September 1, 2015

Ms. Peggy A. Whipple, Esq.
Deputy Chief, Litigation Division
Missouri Attorney General's Office
Supreme Court Building
P.O. Box 899
Jefferson City, Missouri 65102

Subject: Expert Opinion of the Bridgeton Sanitary Landfill Incident, Bridgeton, Missouri

Dear Ms. Whipple:

As requested, I have prepared a letter report discussing the issues and opinions concerning the smoldering/pyrolysis/heating incident at the Bridgeton Sanitary Landfill (BSL) located at 13570 St. Charles Rock Road in Bridgeton, Missouri. Specifically, I was asked to address the following matters surrounding the BSL incident:

1. Is the BSL burning pursuant to Missouri Department of Natural Resources, Division 80, Solid Waste Management Chapter 3, Sanitary Landfill, subsection (13)(C) Air Quality?
2. What caused burning of the solid waste at the BSL?

My opinion of the incident that has occurred and is ongoing at the BSL is based on my prior site visit observations, including my most recent visit on July 21 through July 22, 2015, knowledge of the West Lake Landfill Complex, past subsurface smoldering events (SSEs) at other waste sites, Missouri Department of Natural Resources (MDNR) documents, BSL documents including reports prepared by professional engineers and other BSL consultants, weekly and monthly data submitted by Republic Services, Inc. (Republic), waste industry standard operating procedures, site photographs and videos, prior site evaluation and information concerning Republic facilities with subsurface fires/heating events/subsurface smoldering events, prior landfill fire investigations, fire science, general chemistry of special waste reactions, additional published research for this facility, state and federal regulatory codes and regulations including the facility's Missouri operating permit 0118912, available landfill data, waste management practices, and twenty two 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, research, transcripts, or publications become available. The accuracy and the validity of the Bridgeton Landfill data are assumed.

Site Background

The West Lake Landfill (WLL) is located in Bridgeton, Missouri. The WLL is within the Missouri River flood plain, within close proximity to Lambert-St. Louis International Airport, and is surrounded by a major population center. The WWL complex is listed on the United States Environmental Protection Agency's (U.S. EPA's), Superfund National Priorities List due to the disposal of radiological wastes. Within the WLL complex resides the BSL, which is inactive and no longer accepting waste for disposal. Overall, the WWL site has four distinct areas:

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

The U.S. EPA oversees the first two units, while the MDNR has permitting and oversight authority for BSL.

The BSL site is a former limestone quarry. Rock crushing operations began in 1939 and quarry operations ended in 1988. The quarrying resulted in two quarries, commonly referred to as the North and South Quarries, which were excavated to a maximum depth of 240 feet below ground surface (bgs). Both of these quarries or "pits" were joined during the disposal of waste by a narrow area referred to as the "Neck." The North and South Quarries, including the "Neck," area cover an area of approximately 52 acres.

The total waste thickness before the SSE was approximately 320 feet which means about 80 feet of waste is above the ground's surface and 240 feet is bgs. The landfill was constructed without a bottom liner or side liner and the final cover was composed of two feet of compacted clay with a one foot soil vegetation layer. The landfill accepted approximately 17,000,000 of in-place cubic yards of waste, including commercial, industrial, and municipal solid wastes. The general site geology consists of alluvium and limestone. The BSL collects its leachate from six leachate risers and facility records do not show that leachate has been recirculated through the waste mass (SCS Engineers 2012 a).

The BSL was initially permitted on November 18, 1985, and ceased accepting waste in 2005. The BSL is currently owned by Bridgeton Landfill LLC whose parent company is Republic Services, Inc. The BSL stopped accepting waste in order to reduce the risk of bird strikes and other wildlife from interfering with nearby airport operations at Lambert-

St. Louis International Airport. BSL has been operated under the following permit numbers: 0118906, 0118909, and 0118912.

Compliance Background

In addition to, the recent Agreed Order, Case No. 13SL-CC01088, effective May 13, 2013, concerning the SSE, the BSL has been under two other settlement agreements for continued violations of the Missouri Solid Waste Management Law and regulations relating to landfill gas migration, dating back to May 14, 2003. Under the first order, BSL agreed to repair, upgrade and maintain the gas collection and control system at the BSL and to complete final closure of the 52 acre site by December 1, 2006. On January 11, 2010, the MDNR issued a Notice of Violation, No. 30395 for methane migration in excess of regulatory limits in monitoring wells GMP01, GMP05, GMP07, and GMP11 dating back to June 17, 2008. In December 2010, MDNR and BSL entered into a second settlement agreement for continued methane migration. The agreement stated that BSL shall implement the Landfill Gas Corrective Action Plan, dated July 2010, and that BSL shall observe the methane wells and collect methane concentration in all gas monitoring wells every week for 180 days after the completion of corrective actions to determine if methane concentrations in all methane monitoring wells were reduced to below the regulatory limits. Since the corrective actions above did not reduce the methane in the monitoring wells to below regulatory limits, BSL was directed to expand or improve the existing gas extraction system or take other corrective actions to ensure methane migration was controlled on-site.

In May 2013, BSL entered into the current Agreed Order to address the SSE. Part of this order required the preparation of an updated "Landfill Gas Corrective Action Plan" to address the continuing methane migration off-site. Currently there are 18 probes with greater than or equal to the regulatory limit of 2.5% methane (i.e., 50% of the flammable lower limit for methane) and four probes with no reading due to excessive pressure and liquid at the monitoring point during the reporting period between March 2015 and May 2015 (Feezor 2015). While BSL continues to work towards compliance with off-site methane migration, the migration continues to occur as of May 2015 (Feezor 2015).

Incident Background

Detailed monthly reports from BSL's landfill gas monitoring contractor, Monitoring Control and Compliance, Inc. (MCC), indicate the landfill was being operated within normal landfill gas wellfield temperature parameters until May 12, 2009, when MCC discovered three gas extraction wells (i.e., BRIEW12A, BRIEW-59, and BRIEW-63) that indicated the presence of "subsurface oxidation." This event caused MCC to monitor for the presence of carbon monoxide (CO) on May 26, 2009, and to collect CO samples on June 11, 2009. By September 2009, BSL applied for Higher Operating Values for seven interior extraction wells that included GEW-12A, -13, -19A, -28, -34, -56, and -67 (SCS Engineers 2012 a). These wells had gas temperatures above 150°F and were out of compliance with the U.S. EPA's New Source Performance Standard (NSPS) air pollution control temperature limit of 131°F for interior wells measured at the well head. BSL also applied for HOVs for oxygen content in the leachate extraction wells for a six month period from January 2009 through June 2009 (AquaTerra 2009). In November 2009, MCC reported to Republic that four wells (i.e., BRIEW12A, *BRIEW-57*, BRIEW-59, BRIEW-63) indicated the presence of a "subsurface oxidation." In MCC's December 2009, *Monthly Landfill Gas Report,* gas wells 12A and 67 indicated the presence of subsurface oxidation. MCC temporarily decommissioned these wells and performed CO sampling. The sample results indicated CO levels from 350 ppm to 700 ppm, which raised a concern for MCC. By April 2010, MCC reported five gas wells (i.e., BRGEW16R, BRGEW62R, BRGEW70R, BRGEW72R, and BRIGEW85) and one leachate collection sump well (BRLCS-6A) were out of compliance with NSPS for oxygen and two wells, BRIEW12A and BRIEW-57 were decommissioned. Then in August 2010, MCC reported to Republic that the "subsurface oxidation" was present in five wells (i.e., BRIEW12A, BRIGEW-13, BRIGEW-59R, BRIGEW-63 and BRIGEW-67[1]). Based upon the December 2010, 4th quarter CO samples, MCC determined the potential impact zone had grown to 28 gas wells.

By January 2011, GEW-60R and GEW-65A exceeded 180°F at the wellhead, while methane concentrations at GEW-60 dropped from between 40 to 50% to less than 1%. According to SCS Engineers, historically such conditions were indicative of a subsurface fire; however, no smoke or other evidence of a fire was observed. By September 2011, the wellhead temperature at GEW-67 reached 183 degrees Fahrenheit and by January 2012, the wellhead temperatures at GEW-61R and GEW-62R reached 195 degrees Fahrenheit. In February 2012, the wellhead temperature at GEW-32R reached 190 degrees Fahrenheit. By April 2012, twenty-five extraction wells were considered to have been impacted by the "SSO", based on increased wellhead temperature and/or decreased methane concentration (SCS Engineers, 2012 a). Table 1 presents a 2009 to 2012 overview of the impacted wells, while figures 1 through 3 present selected landfill gas data from the impacted gas wells from 2009 to 2012.

The May 2103 data package showed general overdraw conditions in the well field and the settlement continuing to expand in the South Quarry (Thalhamer 2013, Stark, T.D and Jafari 2014). During the period between 2012 and 2013 the smoldering event caused and continued to cause damage to the engineered control systems at BSL. Photos 1, 2, and 3 show damage to the engineering control systems at BSL.

[1] Note: Gas wells names were changed by the BSL in 2011. Only the prefix name changed, for example BRIGEW-63 became GEW-63.

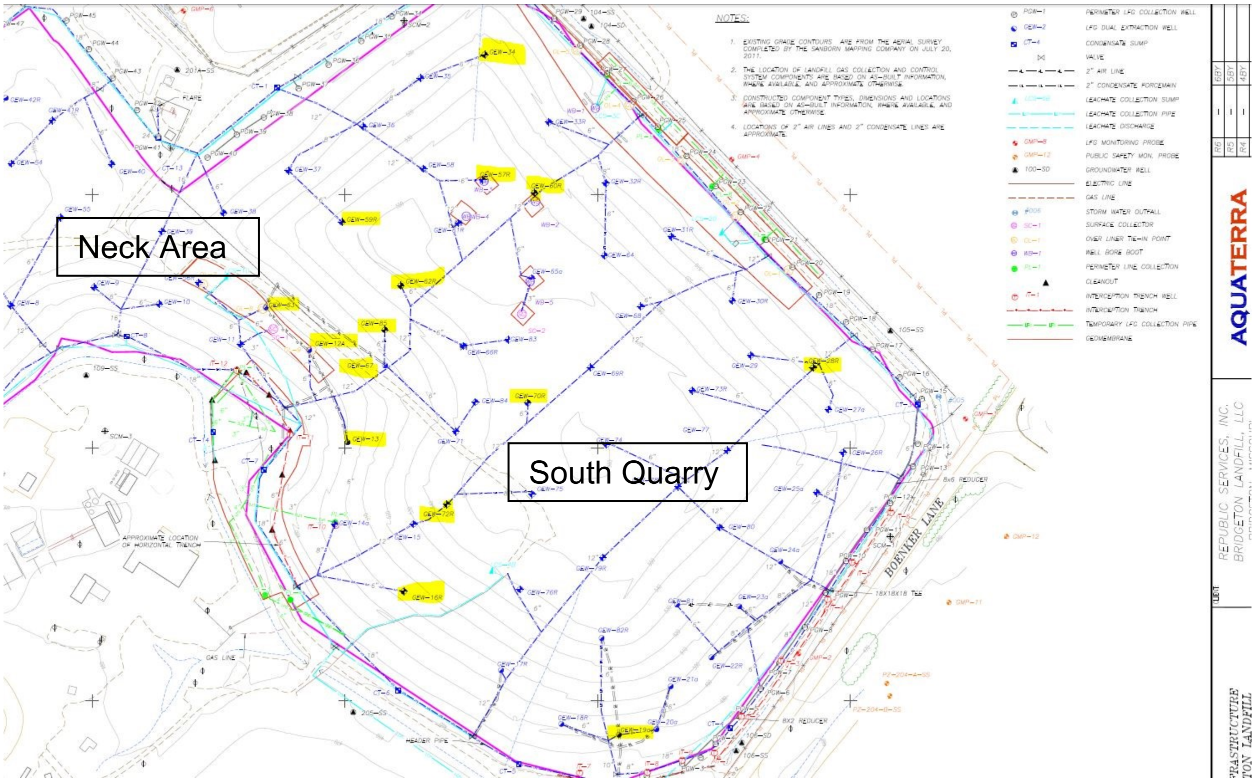


Figure 1. General overview of some of impacted gas extraction wells at Bridgeton Landfill from 2009 to 20011 (Source: Map AquaTerra Site Infrastructure Bridgeton Landfill Drawing March 8, 2012, Details: Todd Thalhamer 2015).

