carbon monoxide (CO) and other trace toxic gases.

A municipal solid waste landfill will undergo four phases during the waste decomposition cycle (Martin et al. 2011; ATSDR 2001; Haarstrick et al. 2001; Bogner et al. 1996; Barlaz et al. 1989). The first phase begins after waste placement and continues until the aerobic bacteria consume the oxygen. During the second phase, the anaerobic bacteria convert the organic compounds into organic acids and begin to produce significant quantities of landfill gas.

The landfill gas produced during this phase consists of 20% to 60% CO_2, 10% to 20% hydrogen (H_2), and 50% to 30% nitrogen (N_2). In the third phase, CH_4 production begins and the composition of the landfill gas changes to 40% to 60% CO_2 and 45% to 60% CH_4 with < 1% hydrogen (Martin et al. 2011). During the last phase, the gas concentrations peak and remain steady and will range from 50% to 70% CH_4, and from 30% to 50%. CO_2. This biological transition time ranges from 180 to 500 days depending on actual landfill conditions (Farquhar 1973).

The above reactions are dependent on a number of factors at a facility including: waste composition, moisture content, temperature, oxygen, compaction, landfill operations, leachate recirculation, LFG operations, cover properties, barometric pressures, waste cell construction, and other environmental issues. If a landfill's gas control system is not properly adjusted, excess oxygen can be introduced into the waste cell or if the cover is not properly compacted, a temporary soil cover may allow oxygen to enter the cell. A facility may also unknowingly accept a reactive waste. These types of factors can negatively impact the biological process or directly cause a landfill fire. The key to preventing a landfill fire is continuous monitoring and management of the facility.

In 2001, after working with US EPA, Region IX, and other state environmental agencies on the Hunter's Point Landfill fire in San Francisco, California, it was requested that I develop guidance on detecting and suppressing smoldering fires. From my field experience investigating landfill fires and research on landfill fires, I authored a white paper to define the parameters of a smoldering fire (Thalhamer 2011). The white paper was written to provide general guidance to local and state agencies engaged in evaluating these types of incidents. At the time this white paper was written, there was limited guidance available to the industry and regulatory community on smoldering events. The following parameters were developed to evaluate if a smoldering fire is present:

- Increased temperatures in the landfill gas control systems and waste mass;
- Temperatures over 170°F;
- Decreased methane production;
- Elevated concentrations of volatile and semi-volatile organic compounds;
- Elevated carbon monoxide concentrations above 1,000 ppm;
- Smoldering odors or smoke emanating from the landfill;
- Flame and/or combustion residue in the landfill gas control systems; and/or
- Unusually rapid and excessive landfill settlement.

While one parameter, such as CO in excess of 1,000 ppm can be sufficient to determine if a smoldering landfill fire is present, one should use multiple parameters to confirm a smoldering event is occurring. The more confirmed parameters mean less likelihood of false smoldering events. Smoldering combustion has been shown to produce carbon monoxide concentration of 1 to 10% (10,000 ppm to 100,000 ppm), where flaming combustion generally produces less than 0.02 % (200 ppm) CO (DeHann 2007). Other landfill fire literature uses CO concentrations as low as a few parts per million to 100 ppm as a possible positive indicator of a landfill fire (Waste Age 1984; Environment Agency 2004; Industry Code of Practice 2008). Based on other landfill fire evaluations and case studies, other processes may produce CO at these concentrations (Martin et al. 2011) and therefore one should use the higher CO concentration of greater than 1,000 ppm as the threshold value to prevent false assumptions. The guideline I developed basically states if CO is detected over 1,000 ppm a smoldering event is likely to be present. Typically, CO from active smoldering events range from 1,000 to 9,000 ppm and have exceeded 28,000 ppm as the smoldering event breaks through the surface. Just as in using landfill temperatures to evaluate the smoldering event, CO readings should also be examined over time and trend plots developed. CO like temperatures from a smoldering event will reside in the waste prism for an extended amount of time. While elevated temperatures can remain for over 18 to 24 months and longer, CO concentrations will begin to drop within 1 to 6 months as the smoldering event diminishes. Since the waste is not homogeneous and other waste management practices (e.g., compaction, leachate recirculation, types of waste, daily cover, waste cell size, access roads, gas extraction collection and rates, etc.) vary in the landfill, some monitoring points will not show high CO while others directly adjacent will show high CO. One must examine the entire landfill and the monitoring points on a continuous timeline to draw any conclusions.

It is also important to understand that waste temperatures control the quality and quantity of landfill gas generated (Hanson et al. 2009; Crutcher and Rover 1982) and are an important factor in determining if landfill fire is present. Some published literature (Meima et al. 2008) and federal regulations (NSPS) consider temperatures over 131°F (US EPA 1999) as an indication of a heating event.

For this report:

- Temperatures over 165°F will be used as an indicator of a heating event and not as confirmation of a fire;
- Once temperatures exceed 176°F, methane production typically stops (Martin et al 2011; Thalhamer 2011) and further evaluation is warranted;
- Between 212°F and 250°F subsurface smoldering will persist in an MSW landfill as documented in a previous study (Ettala et al. 1996);
- If temperatures are reproducible and above 300°F in an MSW landfill, this temperature confirms a fire based on my experience; and
- Should landfill temperatures be below 300°F, then multiple parameters such as carbon monoxide readings should be collected, as confirmatory evidence of a fire.

Heat generated from a smoldering fire or reaction can damage the environmental control systems of landfills. Research has shown sustained temperatures as low as 185°F have impacted the service life and integrity of landfill gas extraction systems, leachate control systems, covers, and materials in composite liner systems (Rowe et al. 2010). Some PVC piping will fail as low as 165°F (SWANA, 1997).

In addition to heat, other combustion by-products including gases, vapors, and smoke will be produced by a landfill fire. These by-products can also be used to evaluate whether a landfill fire is present. A landfill fire will emit air pollutants including, but not limited to, particulate matter, carbon monoxide, volatile organic compounds (VOCs) (e.g., benzene, and methyl-ethyl ketone), Polycyclic Aromatic Hydrocarbons (PAHs), semi volatile organic compounds (SVOCs), chlorinated dibenzo-p-dioxins, and chlorodibenzofurans, that can pose safety and environmental health threats (Martin et al. 2011; Stark et al. 2012; Szczygielski 2008; Bates 2004; Nammari et al. 2004; US EPA 2002; ATSDR 2001; Junod 1976).

Smoldering combustion at waste facilities has also been shown to increase the concentration in some VOCs (e.g., benzene and methyl-ethyl ketone) one to two orders in magnitude (U.S. EPA 1991; Martin 2012 et al; Paker et al 2002). In general, gas concentrations of some VOCs emissions from Subtitle D landfills double with every 18°F of temperature increase (ATSDR 2001). Benzene and methyl-ethyl ketone are the two compounds that have consistently been found at elevated levels during landfill fire investigations. These compounds can be used to examine the likelihood of a landfill fire in conjunction with other parameters (Thalhamer 2011). Benzene has also been shown to be the largest emission compound (979.75 mg/kg) when household waste is burned (U.S. EPA 2002). Benzene has an odor threshold of 840 ppb and is described as a paint-thinner-like odor (ATSDR 2001).

Of the smoldering events that I have evaluated, all have pre-indicators in the landfill gas control data. This data involves decreases and increases in landfill gases and temperatures. While the changes in the data might not initially be significant, when a trend analysis is performed over a significant period of time, cautionary trends can be observed. The operator should closely monitor data for increasing oxygen and temperatures over time. The landfill operator should make adjustments to their gas collection and control system both per the NSPS, Title 40 Code of Federal Regulations (CFR) Section 60.752(b)(2)(ii), and best management practices when gas data indicates:

- Extraction system temperatures above 131°F (55°C);
- Excessive oxygen in gas collection wells >5%; or
- Excessive nitrogen in gas collection wells >20%.