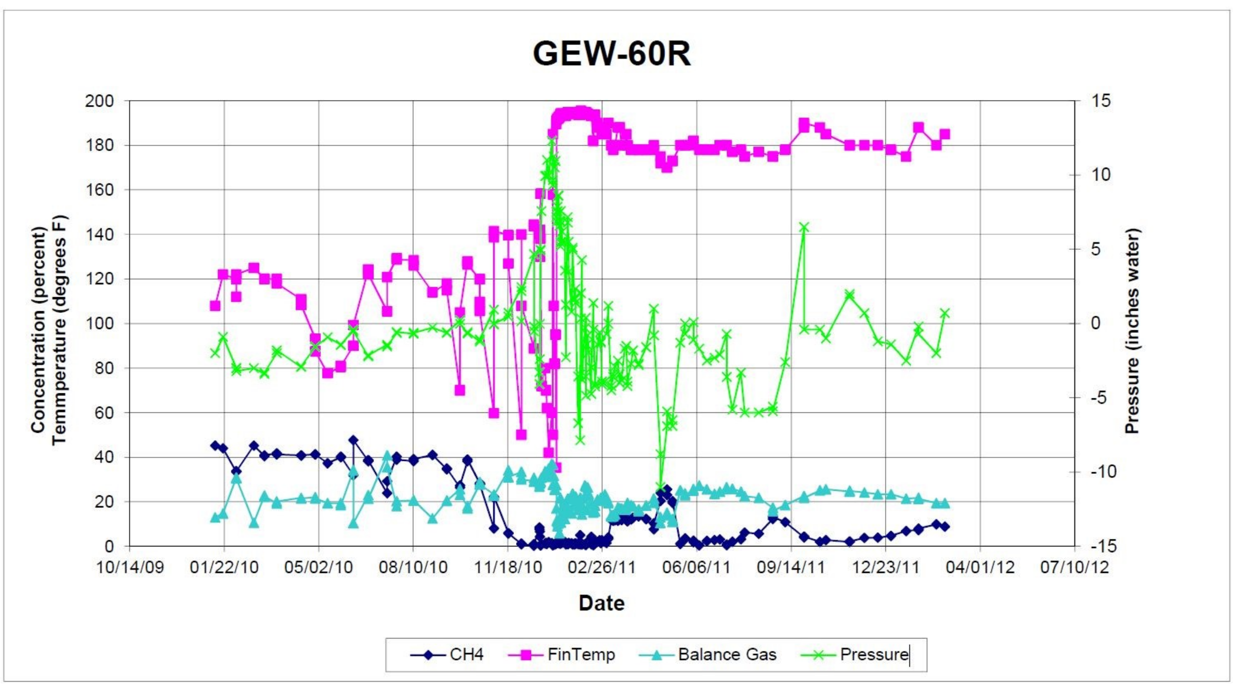


Figure 2. Operational Data for Bridgeton gas extraction well GEW-60A demonstrating the subsurface event in December 2010 (Source: SCS Engineering 2012 b).

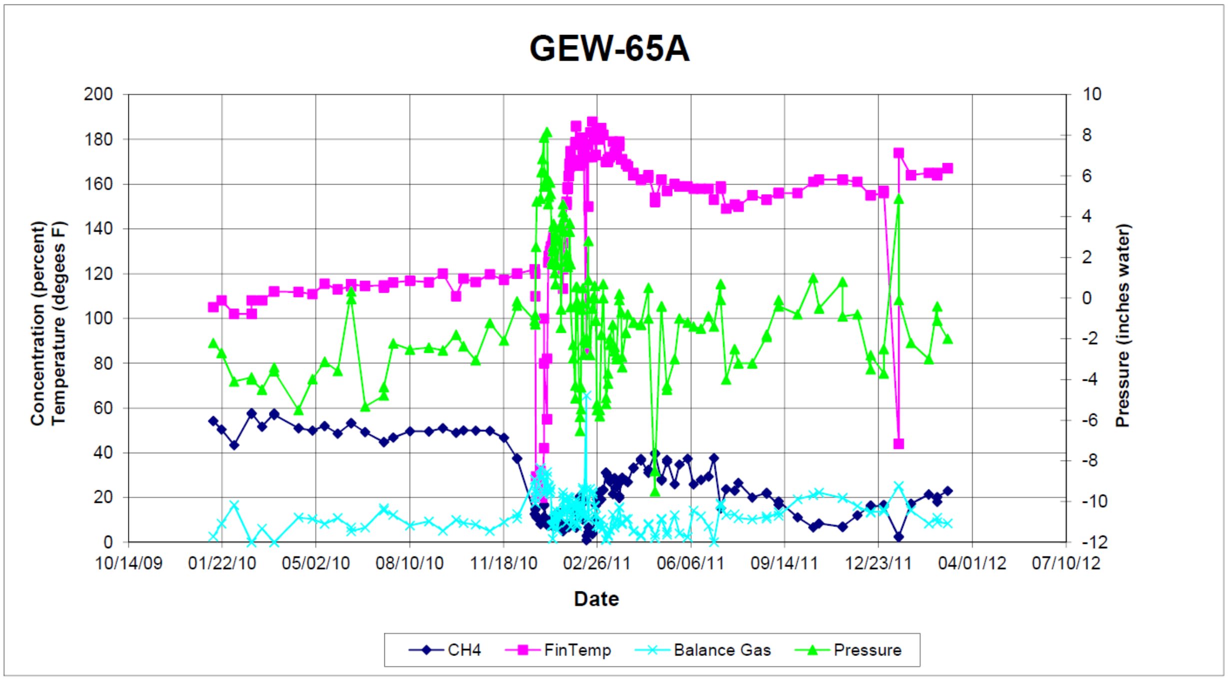


Figure 3. Operational Data for Bridgeton gas extraction well GEW-65A demonstrating the subsurface event in December 2010 (Source: SCS Engineering 2012 b).

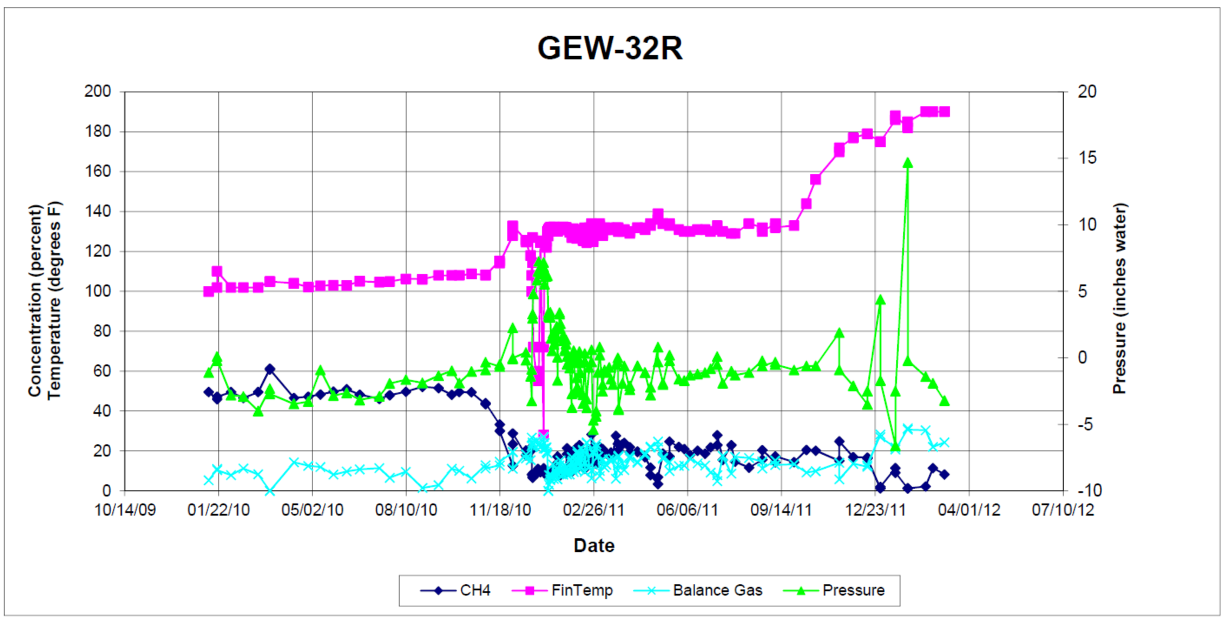


Figure 4. Operational data for Bridgeton gas extraction well GEW-32R demonstrating the subsurface event in December 2010 (Source: SCS Engineering 2012 b).

Table 1. Summary of the subsurface oxidation (SSO) in the gas extraction system, Bridgeton Landfill from February 2012 to March 2012 (Source: SCS Engineers 2012 a).

Well ID	Impacted by SSO	Status of SSO at Well
GEW-11	Yes	Intensifying
GEW-12A	Yes	Diminishing
GEW-13	Yes	Diminishing
GEW-14A	Yes	Stable
GEW-15	Yes	Intensifying
GEW-16R	Yes	Stable
GEW-17R	Yes	Stable
GEW-29	Yes	Intensifying
GEW-30R	Yes	Stable
GEW-31R	Yes	Stable
GEW-32R	Yes	Stable
GEW-33R	Yes	Stable
GEW-34	Yes	Intensifying
GEW-35	Yes	Stable
GEW-36	Yes	Stable
GEW-37	Yes	Stable
GEW-38	Yes	Stable
GEW-56R	Yes	Stable
GEW-57R	Yes	Diminishing
GEW-58	Yes	Intensifying
GEW-59R	Yes	Stable
GEW-60R	Yes	Stable
GEW-61R	Yes	Stable
GEW-62R	Yes	Stable
GEW-63	Yes	Intensifying
GEW-64	Yes	Stable
GEW-65A	Yes	Stable
GEW-66	Yes	Diminishing
GEW-67	Yes	Stable
GEW-68	Yes	Stable
GEW-69R	Yes	Diminishing
GEW-70R	Yes	Stable
GEW-71	Yes	Stable
GEW-74	Yes	Stable
GEW-75	Yes	Intensifying
GEW-76R	Yes	Stable
GEW-79R	Yes	Stable
LCS-3C	Yes	Intensifying

Photo 1. Damaged gas extraction well (Source: MDNR Staff 2012).

Photo 2. Heat deterioration of flexible membrane liner (FML), measured temp. 128°F, April 2013 (Source: MDNR Staff, 2013).

Photo 3. Excessive landfill gas and inflated FML, May 2013 (Source: MDNR Staff, 2013).

In an attempt to contain the smoldering/heating event to the south quarry, the Bridgeton Sanitary Landfill operator installed and activated two lines of gas interceptor wells (i.e., GIW-1 to GIW-13) on April 8, 2013 (Thalhamer 2013).

In June 2013, the BSL Temperature Monitoring Probes (TMPs) indicated the heat front was at TMP-2 and impacting areas in the "neck" or narrow portion of the landfill while the smoldering event(s) was contained in the South Quarry and the most northern front was located between GIW-5 to GIW-6 and GIW-8 and GIW-10 (Thalhamer 2013). Figure 5 shows the approximate location of the heat front in the neck using TMP data from May to June 2013, while Figure 6 shows the approximate location of the smoldering event(s) based on the CO results from June 7, 2013.

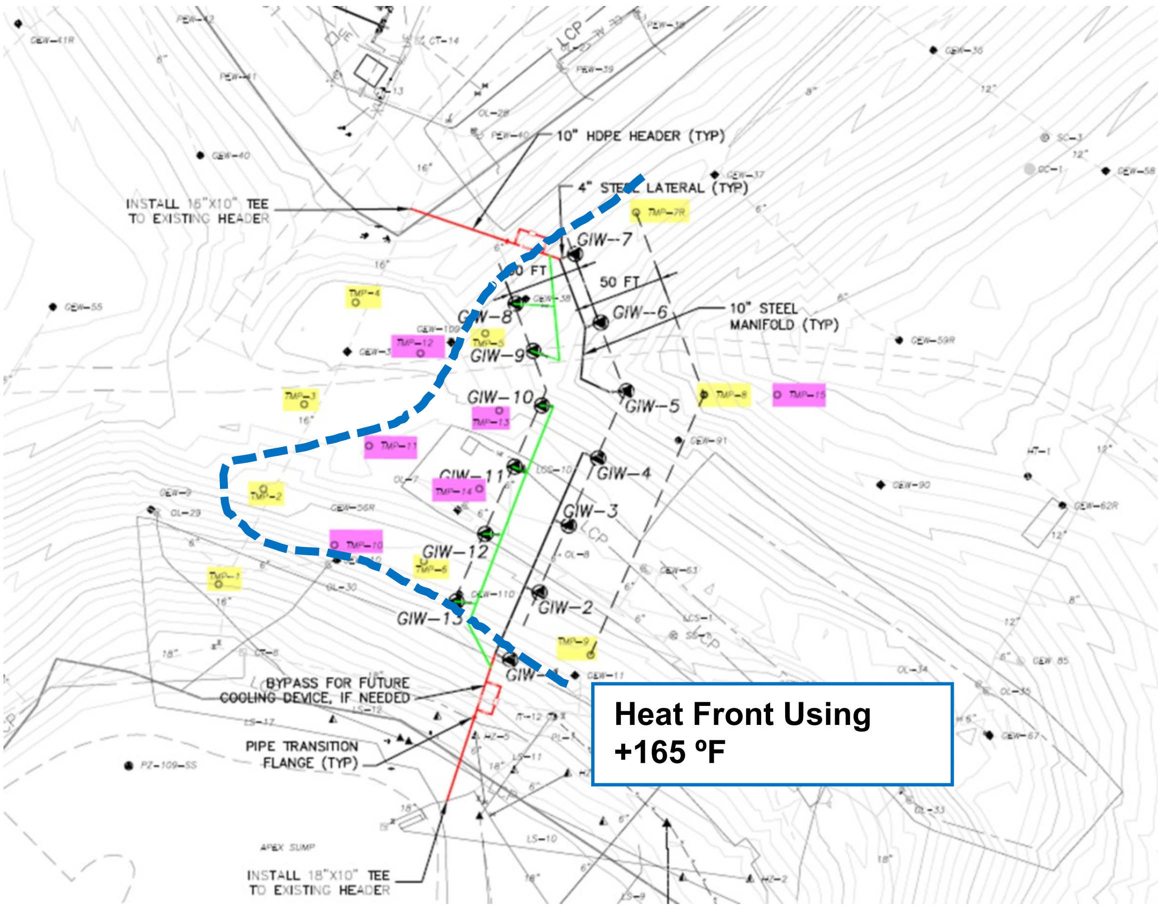


Figure 5. Approximate location of heat front using a temperature criteria 165 ºF at the BSL as of June 2013 (Source: Map - SCS Engineers 2012, Data - Thalhamer 2013).

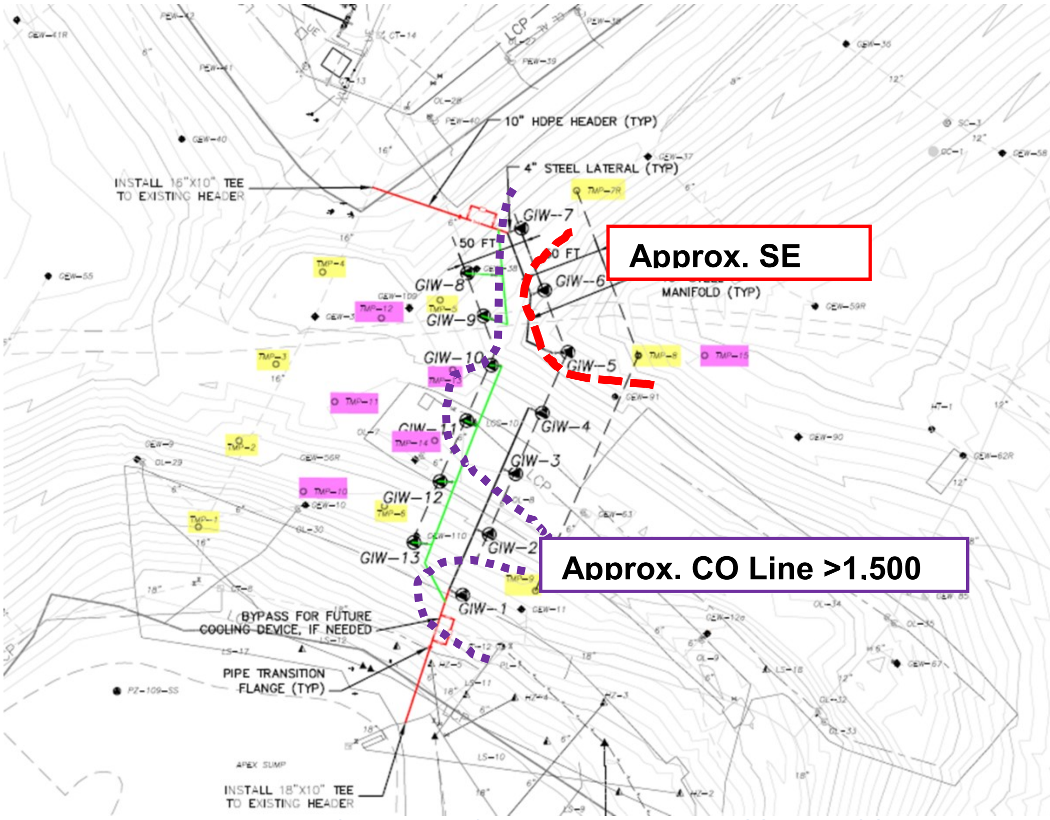


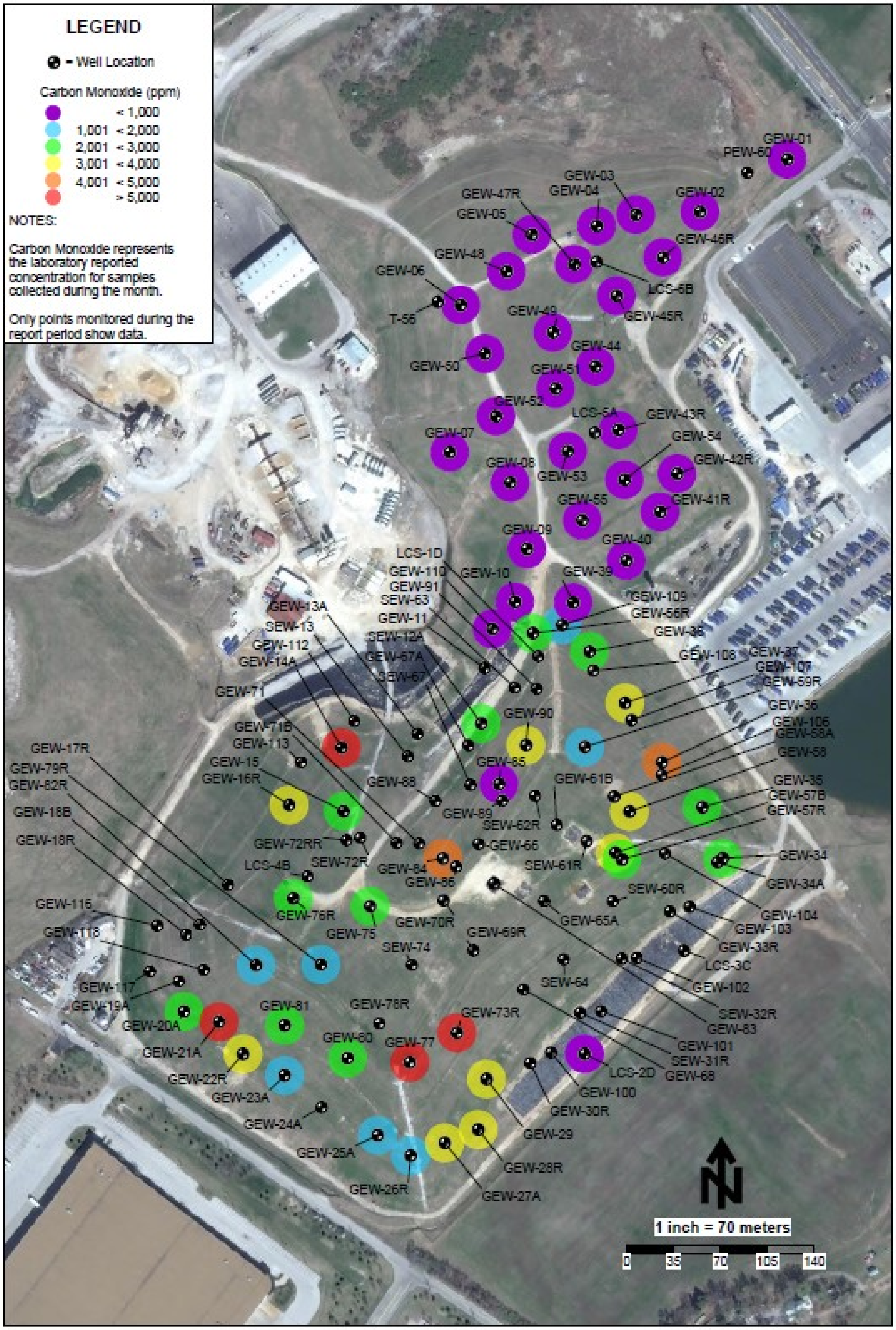
Figure 6. Approximate area of the subsurface smoldering event (SSE) and CO Line using the criteria of above 1,500 ppm at BSL (Source: Map - SCS Engineers 2012, Data - Thalhamer 2013).

On February 16, 2014, the local fire departments responded to a surface fire along the southern edge of the BSL's South Quarry. Photos 4 and 5 show the magnitude of the smoke off-site and the surface fire.

Photo 4. Surface fire at BSL along Boenker Lane on February 16, 2014. (Source: Pattonville Fire Dept. 2014)

Photo 5. Surface fire at BSL along Boenker Lane on February 16, 2014. (Source: Pattonville Fire Dept. 2014)

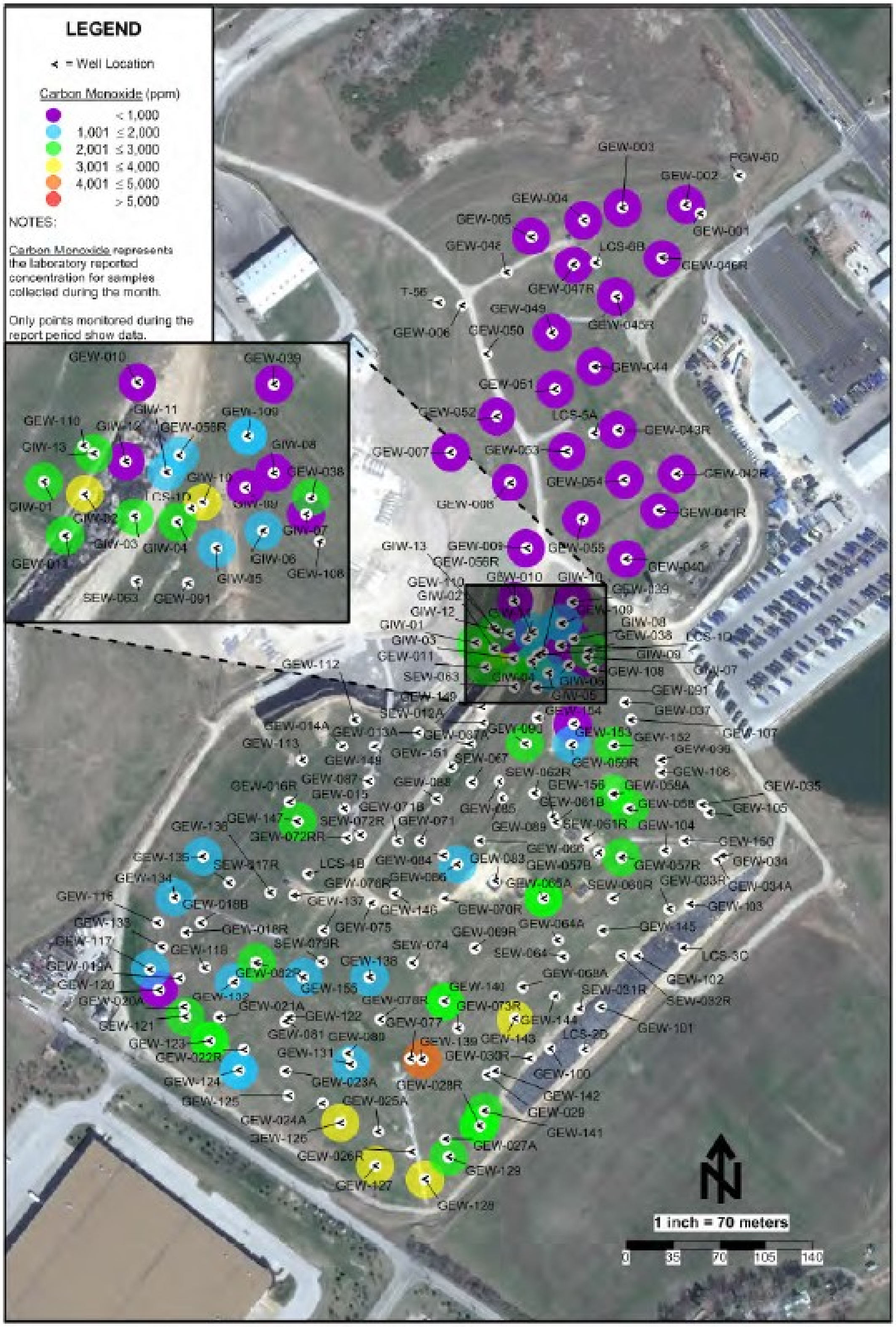
During 2014 and 2015 the smoldering and heating events expanded further into the South Quarry and into the "Neck" (BSL, Monthly Data Submittals various dates from 2013 to 2015). Figures 7 and 8 show the expansion of the smoldering and heating events based on CO results from January 2014 to July 2015, while Figures 9 and 10 show the expanding events based on temperatures for the same period of time.