The landfill operator should make additional adjustments to the landfill gas collection system and begin a fire evaluation when gas well data indicates the following trends:

- Upward temperature trend in gas collection wells >3 to 5°F (37 to 41°C) in less than one week;
- Dramatic downward trends in methane concentrations in less than one week;
- Methane concentrations dropping 20% within one month;
- Excessive balance gas (primarily nitrogen (N_2)) in the gas collection wells within one month;
- Orders of magnitude increases in benzene and/or methyl ethyl ketone (MEK) concentrations; or

The operator should take additional proactive steps in when any of the following conditions occur:

- The melting, collapsing, or pinching of gas collection wells or leachate collection systems;
- Methane concentrations dropping below 30% in a short period;
- Temperatures exceeding 165°F;
- Spike in nuisance odors;
- Change in gas composition;
- Increase in gas pressure and flow;
- Unusual rate of settlement;
- Increase leachate volume and leachate outbreaks

Industry Standard Operating Procedures

The true test of laws, regulations, and policies is "how the industry accounts for them through their standard operating procedures (SOP)". By evaluating SOPs and design manuals for landfill gas management, one can understand how the industry meets the laws and regulations to properly control landfill odors, gas migration, and prevent landfill fires. These SOPs can also provide guidance on managing smoldering events and best management practices. The following SOPs and design documents were consulted on gas collection and prevention of landfill fires:

- Landfill Gas Management Standard Operating Procedures, prepared by Republic Services, Inc., dated May 1, 2009;
- Operations Manual for the Landfill Gas Collection and Control System at the Washington County Landfill, Washington, Utah, prepared by Cornerstone dated October 2011;
- Brawley Solid Waste Site Landfill Gas Collection and Control System, Operation and Maintenance Plan, prepared by Geosyntec Consultants, dated April 2012;
- Landfill Gas Operation and Maintenance, Manual of Practice, Solid Waste Association of North America (SWANA), dated March 1997;
- Field Procedures Handbook for the Operation of Landfill Biogas Systems, prepared by the International Solid Waste Association (ISWA), Working Group of Sanitary Landfills, dated winter 2005;
- Landfill Gas Management Facilities Design Guidelines, prepared by Conestoga-Rovers and Associates, Ministry of the Environment (ME), British Columbia (BC), dated March 2010;
- Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities, prepared by U.S. Environmental Protection Agency (US EPA), dated September 2005;
- Landfill Off-Gas Collection and Treatment Systems, Engineering Manual, prepared by U.S. Army Corps of Engineers (USACE), dated May 2008;and
- Higher Operating Value Demonstrations and Response to Comments, prepared by Ohio Environmental Protection Agency (Ohio EPA), dated December 2010.

As expected the procedures to detect, evaluate, and mitigate a landfill fire vary among the documents; however, there are a number of common criteria. Table 1 is shown to simplify information on landfill operations and prevention of fires.

Table 1. General Parameters for Landfill Operations and Prevention of Fires

Document	Recommended /Allowed Oxygen Intrusion	Normal and Action Methane Range	Temperature Action Range	Carbon Monoxide (CO) Action Level	Symptoms/Indications of a Smoldering Event or Comments
Republic	<1% typical <2% Max	Normal Arid 43-48% Non Arid 48-52% Action Level <48%	>120°F Temperature exceeding an est. variance >20% from historic temp	>300 ppm	• Dramatic localized landfill settlement • Charred or cracked surface cover • Stressed or dead vegetation • Smoke or smoky odor • Drastic or unusual increase in flowing gas temperature • Abnormal discoloration of a wellhead/riser
Cornerstone	Hold at 0.2% Never allowed to exceed 1%	Normal 50% to 70% Action Level <47% Extreme well stress <40%	Should not exceed 130°F	CO near a subsurface fire may vary from 100 to 1,000 ppm	• Smoke emitting from landfill cover openings • Extraordinary and rapid subsidence of a localized landfill area • Presence of carbon monoxide in the extracted LFG.
Geosyntec	<5%	*No Information*	>140°F	>1,000 ppm	• Gas temperatures exceeding 167°F and CO greater than 1,000 ppm are indicators of a potential fire
SWANA	Ideal 0 to 0.5% <1%	Normal 45 to 58%	Typical range is 60ºF to 125°F Action 125ºF to 140°F	Trace <25 ppm	• CO is an indicator of the possible presence of a subsurface fire • 165°F is the temperature limit for PVC • CO is a byproduct of incomplete combustion and hence an indicator of a possible subsurface fire • Landfill fire may be tested by monitoring CO • Best way to treat a LFG fire is to starve the fire of oxygen • High residual N_2 levels may indicate a landfill fire • If oxygen is sufficiently high (around 10% or greater) the LFG can be in the combustible range within the collection piping
ISWA	3 to 4%	Normal 35 to 50%	*No Information*	*No Information*	• Operators should also periodically monitor for the presence of high levels of residual nitrogen since

					this could indicate conditions that could spark a landfill fire • Operation of extraction wells at temperatures greater than 145°F may result in the weakening and possible collapse of thermoplastic well casings.
ME-BC	2.0% Shall not exceed 2.5%	Normal 30 to 60%	Action Level >140°F	>1,000 ppm	• Active LFG collection areas that are overdrawn and may have too much available vacuum being applied to the well field • Monitoring data shows high O_2, high CO (> 1,000 ppm), and high LFG temperature (> 140°F) • Accelerated landfill settlement in localized areas • Impacted infrastructure such as melted wellheads or piping • Smoke, odor, or residue • A landfill fire may be officially confirmed through the use of field equipment monitoring and laboratory testing for incomplete combustion compounds such as CO. • While an effectively-operated LFG management system can be a fire prevention system, inappropriate operations can pose a fire risk
US EPA	Typical 0.1 to 1% Max. <5%	Normal 45 to 60%	Action Level >130°F	0 to 2,000 ppm	• Landfill fires can occur from the excessive influx of ambient air into the landfill wastes. • Underground landfill fires generally occur when ambient air is drawn into the landfill. • There must be data demonstrating that the elevated parameter(s) does not cause fires or significantly inhibit anaerobic decomposition of the waste (40 CFR §60.753)
USACE	Increasing and exceeds 3.2%	Normal 40-70%	Optimum 85ºF to 105ºF Action Level increasing and exceeds >140°F	>1,000 ppm	• Carbon monoxide can be monitored as an indicator of a landfill fire if the gas temperature begins to rise. • If a fire occurs, fire control may be accomplished through the injection of nitrogen or CO_2 into the landfill to suffocate the fire. The following parameters are evidence of fire within the landfill: • Gas temperature exceeds 167°F • Rapid settlement of the cover system • Carbon monoxide levels are greater than 1,000 ppm

					• Combustion residue is present in the LFG lines
Ohio EPA	<1.5% for and HOV request	Action level >45% for an HOV request	>150°F for an HOV request	<100 ppm for an HOV request	• Excess nitrogen may be associated with the consumption of oxygen. • CO is a good indicator for the presence of fires in a waste mass • Agrees with the National Solid Waste Management Association that when methane content of a wellhead drops below 45%, then "something" adverse is happening

GENERAL FINDINGS

The following general findings are based on a review of the submitted information and my past experience with smoldering and heating events.

Overall, the Bridgeton Landfill is experiencing a significant smoldering fire that has the potential to cause severe environmental impacts to the community from the release of landfill gases and contaminated ground and surface water and damage to the landfill's infrastructure. The recent May data package indicates a general overdraw condition and the settlement continues to expand. The May data also allows for CO levels and temperature data to be compared and examined for trends. To date, the smoldering event has caused and continues to cause damage to the engineered control systems at the Bridgeton Landfill and impacts to the surrounding community from the release of landfill gases. Photos 2, 3, and 4 all show damage to the engineering control systems at the Bridgeton Landfill, MO.

Photo 2. Damage Gas Collection Well (Source: DNR Staff, 2012).

Photo 3. Heat Deterioration of FML, Measured Temp. 128°F, April 2013 (Source: DNR Staff, 2013).

Photo 4. Excessive Landfill Gas and Inflated FML, May 2013 (Source: DNR Staff, 2013).

To initially forecast the movement of the reaction, DNR's consultant, Tim Stark, PhD., P.E., calculated the rate at which the reaction in the South Quarry was expanding towards the North Quarry using data from the March 2013 data package. The initial rate in the South Quarry next to the narrow portion was measured at 2.8 to 3.0 feet per day. Since the initial rate was measured, additional data has indicated the rate is now at 1 to 2 feet per day down from the previously measured rate of 2.8 to 3.0 feet per day (Stark 2013). Note: These rates do not account for the possible influence of the Gas Interceptor Well (GIW) System. In an attempt to contain the smoldering/heating event to the south quarry, the Bridgeton Sanitary Landfill operator activated two lines of gas interceptor wells (i.e., GIW-1 to GIW-13) on April 8, 2013.

To project the approximate location of both the heat and smoldering fronts, selected temperature and carbon monoxide data from TMPs, GIWs, and gas collection wells were analyzed. Some of the selected data is provide in Tables 2 and 3 for reference.

Using temperatures above 165 ºF as the indicator of the heat front, the heat front has passed at least one of the farthest north Temperature Monitoring Probes (TMPs), TMP-1 to TMP-4. TMP data from May to June 2013 indicates the heat front is now at TMP-2 and impacting areas in the "neck" or narrow portion of the landfill. The heat front may also be impacting the North Quarry; however until additional TMPs are installed in the North Quarry and/or additional data is collected over time one can only estimate the location of the heat front.

As to the location of the smoldering front(s) with respect to the "neck" and North and South Quarries, the smoldering event appears to be contained in the South Quarry in between GIW-5 to GIW-6 and GIW-8 and GIW-10. Additional carbon monoxide (CO) data over time is required to determine the most probable location(s). Figure 1 shows the approximate location of the heat front in the neck using TMP data from May to June 2013, while Figure 2 shows the approximate location of the smoldering event(s) based on the CO results from June 7, 2013. Both digital captures are from SCS Engineers, Well Layout Plan, dated January 10, 2013. To better understand the spatial complexity of these reactions, a cross section of the neck was prepared (Stark 2013). Figure 3 shows the approximate location of both the heat and smoldering fronts as it relates to the GIW and TMP systems as of April 2013.

Table 2. Selected Temperature in Gas Interceptor Wells June 2013 (Source: Bridgeton Data, 2013).

Date	**Temperatures in Fahrenheit**				
	GIW-01	GIW-4	GIW-5	GIW-6	GIW-10
6/6/2013	173	155	181	169	179
6/7/2013	176	152	176	173	180
6/8/2013	178	150	177	175	181

Table 3. Draft Carbon Monoxide Results from GIW and GEW Dated June 7, 2013 (Source: Bridgeton Data, 2013).

Date	**Carbon Monoxide in ppm**				
6/7/2013	GIW-1	GIW-4	GIW-5	GIW-6	GIW-10
	2,800	**5,000**	**5,200**	**6,000**	**3,600**

Date	**Carbon Monoxide in ppm**							
6/7/2013	GIW-2	GIW-3	GIW-7	GIW-8	GIW-9	GIW-11	GIW-12	GIW-13
	990	**3200**	**3700**	450	800	1,400	850	1,600

Date	**Carbon Monoxide in ppm**		
6/7/2013	GEW-40	GEW-55	GEW-9
	ND	**ND**	**ND**

GEW = Gas Extraction Well GIW = Gas Interceptor Well

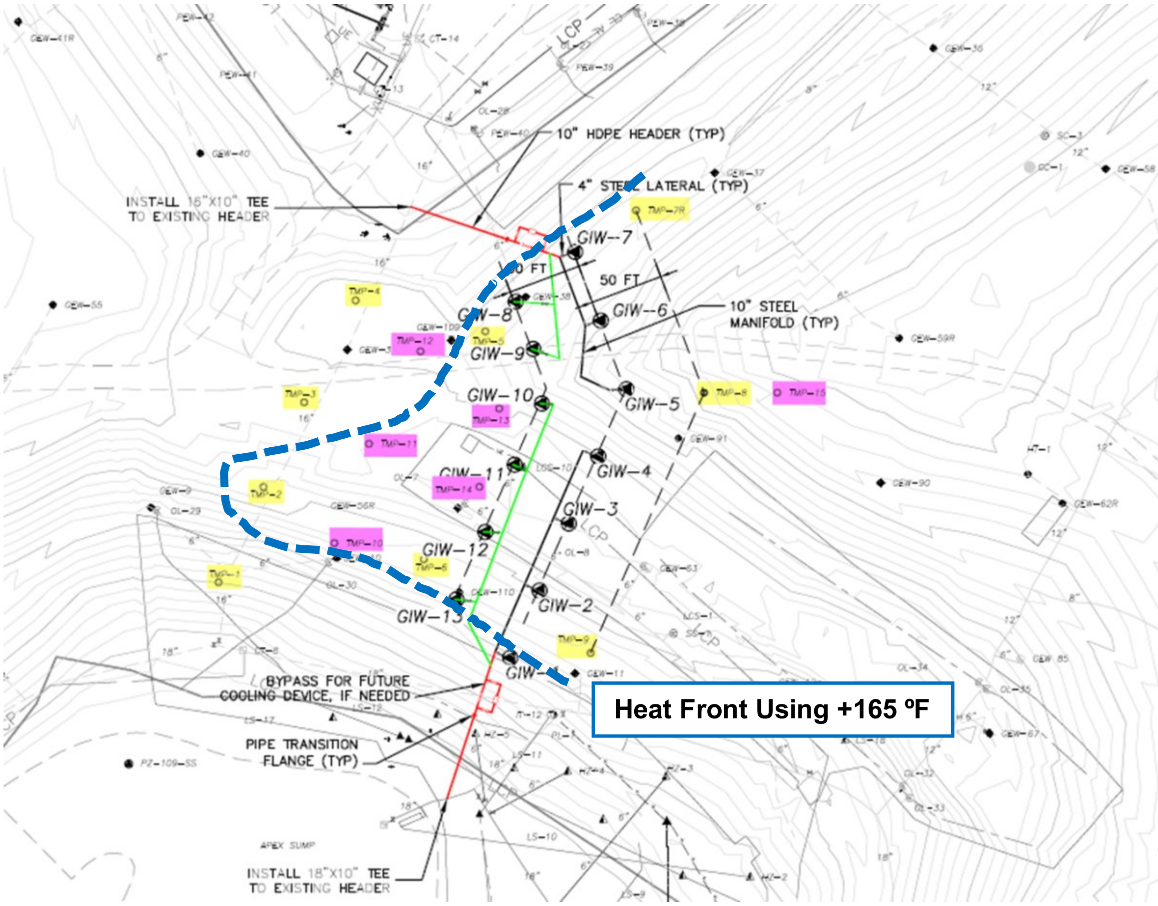

Figure 1. Approximate Location of Heat Front Based 165 ºF at the Bridgeton Landfill, MO (Map Source: SCS Engineers, 2012).

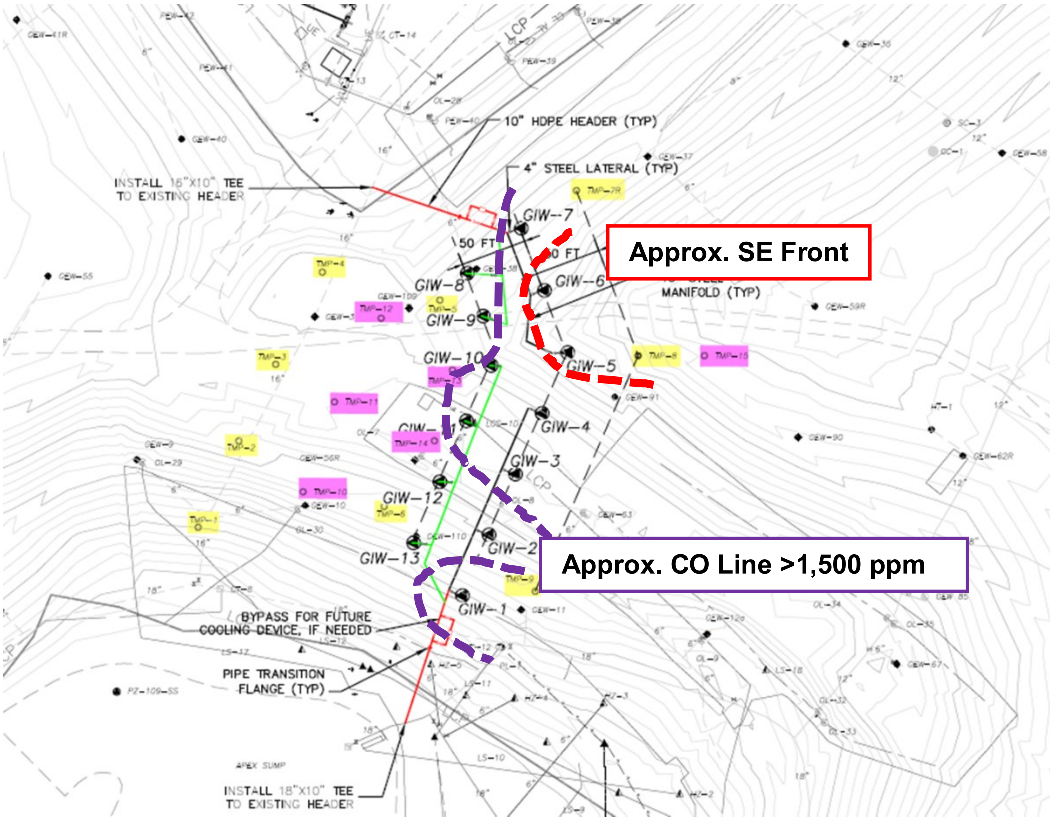

Figure 2. Approximate Area of the Smoldering Event (SE) and CO Line above 1,500 ppm at the Bridgeton Landfill, MO (Map Source: SCS Engineers, 2012).