Carbon Monoxide Data Map - January 2014 - Bridgeton Landfill

SCS ENGINEERS

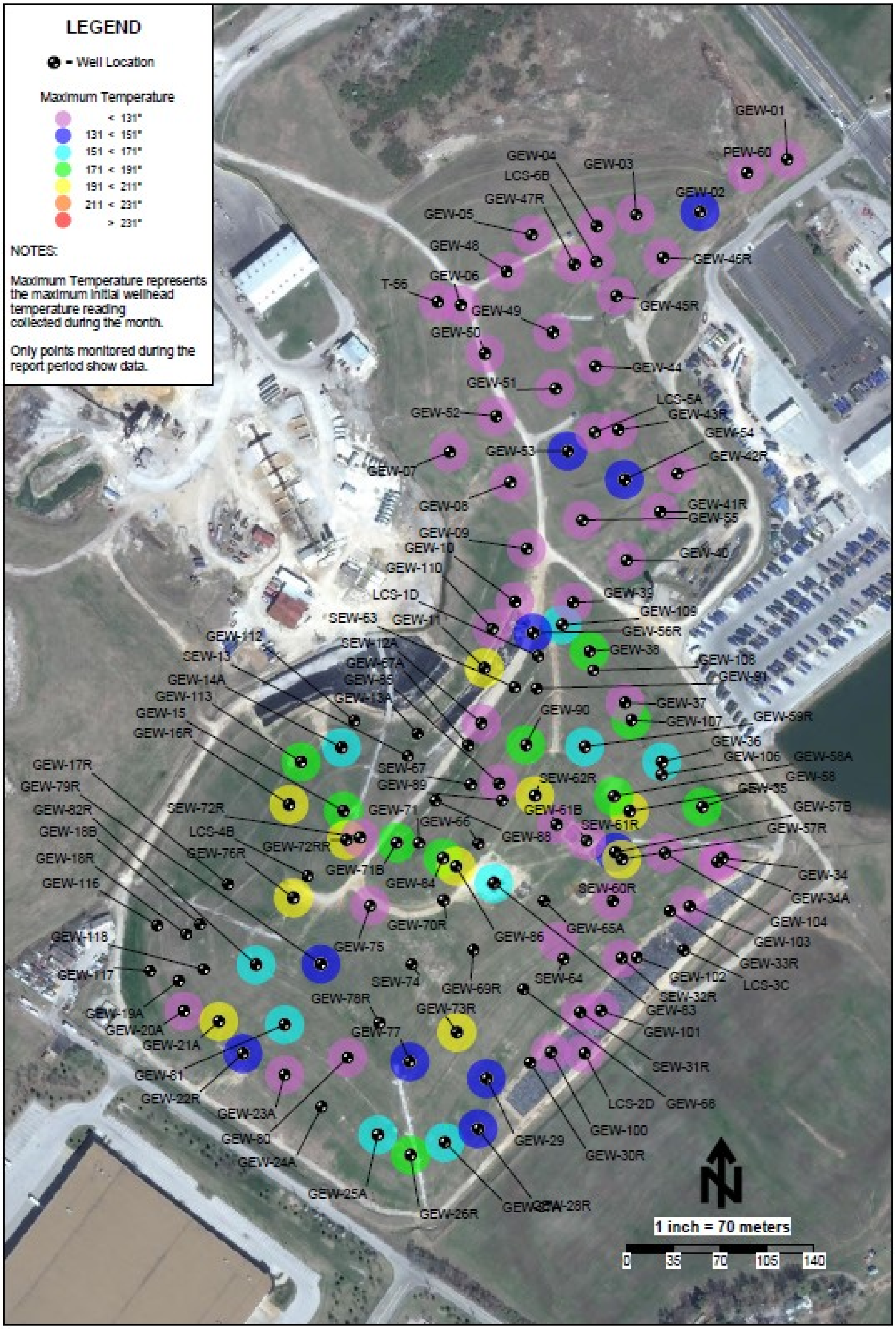
Figure 7. CO Map for BSL dated January 2014 (Note: only points monitored are shown) (Source: BSL Monthly Report 2014)



Carbon Monoxide Data Map - July 2015 - Bridgeton Landfill

REPUBLIC SERVICES

Figure 8. CO Map for BSL dated July 2015 (Note: only points monitored are shown) (Source: BSL Monthly Report 2015)



Initial Temperature Maximums - January 2014 - Bridgeton Landfill

SCS ENGINEERS

Figure 9. Initial Temperature Maximums Map for BSL dated January 2014 (Note: only points monitored are shown) (Source: BSL Monthly Report 2014)

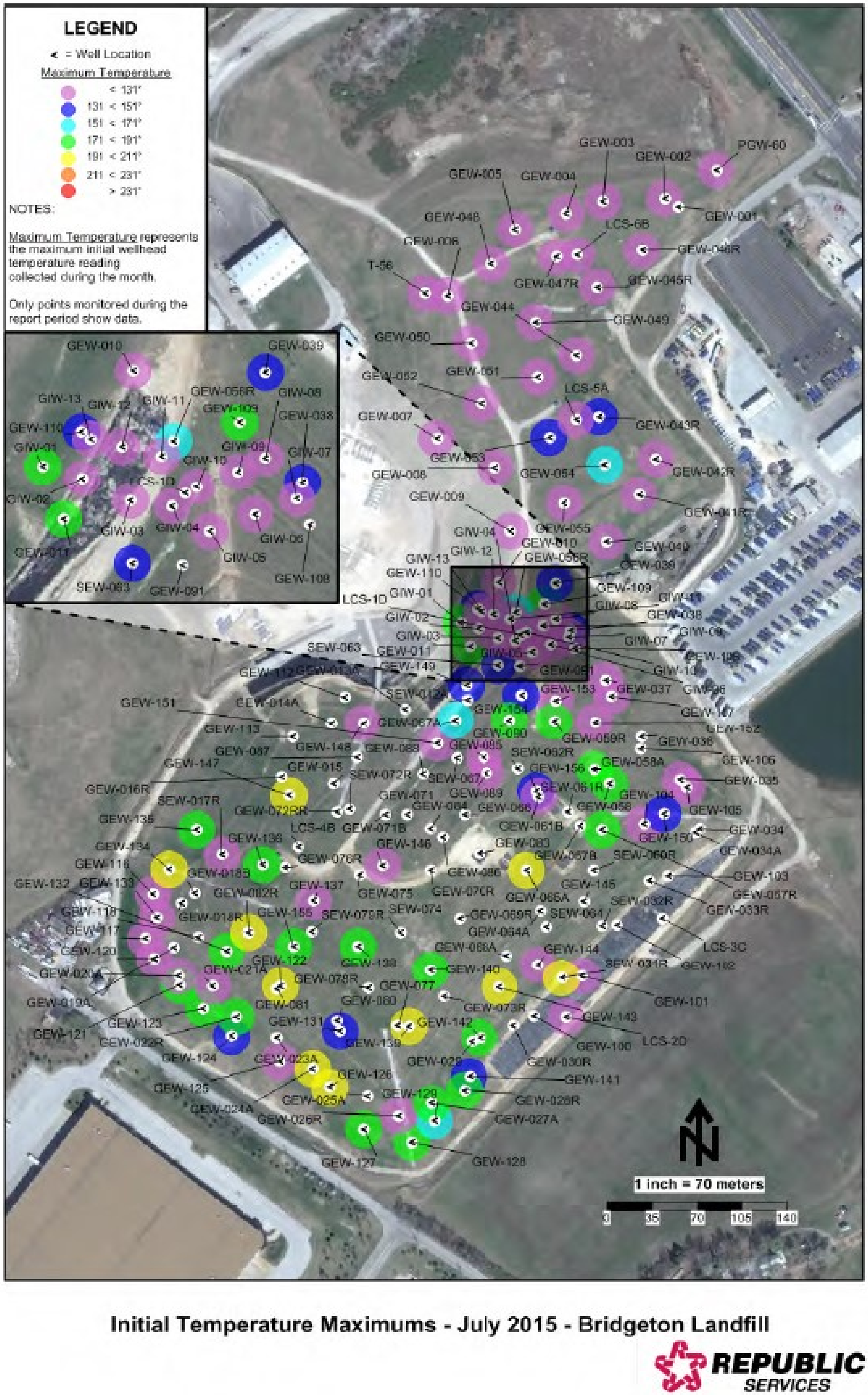


Figure 10. Initial Temperature Maximums Map for BSL dated July 2015 (Note: only points monitored are shown) (Source: BSL Monthly Report 2015)

Parent Company Experience with Subsurface Smoldering Events

Within the past six years, Republic Services, Inc., the parent company of Bridgeton Landfill, LLC, has had experience in managing subsurface smoldering, subsurface reactions, and/or heating events at other municipal solid waste landfills. As disclosed in the company's U.S. Securities and Exchange Commission (SEC) 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 required the company to implement a comprehensive operation and maintenance program to manage the remediation area at the Countywide Recycling and Disposal Facility. The Countywide facility operated within the normal landfill temperature parameters until 2001. Then sometime prior to December 2005, the facility experienced an "event" that caused excess landfill gasses and heat to be produced. These landfill gases exceeded the landfill gas (LFG) collection and flaring system capacities and produced on-site and off-site odors (Cornerstone 2006).

The same SEC filing reported that in August 2010, Congress Development Company agreed with the State of Illinois to have entered a Final Consent Order in 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 to be $50 million to $240 million. As disclosed in the company's SEC filing for the 12 month period ending on December 31, 2014, the company modified its estimate for the BSL stating the reasonably possible range of loss for remediation costs is $210 to $360 million.

Additionally, the Middle Point Landfill near Murfreesboro, Tennessee has experienced a subsurface smoldering and/or heating event as this facility is cited by the company as the source for the gas interceptor well plan. Further, the company has settled a case with the U.S. EPA and the local air district on a number of smoldering events that occurred at the Forward Landfill near Stockton, California in 2008.

Qualifications

I am a registered professional civil engineer for the State of California (License # C055197), specializing in environmental engineering issues related to solid and hazardous wastes and emergency response involving waste fires and disasters. I have twenty three years of experience in the waste industry and over sixteen years in the fire service. I am currently a lieutenant for El Dorado Hills Fire Department and an

Operations Section Chief for CalRecycle's Disaster Recovery Incident Management Team.

I earned my Bachelor of Science in Environmental Resources Engineering with a concentration in Hazardous Waste Management from Humboldt State University, Arcata, California in 1992. While earning my degree, I was employed as a seasonal firefighter for CalFire (California Department of Forestry and Fire Protection) for four seasons. After earning my engineering degree, I briefly worked for General Mills as a quality control laboratory technician before being hired as a waste management engineer with the Department of Resources Recycling and Response (CalRecycle[2]). During my twenty three years at CalRecycle, I have consulted, investigated and/or evaluated over thirty five waste fires and heating events throughout the United States and internationally. My current position as a Senior Waste Management Engineer includes work in, environmental site assessment, waste assessment, remediation plans, employee safety plans, spill plans, community safety plans, asbestos determinations, waste removal, contractor management, abandoned vessel and debris removals, and disaster operations. While working for CalRecycle, I have performed numerous landfill fire investigations, published guidance on waste fires, and been involved with emergency responses at waste fire sites. I began my subsurface fire experience in 1992 when I was tasked to investigate, excavate, and suppress the Berry Street Mall Landfill Fire in Roseville, California.