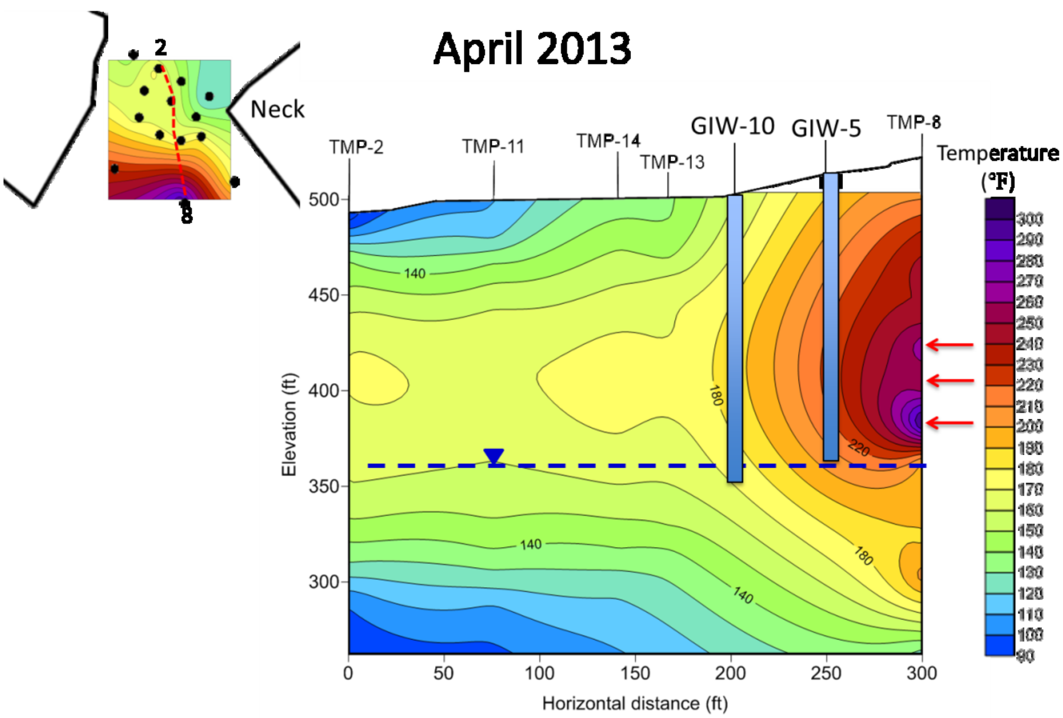

Figure 3. Cross Section of the Estimated Smoldering and Heating Events as of April 2013 at the Bridgeton Landfill, MO (Source: Stark, 2013).

GENERAL COMMENTS AND CONCERNS ON THE LANDFILL DATA

The most recent inlet gas and temperature data provided by SCS Engineers has shown a significant increase in oxygen and nitrogen concentrations beginning in April 2013. Nitrogen was reported to 40% and oxygen was reported to 11%. While the inlet gas to a flare is not regulated by US EPA's NSPS, the data suggest the gas collection system is being "overpulled." NSPS states that each *interior wellhead in a gas collection system shall be operated with a landfill gas temperature less than 55 degrees Celsius (55°C) [131 degrees Fahrenheit (°F)] and with either a nitrogen level less than twenty percent (20%) or an oxygen level less than five percent (5%). The owner or operator may establish a higher operating temperature, nitrogen, or oxygen value at a particular well. A higher operating value demonstration shall show supporting data that the elevated parameter does not cause fires or significantly inhibit anaerobic decomposition by killing methanogens.* This issue has been observed before in SCS Engineers' "*Combined Inlet Oxygen (GEM 2000)"* and in the "*Inlet Gas and Temperature*" graphs. Figure 4 and Figure 5 are highlighted to show the overdraw conditions in the gas collection system. The overdrawn situation has also been documented in the most recent SCS Engineers' *Gas Interceptor Well* data with a concentration of 11.8 % oxygen in GIW-12, dated 5/3/2013, *Laboratory Analysis –Bridgeton Landfill*, and the April 2013 Wellfield Monitoring Data – Bridgeton Landfill. Table 4 provides a summary of the exceedances. Note: Additional information is required to validate the reported oxygen exceedances for the SCS Engineers' *Laboratory Analysis*. The combination of oxygen with argon concentrations is not common in reporting detected oxygen levels in gas extraction wells. Actual laboratory reports are required to confirm the exceedances.

A review of the April 2013, SCS Lab Analysis data and SCS April Wellfield data revealed a number of wells and other collection points have allowed excess oxygen to enter the landfill. Three wells in the North Quarry and twelve wells in the South Quarry are in an overdraw state. With the location of wells GEW-10 and GEW-9 (i.e., in the narrow portion or neck area), immediate re-adjustments should be made to prevent overdraw in this area. Overdraw in this area should be minimized and the oxygen level should not exceed 0.5%.

The Combined Inlet Oxygen data (See Figure 5) continues to reveal the facility is overdrawing the gas collection and control system. The duration and concentrations of oxygen above the 5% limit have decreased since January 2013. However, the inlet oxygen levels went above 5% in February 2013, March 2013, and April 2013.

In addition to the gas extraction and interceptor wells, I reviewed the TMP data and examined trend lines in the data. Trend lines are essential for predicting the overall direction of a heating and/or a smoldering event. The gradient or slope of a line will also indicate the rate of change in a reaction. The graphs below indicated the heating event and/or smoldering event is expanding into the narrow portion of the landfill. In order to evaluate the location of both the heat and smoldering fronts, one must examine temperatures and CO results. Given the importance of the TMPs 1, 2, 3, and 4, which are acting as a sentry line, and TMP-13, which is the closest TMP to the possible smoldering event and outside the GIW system, I selected these TMPs as the markers of the event. While I examined all the TMP trends, I selected these five and TMP-8 (Note: TMP-8 was selected as the known location of the smoldering event) to evaluate the current conditions. Figures 6 through 10 show the data trends for theses TMPs. I also reviewed and plotted the available data from TMP-8, where the reaction is currently the most active and temperatures have exceeded 300°F. Based on the reported data, TMP-8 may have reached its functional limits due to the presence of high temperatures or settlement. Figure 11 shows the temperature trend line at 140 feet as of the last reported data point on April 30, 2013 (Republic Services Report, May 2013).

All the trends in reported TMPs were positive or increasing in temperature; however, there has been a slight short-term decrease in overall temperatures. This short-term decrease may be due to the activation of the GIW system.

As the GIW system draws heated landfill gas from the South Quarry, the interceptors are also drawing cooler landfill gas from the North Quarry. It will take a number of weeks to determine if the GIW system is working. It is critical during the operation of the GIW system to not "overpull" and allow excess oxygen to enter into an area where the reaction is being accelerated towards the interceptor zone. To determine the effectiveness of this system in stopping/controlling movement of the subsurface smoldering event into the North Quarry additional long-term temperature and CO monitoring will be necessary. Gas temperature data from the GIW system should be plotted and submitted weekly to DNR until all the data shows a decreasing trend and all gas temperatures are below 165°F.

Finally, I reviewed the April 2013 Laboratory Analysis, Wellfield Temperature, Maximum Initial Temperatures and monthly data maps for the landfill. Positively speaking, 28 of the wells listed showed a decrease (i.e., downward trend) in CO levels, while only 12 showed an increase (i.e., upward trend) and 20 remained at a steady for CO levels. Four of the wells were not assessed due to low CO levels.

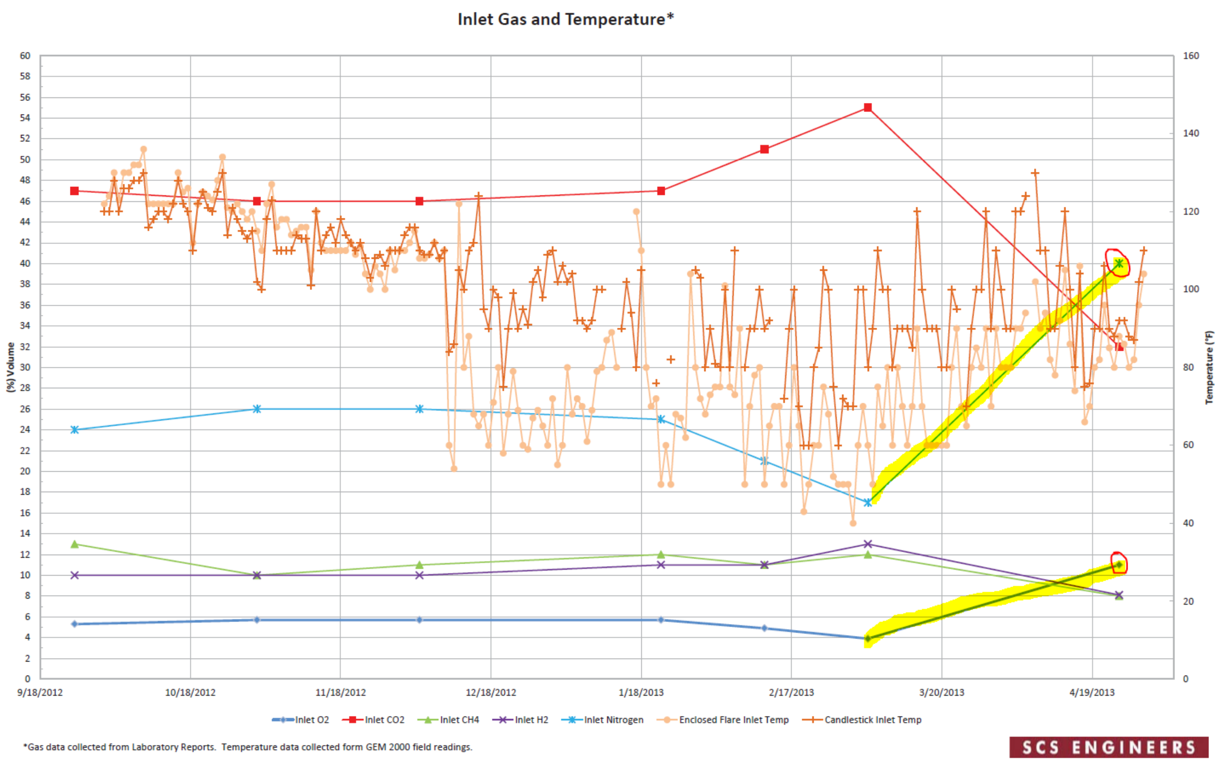

Figure 4. SCS Engineers' Inlet Gas and Temperature for the Bridgeton Landfill, MO.