In addition to my duties for CalRecycle, I completed a four year interagency personnel assignment for the U.S. EPA, Region IX, Air Division. During my interagency assignment, I provided technical assessment, analysis, and recommendations for three landfill fires and one heating event in Region IX. I also reviewed landfill facility gas extraction plans and examined issues surrounding pending updates to U.S. EPA's NSPS for landfill gas extraction.

I am also the founder and president of Hammer Consulting Services. My consulting company provides waste fire training and fire investigations throughout the United States and Canada. My services have been retained by a number of government agencies and waste industry professionals for landfill fires and disaster procedures.

In addition to my education, I have working knowledge and experience with California and Federal Occupational Safety and Health Administration (OSHA) regulations, and National Institute for Safety and Health (NIOSH) and American Conference of Governmental Industrial Hygienists (ACGIH) standards. I have spent over 20 years in the field working with waste industry stakeholders, and local, state and federal government agencies, on the assessment and removal of waste. During this time I

[2] The California Integrated Waste Management Board (CIWMB) changed names in 2010 and became the Department of Resources Recycling and Response (CalRecycle).

have developed a number of best management practices to reduce exposure to environmental contaminants from disaster, waste fires, and environmental removals. I also have working knowledge and experience with hazardous materials incidents, firefighting procedures, confined space rescues, radiological response, fire command, national incident management systems, and industrial firefighting.

To communicate these landfill fire investigative techniques, hazards, environmental issues, employee risks, and suppression methodologies, I have developed a series of training modules (e.g., Landfillology, Combustion, Detecting, Investigating, Evaluating, Confirming Environmental Suppression, Fire Suppression Tactics, Site Safety, Incident Command, Heavy Equipment Operations, Communications, and Incident Action Plans) for industry, the fire service, and regulatory agencies. These training modules have been presented at US EPA emergency response conferences, Solid Waste Association of North America (SWANA) conferences, fire departments, and other State and industry sponsored conferences.

I have recently been a contributing author on two technical journals concerning aluminum waste reactions and waste fires. The two articles are “Aluminum Waste Reaction Indicators in MSW Landfills” and “Detection of Aluminum Waste Reactions and Waste Fires” and can be found in the American Society of Civil Engineers (ASCE) Journal of Geotechnical and Geoenvironmental Engineering, March 2012 and the ASCE Journal of Hazardous, Toxic and Radioactive Waste, October 2011 respectively. I am currently a contributing author on an additional paper entitled “Progression of Elevated Temperatures in Municipal Solid Waste Landfills” for submittal to the ASCE Journal of Geotechnical and Geoenvironmental Engineering.

In addition to the BSL incident, I have knowledge of four prior Republic landfill facilities experiencing SSE/heating/pyrolysis/reaction events (i.e., pre 2010) and one Republic landfill facility post the BSL. Specifically, I have knowledge of: (1) Countywide Recycling and Disposal Facility in Ohio, (2) Forward Landfill in California, (3) Congress Development Company in Illinois, (4) Middle Point Landfill in Tennessee, and (5) Sunshine Canyon Landfill in California. The first two facilities I have broad knowledge from the preparation of reports, consulting, court appearances, direct agency assignment for CalRecycle, enforcement proceedings, and depositions. I have reviewed the third facility as a consultant in one court case, while the fourth facility I have limited knowledge based on the aluminum dross reaction and research involving the SSE at BSL. Additionally, I am only aware that Sunshine Canyon Landfill in California had a heating event and a subsurface oxidation was conducted from a regulatory agency perspective.

I have testified at depositions as an expert witness on numerous cases involving waste fires and about their causes, impacts, and environmental damage. Additional information on my education, training, experience, publications, and testimony is contained in my Curriculum Vitae, which is attached as Appendix A and hereby incorporated by reference.

Personal Site Knowledge

On June 14, 2012, and on August 22, 2012, I was requested by MDNR to observe the site conditions at the Bridgeton Landfill. Upon my arrival on June 6, 2012, MDNR staff, Timothy D. Stark, PhD, P.E., another MDNR 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 my field observations, I determined the facility was experiencing two distinct areas of subsidence, the west bowl and east bowl. A geomembrane (Note: BSL changed to flexible membrane liner (FML) cover later in the project) cover had been installed in both areas in an attempt to control the odors; however the geomembrane liners in two locations were being inflated by excessive landfill gas. During my site visit, I observed two strong, distinct odors similar to other subsurface smoldering events I have responded to as consultant or emergency responder. A smoldering landfill fire has a very distinct smell that is separate from the standard odors found at or near municipal solid waste facilities.

During the visit I also noted a number of fissures and erosion rills in the soil cover and observed bubbling leachate in the west bowl area. I also witnessed geomembrane being inflated by excess gas along with multiple soil fissures. Photo 5 shows the “pillowing effect” of the FML in June 2012. Due to the rancid, putrid odors from the subsurface fire and other site conditions, I concluded the current landfill gas extraction system was not capable of meeting gas generation rate caused by the SSE. After our site evaluation I provided the following guidance and recommendations to Bridgeton’s environmental staff:

- Repair and cover all fissures and erosion 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;

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

Photo 6. Excessive landfill gas and inflated FML dated June 2012 (Source: Todd Thalhamer 2012).

On August 22, 2012, Dr. Stark and I again met with MDNR 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 and the odors related to smoldering/burning municipal waste, I determined the facility was still experiencing two distinct areas of combustion and settlement. 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 with the potential to move into Operable Unit 1. Appendix B provides both observation reports.

I also attempted to visit the BSL with MDNR staff on June 23, 2013, and was not allowed to enter because BSL staff was unavailable. We were able to visit the site on June 24, 2013 to view the experimental gas interceptor wells that were installed in the neck. During this visit I again noted a strong odor related to smoldering/burning municipal solid waste.

On April 2, 2014, I was again requested to visit the BSL to perform a site evaluation. I again noticed the smoldering/burning municipal waste odor; however, it was not as strong as my visits in 2012 and 2013. During the site visit I collected a number of photographic and thermal images with a MDNR FLIR, Model Number K60, Compact Infrared Camera. The infrared camera was used to locate hot spots and to provide thermal images to allow for safe passage at the facility. I again observed damaged landfill gas extraction infrastructure from the SSE. I was able to field document temperatures over 180°F. Photo 7 shows a thermal image of a gas extraction well at the BSL in April 2014 indicating a temperature of 184°F.

Photo 7. Thermal image of gas extraction well at Bridgeton Landfill indicating temperature of 184°F, dated April 2, 2014 (Source: Todd Thalhamer 2014)

From July 20 to 22, 2015, Dr. Stark, Dr. Sperling, Dr. Abedini, Mr. Wright and I performed a site evaluation, field assessment, and collected temperature and gas samples from various locations at the BSL.

On July 20, 2015, we performed a perimeter tour of the facility and discovered potential gas migration across from Boenker Lane and 13201 Corporate Exchange Drive at Gas Monitoring Probe (GMP-12). With the recent heavy rain fall, the soil around the gas probe was fully saturated and standing water was present on top of the probe. We observed active gas coming out of GMP-12 and were able to detected flammable gas at the water-interface interface. A video (20150720_200116.mp4) of the gas bubbles will be provided separately as Appendix C.

During the site visit on July 21 and 22, 2015, I collected a number of photographic and thermal images with a MDNR FLIR, Model Number E64501, Compact Infrared Camera. The infrared camera was used to locate hot spots and to provide thermal images to allow for safe passage on the facility. I again observed damaged gas infrastructure from the subsurface event and erosion and fissures in the soil area not covered by the FML at the BSL specifically in the North Quarry. I also observed over 30 feet of settlement in the "Neck" area and in the area where the subsurface smoldering event(s) began in the amphitheater to the west in the South Quarry and along the northeast area in the South Quarry. While the odor at the BSL was not as pungent as the previous site visits in 2012, I was able to distinctly observe the classic odor of smoldering/burning municipal solid waste in the "Neck" area and in the southeast corner of the South Quarry.

Photo 8. Gas coming from GMP-12 BSL, July 20, 2015 (Source: Dr. Abedini and witnessed by Todd Thalhamer, Dr. Sperling, and Brenda Ardrey from MDNR)

Photo 9. Thermal image at BSL dated July 22, 2015 (Source: Todd Thalhamer 2015)

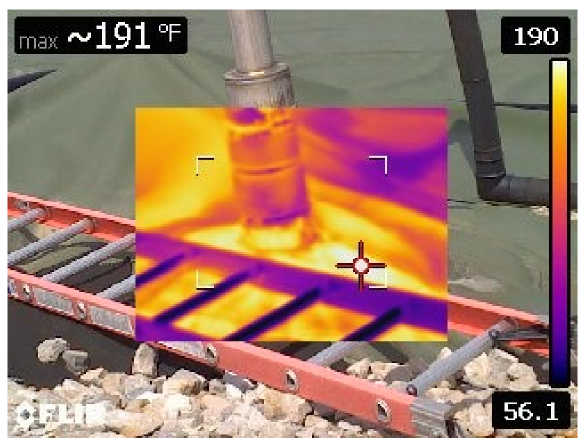


Photo 10. Thermal image at BSL dated July 22, 2015 (Source: Todd Thalhamer 2015)

Finally, based on my July 2015 site visit, the captured site thermal images, and BSL May 2015 monthly laboratory gas data, I provided a Hazard Awareness Update presentation to the local first responders. This presentation included incident objectives, a review of the most credible threats (i.e., man down scenario, plastic liner fire, hazmat release, failure of interruption of environmental control system, entrapment of equipment and/or personnel, and structural collapse), current site conditions, an overview of the current "watch out" areas or dynamic zones, incident response criteria, watch out situations, potential collapse areas, failing infrastructure, elevated temperatures, and other responder issues. The presentation was provided to local first responder coordinator, Chief Matt Lavanchy of Pattonville Fire Department and Commander of Hazmat Branch for St. Louis County and will be provide separately as Appendix D.

Personal Data Knowledge

As part of my contract with MDNR, I have been reviewing and commenting on BSL data since April 2012. During this time I have reviewed agency correspondence, photos, videos, and reports concerning BSL. I have prepared a number of reports and memos on the BSL and issues relating to the potential release of radioactive materials if impacted by subsurface events located at the WLL. I also have reviewed the required weekly and monthly data submittals from Republic for the BSL required by Section 52.F of Agreed Order, Case No. 13SL-CC01088.

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. Approximately 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

Understanding fire types is paramount to prevention. 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 type of event develops below ground and can extend past the 100 feet below ground surface level depending on geological and site conditions.

Most people have a defined concept of burning or fire. However, when one examines how a landfill combusts, an evaluation is needed of the environmental circumstances and combustion (or fire) must be defined. 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 hydrogen and methanol burn they result in fires that are not visible to the human eye. Additionally, for burning or combustion to occur the following conditions must be present:

- A combustible fuel (e.g., a substance that can be burned to provide heat) ;
- 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 10, the signs of a smoldering fire are not always readily apparent to the human eye. During a San Francisco landfill fire investigation, I conducted, 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 proper control of the available oxygen, 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 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. Photo 11 shows a typical sinkhole related to a subsurface smoldering event. 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.

Photo11. Damaged landfill gas extraction infrastructure from the smoldering/heating event at BSL dated July 22, 2015 (Source: Todd Thalhamer 2015)

Photo 12. Smoldering subsurface event at Candlestick State Park, California (Source: Todd Thalhamer, 2006).

Photo 13. Typical sinkhole at a solid waste landfill caused by a subsurface smoldering event (Source: Todd Thalhamer)

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/consumes organic materials they produce heat (Δt) along with degraded organic matter, methane (CH_4), carbon dioxide (CO_2) and other gases. The reaction is shown below:

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 extraction 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 California 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 an SSE is present:

- Increased temperatures in the landfill gas extraction 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 (typically above 1,500 ppm);
- Smoldering odors or smoke emanating from the landfill;
- Flame and/or combustion residue in the landfill gas extraction 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 states if CO is detected over 1,000 ppm then a smoldering event is likely to be present.

After years of the examining CO results and working with multiple data plots of CO vs CH_4 (Stark 2013) from SSEs, I recently revised my guidelines to state increasing levels CO levels over 1,500 ppm is an indication of an active SSE. Levels of CO over 1,000 ppm can still be an indication of an SSE if other trends in the data are observed. Typically, CO from active smoldering events range from 1,000 to 9,000 ppm and have been documented as exceeding 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. Similar to temperature, CO from a smoldering event will reside in the waste prism for an extended amount of time. While elevated temperatures can remain 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.) may be found to vary across 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 conclusions.

It is also important to understand that waste temperatures control the quality and quantity of landfill gas generated (Hanson et al. 2010; 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);
- Increasing carbon monoxide readings over 1,500 ppm indicate an active smoldering event;
- 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 or landfill gas ratios of CH_4 to CO_2 plots are used as confirmatory evidence of an SSE or fire.

Heat generated from a smoldering fire or reaction can damage the environmental control systems of landfills. Elevated temperature in a municipal solid waste landfill can pose a health, environmental, and safety risks because the elevated temperature can generate excessive gases, pressure, and damage landfill infrastructure. Elevated temperatures have been documented in municipal solid waste (MSW) landfills, construction demolition debris landfills, industrial waste fills, and sanitary dumps (Martin et al. 2013; Sperling and Henderson 2001; Hogland and Marques 2003; Ettala et al. 1996; Riquier et al. 2003; Øygard et al. 2005; El-Fadel et al. 1977; Nikolaou 2008; Merry et al. 2005; Koelsch et al. 2005; Frid et al. 2009). The presence of elevated temperatures, particularly in MSW landfills, can impact the integrity of the cover and liner systems, leachate quality, gas composition, slope stability and differential settlement, odor mitigation, and abatement operations (Lewicki 1999; Øygard et al. 2005; Jafari et al. 2014a; Stark et al. 2012; Øygard et al. 2005). 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).

Several factors can lead to landfill temperatures above 65°C, including aerobic decomposition, self-heating, partially extinguished surface fires, exothermic chemical reactions, spontaneous combustion, and smoldering combustion. MSW landfills have experienced elevated temperatures due to possible exothermic chemical reactions of industrial wastes, including APW, incinerator ash and bottom ash (Klein et al. 2001; Klein et al. 2003), tires (Wappett and Zornberg 2006), iron waste, steel mill slag, petroleum coke, flue gas desulfurization gypsum, fluidized bed combustion residues (Anthony et al. 1999), lime kiln dust, and dried wastewater sludge (Zerlottin et al. 2013).

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).

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 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. To date, I have not observed an SSE at a landfill with an active gas collection system that has just appeared. The data relating to SSEs has always involved 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 and the ratio of CH_4 to CO_2. The landfill operator should make adjustments to their gas extraction 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 exceed 130.9°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 an SSE 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;
- Decreasing ratio of CH_4 to CO_2 below unity (<1.0);
- Temperatures greater than 149°F (65°C)
- 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) or H_2) in the gas collection wells within one month; or
- Orders of magnitude increase in benzene and/or methyl ethyl ketone (MEK) concentrations.

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

- The melting, collapsing, or pinching of gas collection wells or leachate collection systems;
- Ratio of CH_4 to CO_2 below .5;
- 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/subsurface smoldering events. 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 2 summarizes industry SOPs and other documents on landfill operations and prevention of fires.

Table 2. 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 60°F 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

Discussion

As this smoldering and heating event has progressed at BSL and at other Republic solid waste sites with smoldering and heating events, some of the discussions have centered on the terminology and/or the definition of a subsurface smoldering event. By definition a smoldering event is a fire. As previously stated there are two types of fires, flaming and smoldering. At the Countywide facility in Ohio, the subsurface event was referred to as a pyrolysis and/or an SSO. Just recently in an August 29, 2015, publication of the "The Hill," a U.S. EPA spokesman said the BSL is not on fire but only smoldering, which is a common occurrence. Diverging opinions as to the definition of a subsurface fire have legal, insurance coverage, and social perception complications. In my opinion, the term "fire" was avoided by Republic at Countywide so that the facility was not in violation of a number of Ohio EPA's Solid Waste Regulations and U.S. EPA's, NSPS regulations that use the term fire. While the opposite was true at the Republic's Congress incident and other subsurface events, I have consulted on. To meet conditions related to claims for environmental damages, the responsible party has to prove the facility has suffered damages from a fire. Lastly, the term "landfill fire" causes landfill operators, regulatory agencies, and the public to become concerned. Typically the public does not have a concept of an SSE and sometimes envisions subterranean caverns of fire. The term "landfill fire" is not always the best choice of words to describe the subsurface incident. Unfortunately, in March 1984 an industry publication, Waste Age, coined the term "landfill fire" to describe both surface fires (e.g., a surface fire started from a load of barbecue ashes in the active disposal area) and subsurface fires (e.g., a smoldering fire below the surface). As a public relations solution to this issue, some facilities have used terms like ROSE (Rapid Oxidization Subsurface Event), SOE (Subsurface Oxidation Event), SSO (Subsurface Oxidation Event), subsurface reaction, chemical reaction, pyrolysis, heating event, and one facility in the eastern part of the United States used the term "Puff the Magic Dragon" to describe a smoldering event (Thalhamer 2011).

While I recognize the above terminology is meant to convey a passive message to the public about a localized incident, one must realize these terms should not be used to avoid the possible violations of state and federal statutes and/or circumvent the definition of burning or fire. Also, under the Community-Right-To-Know Act, a facility should provide local government responders and the public with information about possible chemical hazards in their communities if an SSE damages landfill infrastructure or release environmental contaminates. Even BSL's consultant SCS Engineers recognized this terminology dilemma and adjusting their reports over time. In January of 1994, SCS Engineers prepared a "Landfill Fire Mitigation" proposal for the 1992 underground fire at BSL. In the 1994 proposal, SCS Engineers discussed the "symptoms" of a *landfill fire*, and proposed using thermography they had done on other similar *landfill fire* projects. The proposal also discussed previous emergency response contract work with U.S. EPA on other *landfill fires*, how to mitigate a *landfill fire* by soil cover, foam, liquid nitrogen or carbon dioxide, water application, and bentonite slurry. SCS Engineers also discussed best management practice for *landfill fires* such as not using infrared thermography when "combustion is contained at greater depth, as often occurs in deeper landfills." In April 2008 SCS Engineers presented a document to the California Integrated Waste Management Board entitled "*Fire Investigation Summary Report, Former Lawson Dump, Torres Martinez, Desert Cahuilla Indian Community" where* they described using temperatures and carbon monoxide as the primary indicators of a *subsurface fire*.

In April 2012, SCS Engineers prepared a report entitled "*Contingency Plan, Bridgeton Landfill, Subsurface Oxidation Event,"* for BSL. In this report SCS Engineers stated that BSL experienced a fire in 1994 and monitoring indicated the presence of subsurface combustion. Later in the document SCS Engineers describes a subsurface oxidation (SSO) event, which can include "a range of conditions, from active smoldering of waste in the shallow subsurface, to ongoing chemical reactions at greater depths." They describe the primary impacts of an SSO as being high temperatures and rapid settlement. SCS Engineers also stated the landfill gasses generated by an SSO are significantly different from typical landfill gas odors and the higher temperatures can cause additional volatile organic compounds to be present in both landfill gas and leachate. They state that "Active *landfill fires* are marked by higher temperatures than those found at Bridgeton to date." Lastly, when it comes to a remediation approach for the BSL incident, SCS Engineers state "At this time, no practical approach to chemically counteract the ongoing reaction have been found… the most effective approach to manage an SSO is to prevent oxygen infiltration, control the impacts of the SSO, maximize capture of the gases being generated, and continue focused monitoring to understand the status of the SSO."

Cover Integrity

SCS Engineers are correct in stating the most effective approach to managing an SSO or SSE is to prevent oxygen infiltration. However, based on a review of the MCC report from April 2008 to December 2010, the BSL was experiencing chronic long-term site erosion issues in the South Quarry final cover that could allow for oxygen to infiltrate the cover and into waste. Starting in June 2008, erosion issues were reported in June, July, August, and September with a statement that large subsidence occurred by GEW-65 in July. In 2009, erosion control problems were reported every month except November. In March 2009, MMC's report stated no erosion had been fixed and there were multiple cases of erosion on the north, south, east, and west side slopes. Additionally, MCC reported in three consecutive monthly cover integrity reports, "extreme erosion" existed by Rock Brain close to GEW17 and erosion through the berm, while the fourth month

MCC changed it to read “extensive erosion.” In 2010, the problems with erosion continued for the first seven months. In March and April 2010, MCC reported that approximately 10 yards from GEW-79 a hole in the ground was discovered that measured three feet by two feet deep and that pipes were out of the ground that need caps.

Also an erosion control issue was identified by Saint Louis County Health Department in there Sanitary Landfill Inspection Report, dated July 31, 2008. The inspector reported “Several erosion gullies (3-4 ft deep) in the final cover were observed all over the landfill. The inspector did not observe any exposed waste.” Figures 11 to 13 are MCC’s summary monthly cover integrity inspections for 2008 to 2010.

I witnessed some of these types of erosion control issues during my site visit in June 2012 in the South Quarry and in July 2015 in the North Quarry.

Monthly Cover Integrity Inspection
Surface Monitoring Design Plan

Site: Bridgeton

Month	Inspection Date	Inspection Initials	Cover Integrity Problems found during the Inspection
January			
February			
March			
April			
May			
June	6/4/2008	ML	Erosion: on southside of landfill between PEW's 7 and 6, by PEW 9, by PEW 11, by GEW 8, up hill from GEW 63, by GEW 37, by GEW 34.
July	7/11/2008	ML	Erosion: uphill from CT-10, by GEW 37, 8, 34, uphill from GEW 63, by PEW 9 and 11, on southside between PEW's 1 and 6, between PEW's 5-12 and 22-24. Large subsidance by: GEW 65
August	8/22/2008	ML	Erosion by: GEW 8, betwwen GEW 12A and 13, small erosion by GEW 20A, GEW 29, GEW 44, between GEW 59 and 58 (top of hill), by GEW 78, between GEW 78 and 77, by 81, between 80 and 81, by GEW 82.
September	9/2/2008	ML	Erosion: B4 - GEW8, GEW29, GEW44, GEW78, GEW81, GEW82, between GEW's = 12A and 13, GEW's 59 and 58 (top of hill), GEW's 78 and 77, GEW's 80 and 81, small erosion by GEW20A.
October			
November			
December			

Figure 11. 2008 monthly cover integrity inspections for BSL (Source: MCC September 2008)

Monthly Cover Integrity Inspection
Surface Monitoring Design Plan

Site: Bridgeton 2009

Month	Inspection Date	Inspection Initials	Cover Integrity Problems found during the Inspection
January	1/5/09 & 1/6/09	ML	Erosion by GEW's: 18, 29, 34, 37, 44, 45, 63, 57, 64, 68, 69, 78, 82, 2 cases by Gew 25A, GEW 8. Erosion between GEW's: 10 and 11, 12A and 13, 67 and 71 (along road), multiple cases between: 59 and 58, 77 and 78, 80, and 81. Erosion: North of GEW 52, above GEW 7, North of GEW 12A, NW of GEW 19A, South of 21A, 20 yds. NW and NE of GEW 23A, directly below LCS-4A.
February	2/5/2009	ML	Erosion by = approximately 40 yds East of 12A, West of 14A, West of 15, 20, and 40 yds West of 16, by 18, 20 yds South and 30 yds East of 20A, by 26 and 27A, 29, 32, 69, (big) by LCS-4A, approximately 40 yds West of %-56, North of PEW3. Erosion between = 6 and 7, 10 and 11, 12A and 13, 16 and 17, 33 and 34, 67 and 71, (along road), 59 and 58, 64 and 68, 80 and 81, PEW 23 and PEW 26. Multiple cases = around 7,8,11, and 19A, 5 cases (big) North of 23A, 4 cases South of 25A, around 78 and 82.
March	3/3/2009 TR & 3/3/09 ML	TR/ML	TR: Erosion in berm between GEW43 and GEW44. ML: After performing the monthly cover integrity inspection for March, found that no erosion has been fixed from February. Multiple cases of erosion on north, south, east, and west sides of landfill. (see February).
April	4/6/09-4/7/09	ML	Erosion by GEW's: 7, 8, 10, 11, 12A (above), 15, 16, 18, 19A, 21A, 23A (4 cases above well), 25A, 27A (below), 29, 36 (above), 44, 45, LCS-4A (below), 63, 69, 78, 82, PEW 6, PEW 3. Erosion between: 12A and 13, 16 and 17, 33 and 34, 32 and 33, 67 and 71 (along road), 57 and 58, 80 and 81.
May	5/13/2009	ML	Erosion: Between GEW22 and 23A, multiple cases by 25A, by GEW29 (bad), between GEW33 and 34, by LCS-4A, between PEW 9 and 10, between GEW16 and 17.
June	6/16/2009	TR	Extreme erosion by Rock Brain, close to GEW17. Surface erosion between GEW17 & GEW18, GEW15 & GEW16, GEW16 & GEW17, GEW24 & GEW25A, GEW32 & GEW33, GEW77 & GEW78, GEW80 & GEW81. Erosion below LCS-4A. Erosion through Berms by GEW7, by GEW29, between GEW32 & GEW33, between GEW80 & GEW81. Erosion on & around all road on slopes.
July	7/1/2009	TR	Extreme erosion by rock let down by GEW17. Erosion on and around Road up Slope. Surface erosion between GEW17-GEW18, GEW15-GEW16, GEW16-GEW17, GEW24-GEW25A, GEW32-GEW33, GEW77-GEW78, GEW80-GEW81. Erosion below LCS4A. Erosion through berms - by GEW7, GEW29 between GEW32-GEW33, GEW80-GEW81, below GEW15.
August	8/5/2009	TR	Extreme erosion by rock let down by GEW17. Surface erosion between GEW17 & GEW18, GEW15-GEW16, GEW16-GEW17, GEW24-GEW25A, GEW32-GEW33, GEW77-GEW78, GEW80-GEW81. Erosion below LCS4A. Erosion through berms by GEW7, GEW29. Between GEW32-GEW33, GEW89-GEW81, below GEW15. Erosion and around road upslope.
September			
October	10/5/09 & 10/6/09	TR	Holes through berms - between 80-81, by I, 15, 17R, 29, both berms above 20A, below 21A both sides. Erosion - beside letdown at 17R, by road upslope, between 77-78, by 29, 34, 64, 68, 81, between 80-81.
November	11/12/2009	TR	The erosion is all being repaired at this time.