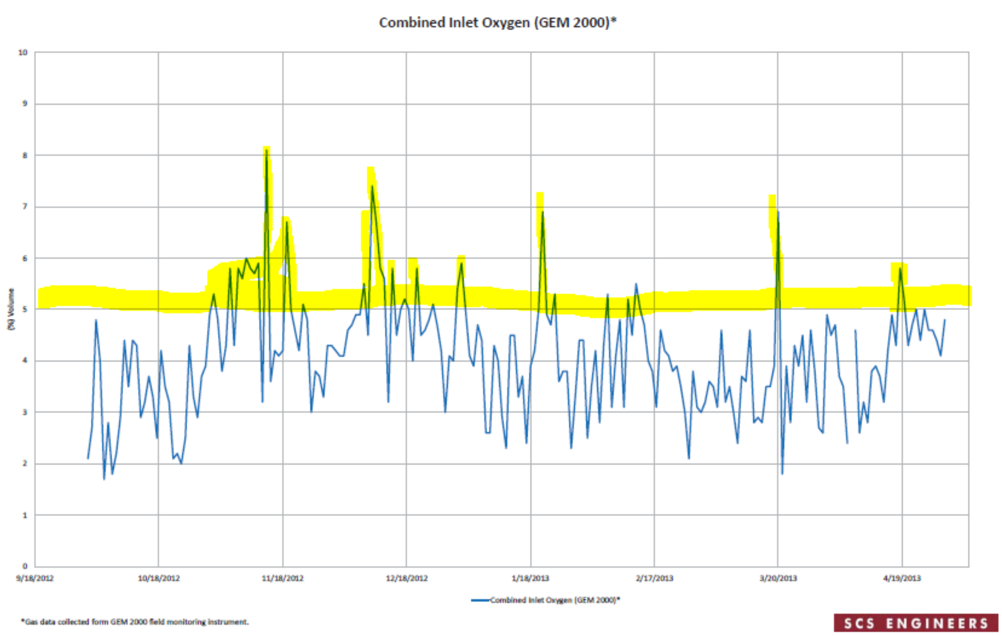

Figure 5. SCS Engineers' Combined Inlet Oxygen for the Bridgeton Landfill, MO.

Table 4. SCS Engineers Gas Control Data Exceedances for April 2013 at the Bridgeton Landfill, MO.

Well Name	Date	% O2 or %O2/Argon [NSPS Limit 5%]	Document
GEW-17R	4/25/2013	**10**	SCS Lab Analysis- 4/13
GEW-20A	4/25/2013	**12**	SCS Lab Analysis- 4/13
GEW-22R	4/25/2013	**7**	SCS Lab Analysis- 4/13
GEW-24A	4/25/2013	**9**	SCS Lab Analysis- 4/13
GEW-34	4/22/2013	**19**	SCS Lab Analysis- 4/13
GEW-35	4/22/2013	**8**	SCS Lab Analysis- 4/13
GEW-36	4/22/2013	**8**	SCS Lab Analysis- 4/13
GEW-37	4/22/2013	**6**	SCS Lab Analysis- 4/13
GEW-62R	4/22/2013	**5.9**	SCS Lab Analysis- 4/13
GEW-64	4/22/2013	**6**	SCS Lab Analysis- 4/13
GEW-71	4/22/2013	**9**	SCS Lab Analysis- 4/13
GEW-1	4/29/2013	**18**	SCS April Wellfield Data
GEW-20A	4/30/2013	**9.1**	SCS April Wellfield Data
GEW-34	4/30/2013	**17.6**	SCS April Wellfield Data
GEW-35	4/30/2013	**8.6**	SCS April Wellfield Data
GEW-36	4/30/2013	**10.8**	SCS April Wellfield Data
GEW-37	4/30/2013	**6.9**	SCS April Wellfield Data
GEW-44	4/2/2013	**10.4**	SCS April Wellfield Data
GEW-62R	4/22/2013	**5.4**	SCS Lab Analysis- 4/13
GEW-71	4/22/2013	**9.0**	SCS Lab Analysis- 4/13
Non-Extraction Well			
LCS-3C	4/25/2013	**17**	SCS Lab Analysis- 4/13
Inlet	4/25/2013	**11**	SCS Lab Analysis- 4/13

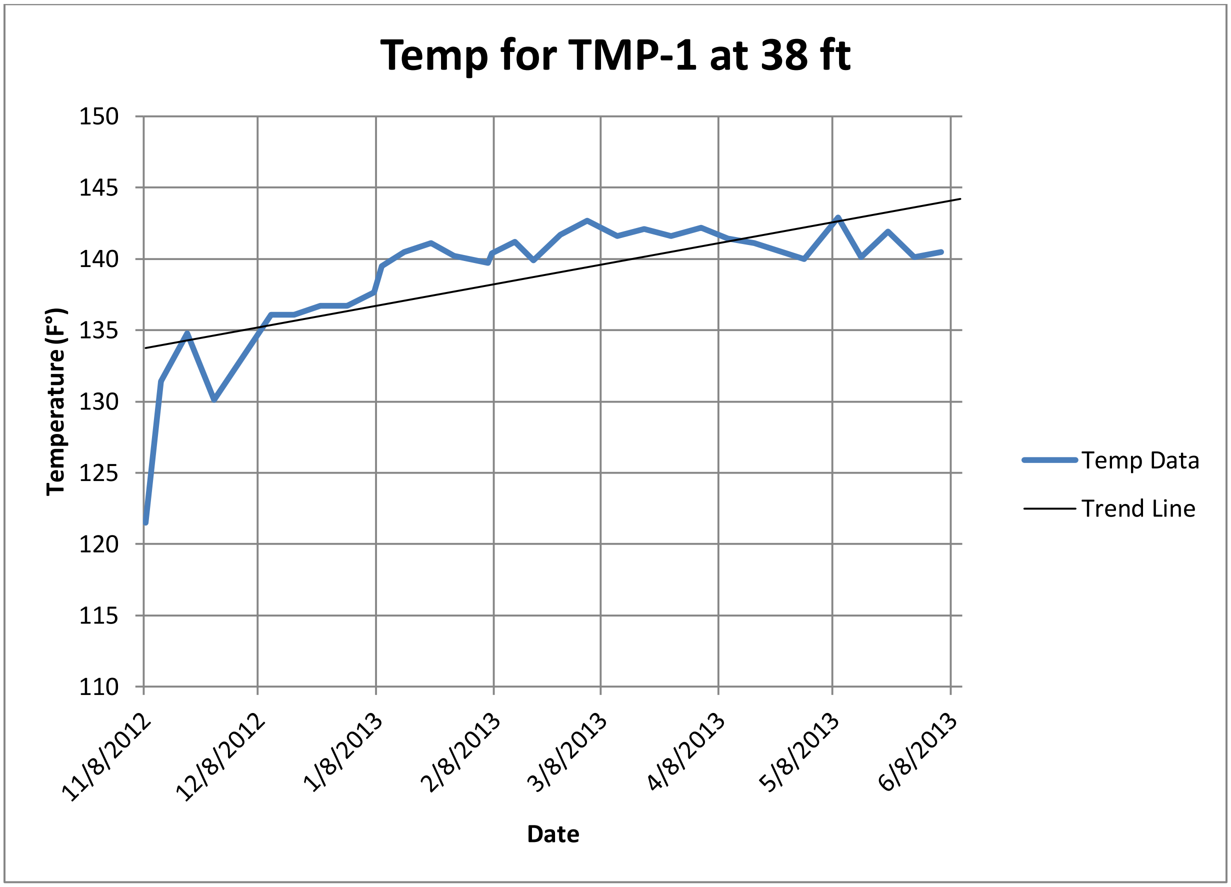

Figure 6. Temperature Trend for TMP-1 at 38 feet at the Bridgeton Landfill, MO.