Figure 12. 2009 monthly cover integrity inspections for BSL (Source: MCC November 2009)

Monthly Cover Integrity Inspection
Surface Monitoring Design Plan

Site: Bridgeton 2010

Month	Inspection Date	Inspection Initials	Cover Integrity Problems found during the Inspection
January	1/4/2010 TR 1/20/2010 ML 1/21/10 ML	TR , ML, ML	Erosion between wells 2-3, letdown - 35, 14A-16R. Erosion by berms, below 8 inches berm, above both berms, below 35. Erosion by 68. 1/20/10 ML - Erosion: small cases of erosion by Gen. 7. Multiple cases of erosion on the west slope. (Erosion repair in progress).
February	2/3/10 & 02/04/10	ML	Erosion: Multiple cases around GEW 8, below GEW 15 (repaired erosion washing out), erosion between 24A and 25A by 26R, by 33R.
March	3/4/10 & 3/5/10	ML	Erosion: multiple erosion by GEW8, erosion by GEW11, GEW15, GEW18R, GEW19A, by GEW22R, GEW25A, GEW31R, GEW33R, GEW84. Wells with dirt around well settling: GEW31R, 45R, 46R, 84, 59R, 61R, 83, and 70R. Note: those wells will need dirt placed around them. * Found hole in the ground 10 yards from 79R, approximately 3 ft. around, need to fill with dirt.
April	4/27-28/10	ML	Pipes out of ground that need caps: 4" SCH40 by GEW11/ 3-3" SCH40 Pipes by GEW60/ 3" SCH40 by 69R / 4" HDPE by GEW 70R/ 4@ HDPE by 78R and 79R/ 4" HDPE by 76R/ 2-2" HDPE pipes by PEW's near flare. Gew's w/settling dirt around well: GEW84, 83, 70R, 78R, and 76R. Approx. 10 yards east of 79R, hole in ground approx. 3' by 2' deep.
May	5/10/10- 5/11/10	ML	Wells with settling - same as April cover Integrity. Erosion - by GEW13, by GEW 15.
June	6/21/10 & 6/23/10	ML	Erosion: by GEW 11, between 12A and 13, by GEW 15.
July	7/12/10 & 7/13/10	ML	Erosion: By GEW 11, between 12A and 13, by 15 (on berm).
August	8/9/10 & 8/10/10	ML	Sharp onsite repairing any erosion and filling around settling GEW's. No erosion was found onsite.
September	9/13/10 & 9/14/10	ML	Found no signs of erosion or any leachate breakouts.
October	10/5/10 10/6/10	ML	Found no cases of erosion or leachate breaks onsite.
November	11/2/10 11/3/10	ML	Small erosion between GEW84 and 85. The rest of the site seemed to be free of any erosion.
December			

Figure 13. 2010 monthly cover integrity inspections for BSL (Source: MCC November 2010)

Special Waste

The has been some testimony in the 2013 Buck vs. Republic Services litigation (Almanza 2013, Exhibit 1, Table 9) concerning disposal of special waste and the relationship to the subsurface reaction. After reviewing the deposition materials relating to Special Waste disposal, I was only able to identify 13 records that may contain potential reactive materials out of an estimated 775 records, which is less than 2%. Without knowing the reactive waste volume accepted by BSL, one would have to assume any reactive materials were mixed throughout the South Quarry and into the Neck to claim the special waste contributed to the subsurface reaction. Furthermore, the facility records produced to date have not identified long-term leachate recirculation as was the case in the Countywide subsurface incident. Finally, Subtitle D landfills, such as BSL are not allowed to accept reactive wastes, so unless the waste stream was misrepresented in the late 1990's or early 2000's during the profiling process, the likelihood of the special waste being reactive and disposed of at BSL is minimal.

Cause

While characteristics resulting from the BSL SSE are similar i.e., odors, leachate and landfill gas outbreaks, waste temperatures greater than 200°F, excessive landfill gas pressures, accelerated landfill settlement, melted/collapsed landfill infrastructure, cover integrity issues, and changes in leachate and gas composition were similar to Republic's incident at Countywide in 2006, the BSL SSE is not related to a chemical reaction with aluminum dross (See Photo 16).

Photo 16. Landfill Gas buildup Under the Geomembrane Cover at Countywide Landfill, Ohio, Summer 2006. (Source: Ohio EPA)

I have a high level of confidence that the cause of the burning incident at the BSL is traceable to three key findings. The first finding was BSL's decision to install and operate an extensive exterior gas extraction system including trenches and closely spaced perimeter extraction wells in an attempt to abate the methane gas migration violations. This decision contributed to the perimeter of the landfill becoming oxygenated or overdrawn with atmospheric oxygen. While this type of design is allowed and therefore not a violation of NSPS regulations, in my opinion this design and its implementation can result in multiple subsurface smoldering events such as those seen at Republic's Forward Landfill in California. The second finding was the consistent overdraw of various interior gas wells and other interior extraction points such as the leachate collection sumps. In fact, BSL requested an HOV for oxygen content in the leachate extraction wells for a six month period from January 2009 through June 2009 (AquaTerra 2009). This decision may have contributed to atmospheric oxygen impacting the waste just above the leachate level. The third finding was the on-going erosion problems to the final soil cover in the South Quarry from 2008 to 2015. It is my opinion the integrity issues of soil cover from 2009 to 2010 were directly correlated to some of the wellfield exceedance. These erosion control problems allowed oxygen to enter the waste mass in the South Quarry. Oxygen intrusion through the cover may have allowed the waste to heat and switch decomposition cycles from anaerobic to aerobic near the surface and possibly at one or more leachate sumps. By examining the MCC cover integrity reports for the period of January 2009 to April 2009 in comparison to the reported gas extraction wells BRIEW12A, BRIEW-59, and BRIEW-63, identified as impacted by an SSO, these impendent events become spatially similar in the South Quarry.

It is my opinion the burning of solid waste at BSL resulted from the three findings. The primary cause of the SSE was oxygen infiltration into the waste mass from overdrawing the gas collection system and/or issues with the integrity of cover. The resulting smoldering and heating events at BSL have damage the integrity of environmental control systems.

Based on the current BSL temperatures and CO, methane, and hydrogen data along with my July 2015 site visit, it is my opinion the subsurface smoldering and heating events have spread throughout the South Quarry and in the "Neck."

Conclusions

Originally, in April 2012, I was requested by MDNR to provide an initial assessment of the situation at the BSL. Based on available data, reports, and a site visit, I concluded the facility has and is currently undergoing a subsurface smoldering and heating event that is associated with the burning of solid waste. My opinion as of July 2015, (Note: this is the latest BSL monthly data package available at the time of writing) is the same: the BSL is still being impacted by a subsurface smoldering and heating event in the neck area and in the southeast site of the South Quarry where burning of solid waste appears to be most active. Moreover, based on my experience, education, training, site documentation, recently available BSL confidential reports, depositions, as well as personal knowledge of the five other Republic solid waste sites with smoldering and heating events, I hold the following opinions to a reasonable degree of professional and scientific certainty:

1. The catastrophic event at the BSL was foreseeable and preventable. It resulted from two practices based on the business decisions of the owners and operators of the landfill: (1) overdraw of the gas collection system to attempt to abate the landfill gas migration violations, and (2) the lack of timely maintenance to protect the integrity in the final soil cover in general from 2008 to 2015 and specifically in the South Quarry from January 2009 to November 2009. By engaging in these practices under the above circumstances, BSL failed to exercise reasonable care.

2. The BSL has sustained the following conditions over a period of years:

    - Erosion and desiccation damage in the soil cover;
    - Cover integrity problems;
    - Increased temperatures and pressures in the landfill gas control systems and waste mass;
    - Long term landfill gas migration violations;
    - Oxygen intrusion above 5% by volume in the landfill infrastructure (Source: BSL Wellfield Exceedance Report for July and August 2015);
    - Landfill surface temperatures over 190°F (Source: July 2015 site visit by Thalhamer);
    - Landfill subsurface temperatures over 220°F (Source: BSL August 2015 TMP readings);
    - Decreased methane production;
    - Elevated concentrations of volatile and semi-volatile organic compounds;
    - Elevated carbon monoxide concentrations above 1500 ppmv;
    - Smoldering odors;
    - Combustion residue in the landfill gas control systems;
    - Unusually rapid and excessive landfill settlement; and
    - Damage to landfill environmental control systems.

3. Based on these conditions above and multiple prior smoldering and heating events and at Republic solid waste sites such as Countywide Recycling and Disposal Facility, Forward Landfill, Congress Development Company in Illinoi,

and Middle Point Landfill in Tennessee, the BSL management should have known this catastrophic event was plausible. As these conditions emerged, investigatory and remedial actions should have been aggressively put into effect. The investigatory and remedial actions that were undertaken were inadequate and/or untimely in preventing the catastrophic event at BSL.

4. The subsurface smoldering and heating events have caused accelerated settlement, gas migration, elevated temperatures, uncontrolled releases of landfill gases, leachate outbreaks, and nuisance and other violations of state and federal air and solid waste laws and regulations.

5. The subsurface smoldering and heating events have caused damage and/or destroyed the landfill leachate and gas control system components.

6. The subsurface smoldering and heating events have caused damage to the soil cover and FML.

7. The subsurface smoldering and heating events have caused excessive leachate and odors to be generated.

8. The BSL facility has allowed solid municipal waste to burn starting in December 2010 and solid municipal waste is burning in the neck and southeast corner of the facility as of July 2015.

My observations and opinions concerning the incident at the BSL in Missouri are provided to the Missouri Attorney General's Office. This report was prepared by a Registered Professional Engineer for the State of California.

Sincerely,

Todd Thalhamer, P.E.
License No., C055197
Hammer Consulting Services

REGISTERED PROFESSIONAL ENGINEER
TODD THALHAMER
No. C055197
CIVIL
STATE OF CALIFORNIA

References

Almazna, C. August 23, 2013. Depositions from Buck v. Republic Services, District Court, Eastern District of Missouri, Eastern Division. 4:13-cv-00801-TCM.

Anthony, E.J., Jia, L., Caris, M., Preto, F., and Burwell, S. (1999”. “An examination of the exothermic nature of fluidized bed combustion (FBC) residues.” Waste Manag. 19, 293-305.

Agency for Toxic Substances and Disease Registry (ATSDR). (2001). “Chapter 2: Landfill gas basics. Landfill gas primer—An overview for environmental health professionals,” “Chapter 3: Landfill Gas Safety and Health Issues, Atlanta.

AquaTerra. (2005 to 2011). NSPS Semi-Annual Reports for Bridgeton Landfill, LLC, Bridgeton, Missouri.