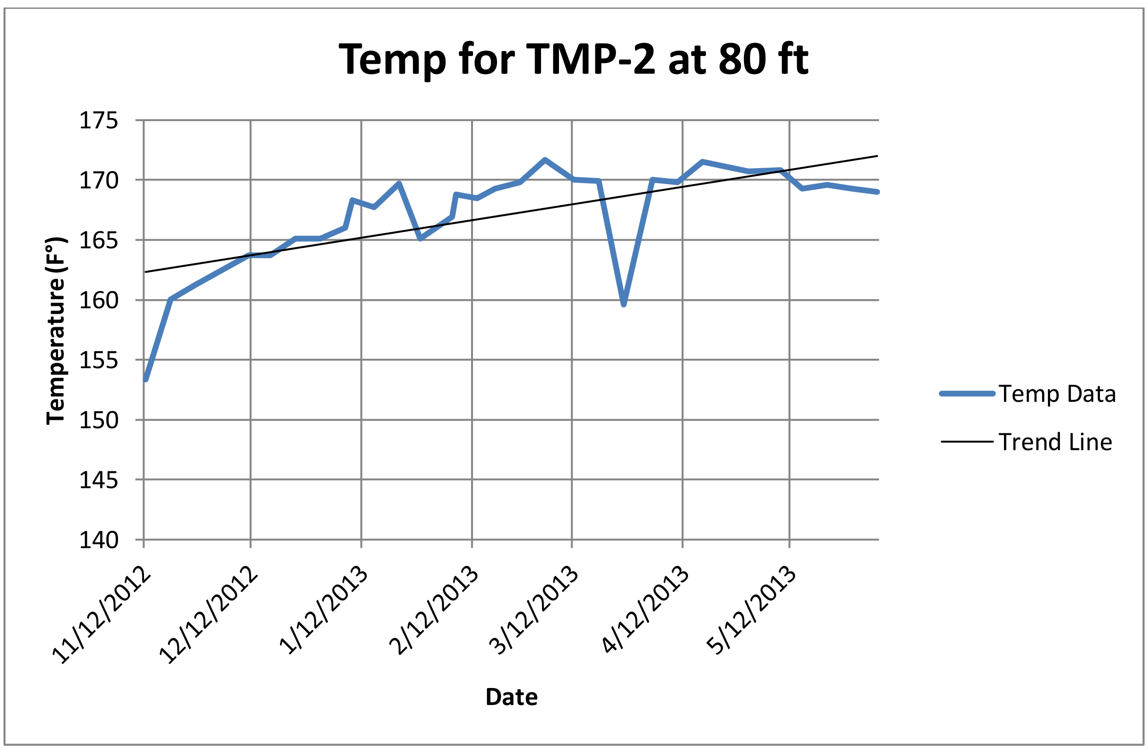

Figure 7. Temperature Trend for TMP-2 at 80 feet at the Bridgeton Landfill, MO.

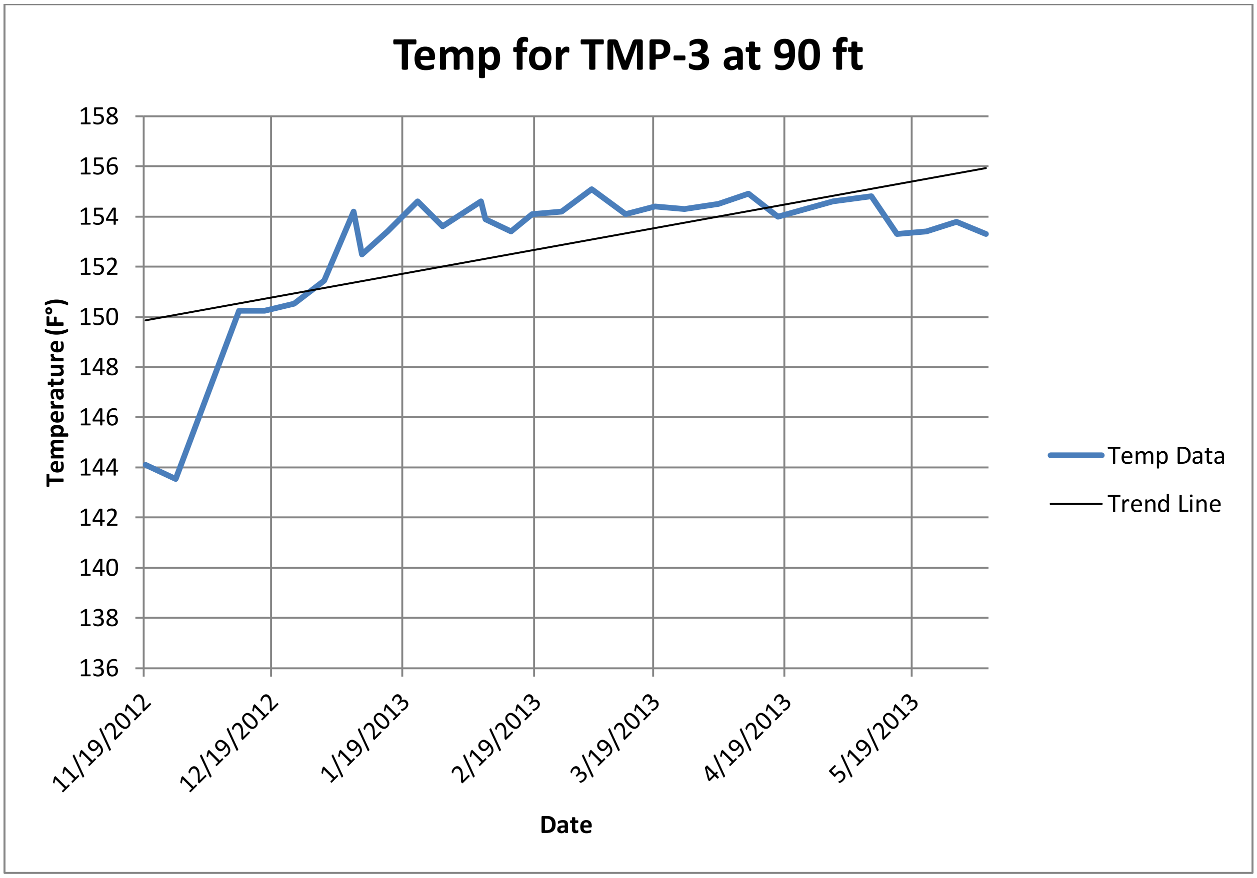

Figure 8. Temperature Trend for TMP-3 at 90 feet at the Bridgeton Landfill, MO .

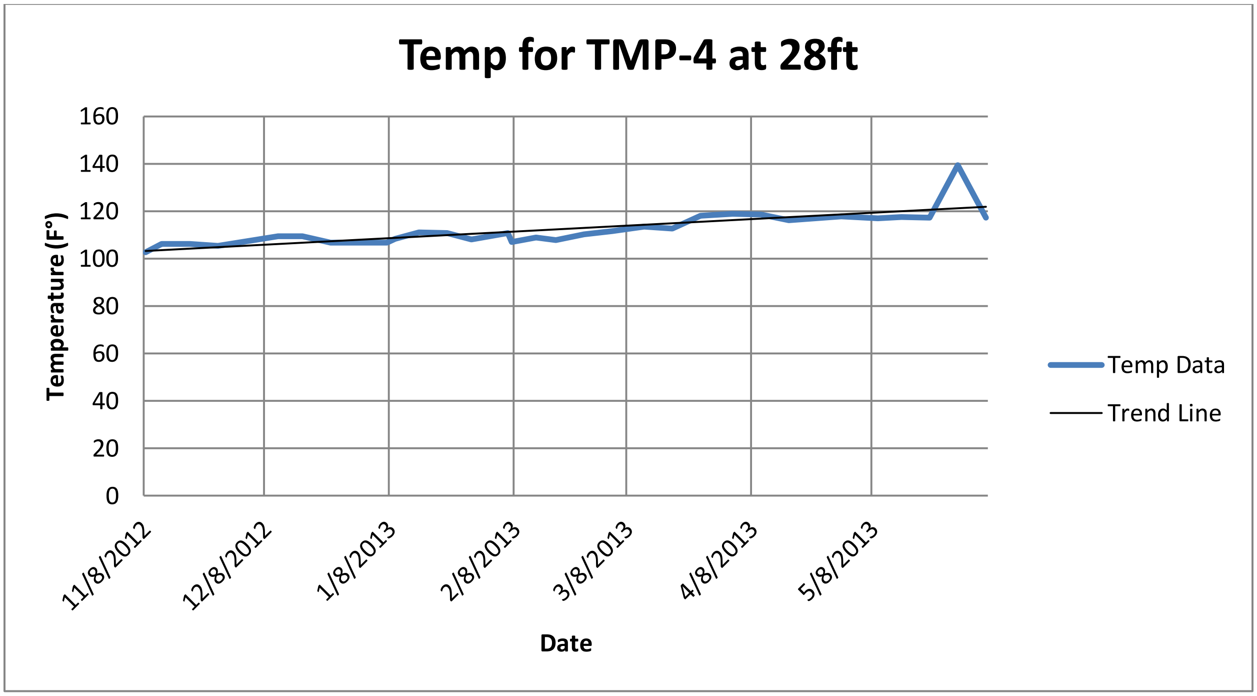

Figure 9. Temperature Trend for TMP-4 at 28 feet at the Bridgeton Landfill, MO.

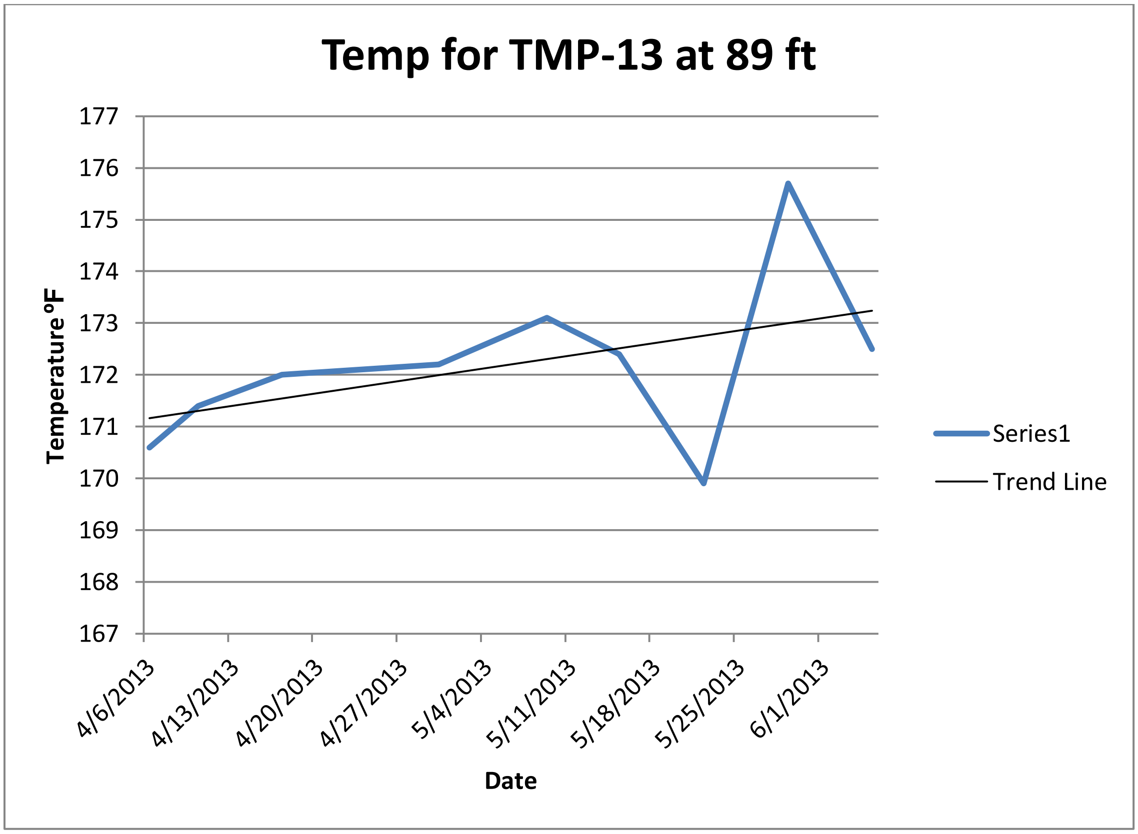

Figure 10. Temperature Trend for TMP-13 at 89 feet at the Bridgeton Landfill, MO.

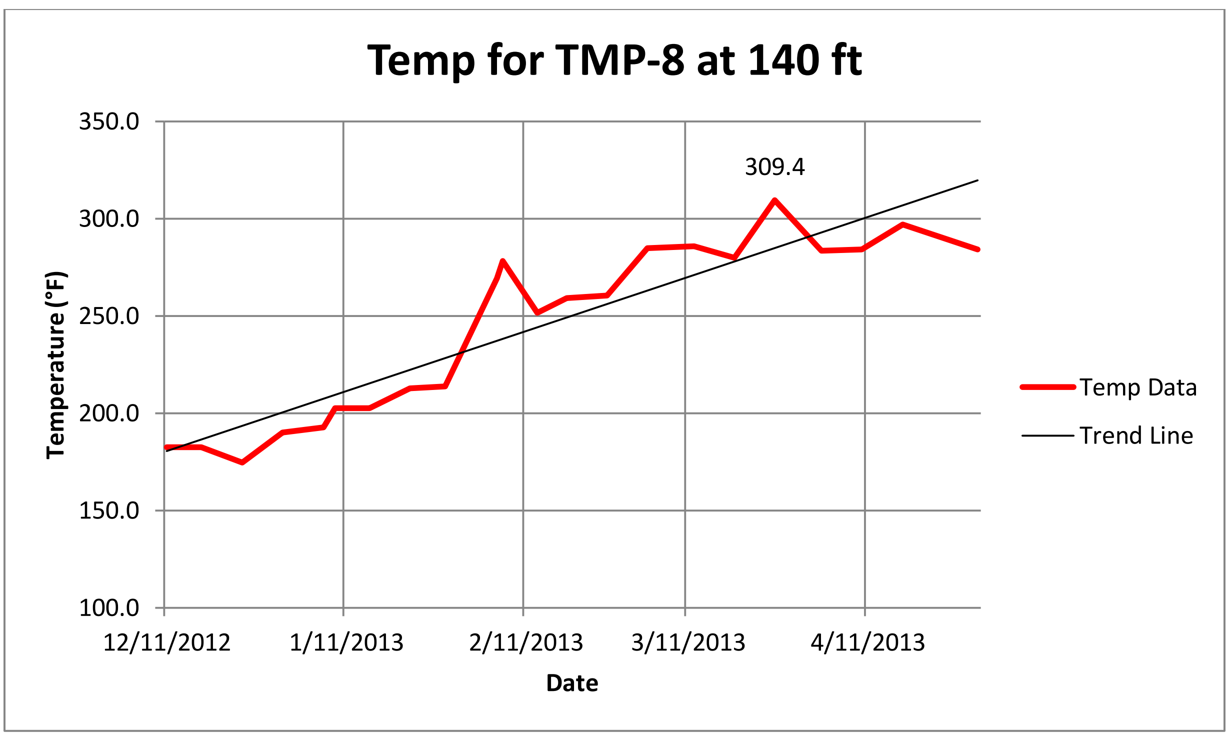

Figure 11. Temperature Trend for TMP-8 at 140 feet at the Bridgeton Landfill, MO (Note: Probe at 140 feet no longer functional as of 5/9/2013).

ISOLATION BREAK CRITERIA

Based on the North Quarry Contingency Plan, Part I in the First Agreed Order, which is required to be submitted to DNR within 45 days of entry of the order or June 27, 2013, the operator is required to:

1. Establish trigger criteria for installation of additional Temperature Monitoring Probes in the North Quarry along with a plan and schedule for installation of the probes, if triggered;
2. Establish trigger criteria for installing interceptor wells within the North Quarry to control further migration of the subsurface fire along with a schedule for well installation, if triggered; and
3. Establish trigger criteria for capping of the North Quarry with an EVOH cap, similar to the South Quarry, and a schedule for such capping, if triggered.

Based on the North Quarry Contingency Plan, Part II in the Order which is required to be submitted to DNR within 75 days of entry of the order or July 27, 2013, the operator is required to

1. Provide a construction plan for the installation of additional interceptor wells in the North Quarry, if triggered;
2. Provide a construction plan for installation of an EVOH cap over the North Quarry, if triggered; and
3. Develop trigger criteria for an isolation break between the North Quarry and radiological materials contained in West Lake Landfill Site OU-1, Area 1, along with a plan and schedule for such break, if triggered.

These criteria are necessary because the operator elected not to install the recommended vertical concrete elements wall at the narrow portion of the quarries that would provide a physical fire break. Instead the operator elected to use a set of 13 gas interceptor wells to contain the reaction at the interceptor zone. In order to ensure public safety and reduce the environmental worry concerning the location of the radioactive material, set definable criteria must be developed and implemented. The key to these criteria being successful is that the criteria must be measurable, reproducible and agreed upon by both parties. If any of the criteria are exceeded, then the operator is required to immediately construct the isolation break at the physical boundary of the North Quarry and Operable Unit 1, the Radiological Unit. A failsafe line should be located north of the location of TMP 1 through 4 and include five to six new TMPs and 6 to 8 steel cased monitoring wells that are screened for two to three elevations in the North Quarry (Note: See Recommendations for further design suggestions) . In evaluating the current reaction, Table 5 is provided as a starting point for the criteria discussion. The table uses temperature, carbon monoxide, and a combination of temperature and carbon monoxide to set the criteria in order to construct the isolation break.

Table 5. Proposed Sentry Criteria for the Construction of the Isolation Break at the Bridgeton Sanitary Landfill, Missouri.

Proposed Sentry Criteria [1, 2] **Bridgeton Sanitary Landfill, North Quarry Isolation Break**

Indicator	Volume or/and Temperature	Isolation Break Required	Parameters
Carbon Monoxide (CO)			
CO levels in any gas extraction well or sentry monitoring well in the North Quarry.	>1,500 ppm	YES	CO result shall be repeatable and re-measured within 8 hours of receipt of the data. CO measurements shall be based on laboratory analysis and not field equipment. DNR and the fire authority shall be notified within 48 hours. Should any result exceed 1,500 ppm CO, the isolation break shall be constructed.
CO levels in two or more gas extraction wells and/or sentry monitoring well in the North Quarry.	>1,000 ppm	YES	Re-measure the initial CO result over 1,000 ppm within five days of receipt of the data. CO results greater than 1,000 ppm, but less than 1,500 ppm shall be re-measured 4 times for 4 weeks. DNR and the fire authority shall be notified within 5 days. Should all the retest exceed 1,000 ppm CO, the isolation break shall be constructed.
CO levels in any gas extraction well or sentry monitoring well in the North Quarry.	<1,000 ppm	No	No additional actions required. Continue monitoring per the First Agreed Order (Case No. 13SL-CC01088).
Temperature (°F)			
Any reportable temperature in a ***TMP*** at the sentry line[3] or in the North Quarry.	>200°F	YES	Temperature result shall be repeatable within 8 hours. DNR and the fire authority shall be notified within 48 hours. Should any temperature exceed 200°F in a TMP, the isolation break shall be constructed.
Any reportable temperature in a ***gas well*** located within the North Quarry.	>180°F	YES	Temperature result shall be repeatable within 8 hours. DNR and the fire authority shall be notified within 48 hours. Should any temperature exceed 180°F in a gas well, the isolation break shall be constructed.
Combination of CO + °F			
Any reportable temperature in a ***TMP*** or ***gas well*** at or past the sentry line exceeding 195°F and any gas well in the North Quarry exceeding 1,500 ppm CO.	>195°F + >1,500 ppm	YES	Temperature result shall be repeatable within 8 hours. DNR and the fire authority shall be notified within 48 hours. Should any temperature exceed 195°F in a gas well in the North Quarry and CO is detected above 1,500 ppm at the sentry line or North Quarry, the isolation break shall be constructed.
Any reportable temperature in a ***TMP*** less than 195°F or ***gas well*** located within the North Quarry or sentry line with CO less than 1,000 ppm.	<195°F + <1,500 ppm	No	Temperature(s) shall be collected weekly. Continue monitoring per the First Agreed Order (Case No. 13SL-CC01088).

[1] These criteria are in addition to the First Agreed Order of Preliminary Injunction (Case No. 13SL-CC01088) between the State of Missouri and the Bridgeton Sanitary Landfill, LLC.
[2] The temperature and CO levels for this matrix are for the establishment of a trigger value and not for the confirmation of a smoldering event.
[3] The sentry line for this matrix is currently defined as TMP-1 through TMP-4 on the Well Layout Plan by SCS Engineers, date 1/10/2013.

DATA GAPS

In reviewing the April 2013 data package, a number of data gaps were observed. Until these data gaps can be fully supported, certain conclusions and recommendations will be limited in nature and other options may be more or less feasible once the additional data is reported. The following data gaps were observed:

- Monthly CO data for the entire GIW system;
- Monthly CO data for the entire North Quarry;
- CO sampling plan;
- CO QA/QC Plan;

- Two years of NSPS records for the North Quarry in an Excel format;
- Temperature sampling plan (i.e., methodology, equipment, calibration, recording process); and
- A CO lab chain of custody and data report to support the results.

RECOMMENDATIONS

The following is a summary of the preliminary recommendations at the Bridgeton Sanitary Landfill.

1. The operator should continue installing the temporary cover/cap in the South Quarry in an expedited manner. The cap is a key component in meeting the objective of reducing odors and minimizing oxygen intrusion.
2. Per the North Quarry Contingency Plan in the Order, the operator should install a line of five to six TMPs capable of measuring 500°F to the northeast of TMP line 1 through 4. All components used in constructing of the TMPs shall be able to withstand temperatures up to 500°F. The line of new TMPs should be placed 25 to 50 feet off center of TMP line 1 through 4. The operator should also install a line of monitoring wells 25 to 50 feet on center that are screened for two to three elevations in the North Quarry 50 feet from TMP line 1 through 4. The screening levels should be defined by the average depth of the waste divided into thirds unless the depth is less than 100 feet, then only two screened levels would be necessary.
3. The combined well and TMP monitoring line should be used as a sentry line; if any of the pre-defined criteria are exceeded, the operator shall immediately implement a fire break/isolation barrier between the North Quarry Landfill and Operable Unit 1, the Radiological Unit.
4. The operator and DNR should agree within the time frames in the established order on a set of pre-defined criteria that will immediately require the implementation and construction of the fire break/isolation barrier between the North Quarry Landfill and Operable Unit 1, the Radiological Unit. The criteria should be based on a sustained temperature and/or CO level, such as detailed in Table 2.
5. To allow for enhanced analysis of the sentry line, temperatures and gas (i.e., CO, methane, hydrogen, etc.) data logs and maps should be collected and provided no less than weekly to DNR.
6. The operator should submit designs for the fire break/isolation barrier between the North Quarry and Operable Unit 1, the Radiological Unit, within the time frames in the established order. The design should completely isolate potentially combustible materials between the Bridgeton Landfill and Operable Unit 1.
7. The additional oxygen concentrations as shown in Figures 2 and 3 may increase the potential rate of spread and should be kept below the 5% NSPS limit for all interior gas extraction wells.
8. In facilities with smoldering events, it is recommended the oxygen concentration for all interior gas extraction wells be kept below 1%.
9. In areas where the gas or waste temperatures exceed 180°F, the oxygen concentrations in the waste mass should be kept below 1% and optimally it should be kept below 0.5% for an interior gas extraction well.
10. All wells in the North Quarry should be kept to below 1% oxygen.
11. Excessive oxygen in the waste prisms should be avoided. While landfill odors can be a driving factor in increasing the vacuum on a gas collection system, the operator should examine the design and operation of the gas collection system first and keep “overdraw” conditions to a minimum.
12. While I understand from discussions with DNR staff that Republic Services previously rejected Dr. Stark’s January 22, 2013, vertical barrier wall design at the border of the neck and North Quarry, based on the latest data markers, there appears to be a small construction window to install this barrier and reduce the likelihood of this smoldering event impacting the North Quarry.
13. I would again recommend the operator start the construction of a vertical barrier wall in the narrow portion of the landfill within 60 days of this report unless new data indicates the reaction is in the North Quarry or the rate at which the reaction is expanding would interfere with completion of the wall construction. The vertical barrier wall should also incorporate a set of 8 to12 gas carbon dioxide, injection wells as a failsafe.
14. Based on the data conditions above, site conditions, fire science, and engineering, I do not recommend allowing the North Quarry to be used as a fire break from the Radiological Unit. There are a number of reasons why the reaction should be contained to the South Quarry, of

primary concern is allowing the North Quarry, an unknown waste mass, to react over time and assume it will respond the same as the South Quarry. The impact to the community from another long term landfill gas exposure must be considered and accounted for in making this decision. All attempts to contain the smoldering and heating event should be done at the narrow portion of the facility. The operator should be required to use all available technology to contain the reaction in the South Quarry and allow no advancement through the neck area into the North Quarry.

15. If Republic Services once again elects not to install the vertical barrier wall put forward by Dr. Stark, a third set of gas interceptor wells at distance of 25% less than previously installed TMP line GIW-8 to GIW-13 or the addition of 8 to 9 GIW should be installed within 45 days of this report to contain the reaction.
16. I also recommend the North Quarry be capped with the same cover system being applied in the South Quarry to further reduce the possibility of oxygen intrusion into the waste mass and to minimize odors.
17. Gas temperature data from the GIW system should be plotted and submitted weekly to DNR until all the data shows a decreasing trend and all gas temperatures are below 165°F.

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Appendix A
Observation Reports