AquaTerra. (2009). Summary Report for Leachate Extraction Wells, Oxygen Limitation, Bridgeton Landfill, L.L.C., Bridgeton Missouri.

Babrauskas, V. (2003a). “Common solids.” Chapter 7, Ignition handbook, Fire Science Publishers, Issaquah, WA.

Babrauskas, V. (2003b). “Pyrophoric carbon and low-temperature, long-term ignition of wood.” ⟨http://www.doctorfire.com/low_temp_wood1.pdf⟩.

Babrauskas, V. (2003c). “Terminology.” Chapter 2,14 Ignition handbook, Fire Science Publishers, Issaquah, WA.

Barlaz, M., Schaefer, D.M., and Ham, R.K. (1989). “Bacterial Population Development and Chemical Characteristics of Refuse Decomposition in a Simulated Sanitary Landfill.” Applied Environmental Microbiology.

Bates, M. (2004). “Managing Landfill Site Fires in Northamptonshire: A research study by the University College Northampton for the Environment and Transport Scrutiny Committee, Northamptonshire County Council.” Sustainable Wastes Management Centre (SITA), University College Northampton, Boughton Green Road, Northampton Northamptonshire.

Benson, C. H., Barlaz, M. A., Lane, D. T., and Rawe, J. M. (2007). “Practice review of five bioreactor/recirculation landfills.” Waste Manage., 27(1), 13–29.

Bogner, J.E., Sweeney, R.E., Coleman, D., Huitric, R., and Ririe, G.T. (1996). “Using Isotopic and Molecular Data to Model Landfill Gas Processes.” Waste Management Research.

Bridgeton Landfill, LLC. (2015). “Wellfield Exceedance Report.”

Calder, G. V., and Stark, T. D. (2010). “Aluminum reactions and problems in municipal solid waste landfills.” Pract. Period. Hazard. Toxic Radioact. Waste Management., 14(4), 258–265.

Crutcher, A.J., and Rovers, F.A. (1982). “Temperature as an Indicator of Landfill Behavior.” Water, Air, and Soil Pollution.

DeHann, J.D., (2007). Kirk’s Fire Investigation, Sixth edition. Pearson Prentice Hall, Upper Saddle River, New Jersey.

El-Fadel, M., Findikakis, A., and Leckie, J. (1977). “Environmental impacts of solid waste landfilling.” J. Environ Manag., 50, 1-25.

Ettala, M., Rahkonen, P., Rossi, E., Mangs, J., and Keski-Rahkonen, O. (1996). “Landfill Fires in Finland.” Waste Management & Research.

Emergency Response Guidebook. (2008). [http://phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/erg2008_eng.pdf]

Environment Agency (2004). “Quantification of trace components in landfill gas” [http://www.gassim.co.uk/documents/P1-491-TR%20Quantification%20of%20Trace%20Components%20in%20LFG.pdf]

Farquhar, G.J., Rovers, F.A. (1973). “Gas Production During Refuse Decomposition.” Water, Air and Soil Pollution 2.

Feezor Engineer, Inc. (20150). “Landfill Gas Corrective Action Update, Bridgeton Landfill.”

Frid, V., Doudkinski, D., Liskevich, G., Shafran, E., Averbakh, A., Korostishevsky, N., and Prihodko, L. (2009). “Geophysical-geochemical investigation of fire-prone landfills.” Environ Earth Sci., 60(4), 787-798.

Fire, F. L. (1996). “Chapter 6: Fire and pyrolysis.” The common sense approach to hazardous materials, 2nd Ed., Fire Engineering Books and Videos, Pennwell Books, Tulsa, OK, 105–123.

Haarstrick, A., Hempel, D.C., Ostermann, L., Ahrens, H., and Dinkler, D. (2001). “Modeling of the biodegradation of organic matter in municipal landfills.” Waste Management & Research.

Hanson, J.L., Yesiller, N., and Oettle, N.K. (2010). “Spatial and Temporal Temperature Distributions in Municipal Solid Waste Landfills.” Journal of Environmental Engineering. 136 (8), 804–814.

Hogland, W., and Marques, M. (2003). “Physical, biological, and chemical processes during storage and spontaneous combustion of waste fuel.” Resource conservation and recycling, 40, 53-69.

Industry Code of Practice (2008). “Management and Prevention of Sub-Surface Fires.” [http://candpenvironmental.co.uk/docs/edition1.pdf]

International Association of Fire Chiefs. (2010). “Hazardous Material Awareness and Operations.” Chapter 3, Recognizing and Identifying the Hazard, Jones and Bartlett Publisher, LLC., Sudbury, Massachusetts.

Jafari, N.H., Stark, T.D., and Rowe, K. (2014a). “Service life of HDPE geomembranes subjected to elevated temperatures.” Journal of Hazardous, Toxic, and Radioactive Waste, 18(1), 16-26.

Klein, R., Baumann, T., Kahapka, E., and Niessner, R. (2001). “Temperature development in a modern municipal solid waste incineration (MSWI) bottom ash landfill with regard to sustainable waste management.” J. Hazard. Mater., 83(3), 265–280.

Klein, R., Nestle, N., Niessner, R., and Baumann, T. (2003). “Numerical modelling of the generation and transport of heat in a bottom ash monofill.” J. Hazardous Materials. B100, 147-162.

Koelsch, F., Fricke, K., Mahler, C., and Damanhuri, E. (2005). “Stability of landfills – the Bandung dumpsite disaster.” Sardinia 2005, 10th Int. Waste Manag. Landfill Sympm., Cagliari, Italy.

Lambrich, M. November 11, 2013. Depositions from Buck v. Republic Services, District Court, Eastern District of Missouri, Eastern Division. 4:13-cv-00801-TCM.

LandTec. (2005a). “LFG Field Monitoring, Part 1” CES-LANDTEC, Colton CA. [http://www.landtecna.com/uploads/resources/7/2/LFG%20Field%20Monitoring%20-%20Part%201.pdf]

LandTec. (2005b). “LFG Field Monitoring, Part 1” CES-LANDTEC, Colton CA. [http://www.landtecna.com/uploads/resources/10/2/Landfill%20Fires.pdf]

Lewicki, R. (1999). “Early Detection and Prevention of Landfill Fires.” Proceedings Sardinia 99, Seventh International Waste Management and Landfill Symposium, CISA, Environmental Sanitary Engineering Centre, Cagliari, Italy.

Martin, J.W., Stark, T.D., Thalhamer, T., Gerbasi, G.T., Gortner, R.E. (2011). “Detection of Aluminum Waste Reactions and Waste Fires.” Pract. Period. Hazardous, Toxic and Radioactive Waste.

Martin, J.W., Gerbasi, G.T., Thalhamer, T., Gortner, R.E. (2012). “Aluminum waste reactions indicators in Municipal Solid Waste Landfill.” Pract. Period. Geotechnical and Geoenvironmental Engineering, 252–261.

Meima, J.A., Mora-Naranjo, N., and Haarstrick, A. (2008). Sensitivity analysis and literature review of parameters controlling local biodegradation processes in municipal solid waste landfills. Waste Management.

Methanol Fire. (1998).
[http://youtu.be/HSFrY9tAH1M]

Merry, S.M., Fritz, W.U., Budhu, M., and Jesionek, K. (2005). "Effect of gas on pore pressures in wet landfills." J. Geotech. and Geoenvir. Engrg., 132(5), 553-561.

Missouri Department of Natural Resources, Air Pollution Control Program. (2009 to 2001). Part 70 Operating Permit, Exceedance Report

Monitoring Control and Compliance, Inc., (2008 to 2011). Reports: "Monthly LFG Reports for Bridgeton Landfill, Bridgeton Missouri.

Nammari, D., Hogland, W., Marques, M., Nimmermark, S., and Moutavtchi, V. (2004). Emission from uncontrolled fire in municipal solid waste bales. Waste Management.

Nikolaou, K. (2008). "Environmental management and landfill fire accidents." J. Environ Protection Ecology. 9(4), 830-834.

Ontario Ministry of Agriculture, Food, and Rural Affairs (1993). "Silo and Hay Mow Fires on Your Farm, Fact Sheet." 93-025, Ontario, Canada.
[http://www.omafra.gov.on.ca/english/engineer/facts/93-025.htm]

Øygard, J. K., Måge, A., Gjengedal, E., and Svane, T. (2005). "Effect of an uncontrolled fire and the subsequent fire fight on the chemical composition of landfill leachate." Waste Manage., 25(7), 712–718.

Parker, T., Dottridge, J., and Kelly, S. (2002). "Investigation of the composition and emissions of trace components in landfill gas." R&D Tech. Rep. P1-438/TR, Environment Agency, Rotherham, UK.

Pitts, W. M. (2007). "Ignition of cellulosic fuels by heated and radiative surfaces." National Institute of Standards.

Riquier, L., Guerbois, M., Budka, A., Hebe I., and Riviere, S. (2003). "Underground fires characterization in landfills: Investigation methods." Proc. Sardinia 2003, Ninth International Waste Management and Landfill Symposium, Cagliari, Italy, CISA, Italy.

Rowe, R. K., Islam, M. Z., Brachman, R. W., Arnepalli, D. N., and Ewais, A. R. (2010). "Antioxidant depletion from a high density polyethylene geomembrane under simulated landfill conditions." J. Geotech. Geoenviron. Eng., 136(7), 930–939.

Saint Louis County Health, Solid Waste Management Program, Field Services Section. (2008). "Sanitary Landfill Inspection Reports."

Sperling, T., and Henderson, J.P. (2001). “Understanding and controlling landfill fires.” SWANA landfill symposium, San Diego, California.

Stark, T.D. (2013). Presentation: “Bridgeton Lab Data.” February 2013.

Stark, T.D. and Jafari, N.H. (2014). Presentation: “Bridgeton Landfill: Subsurface Smoldering Classification.”

Szczygielski, T. (2007). “Fire in the hole: Aluminum dross in landfills.”Waste Management J. Natural Resources and Environmental Law.

SCS Engineers. (2012)a. “Contingency Plan, Bridgeton Oxidation Event”

SCS Engineers. (2012)b. “Draft Summary Report Bridgeton Landfill Subsurface Oxidation Event.”

Tchobanoglous, G. (1993) “Physical, Chemical, and Biological Properties of Municipal Solid Waste.” Chapter 4, Integrated Solid Waste Management, Engineering Principles and Management Issues, McGraw Hill, Inc., New York, New York.

Tetra Tech Bas. (2013). Procedure for Landfill Gas Extraction Well Monitoring and Tuning Protocol for Elevated Subsurface Temperatures at the Sunshine Canyon Landfill.

Teter, J. August 28, 2013. Depositions from Buck v. Republic Services, District Court, Eastern District of Missouri, Eastern Division. 4:13-cv-00801-TCM.

Thalhamer, Todd. (2010). CalRecycle, “Fires at Solid Waste Facilities, Landfill Fire Guidance Document.” Sacramento, California. [http://www.calrecycle.ca.gov/swfacilities/Fires/LFFiresGuide/default.htm]

Thalhamer, T. (2011). U.S. EPA OSC Conference, “Waste Fires, Investigation, Evaluation and Response.” Orlando, Florida.

Thalhamer, T. (2012a). “Bridgeton Site Observation Report.” June 2012.

Thalhamer, T. (2012b). “Bridgeton Site Observation Report.” August 2012.

Thalhamer, T. (2013a). Presentation: “Analysis Report Bridgeton Landfill Data.” June 2013

Thalhamer, T. (2013b). Report: “Data Evaluation of the Subsurface Smoldering Event at the Bridgeton Landfill.” June 2013.

Thalhamer, T. (2014a). Memorandum: “Comments on the Evaluation of Possible Impacts of a Potential Subsurface Smoldering Event on the Record of Decision – Selected Remedy for Operable Unit-1 at the West Lake Landfill – Dated January 14, 2014.”

Thalhamer, T. (2014b). Memorandum: “Addendum to the February 14, 2014 Comments on the Evaluation of Possible Impacts of a Potential Subsurface Smoldering Event on the Record of Decision – Selected Remedy for Operable Unit-1 at the West Lake Landfill – Dated January 14, 2014.”

Thalhamer, T. (2014c). Memorandum: “Data Package Review for the Month of May and June 2014.”

Thalhamer, T. (2014d). Memorandum: “Data Package Review for the Month of July and August 2014.”

Thalhamer, T. (2015). Memorandum: “Data Package Review for the Month of July and August 2015."

Thalhamer, T., and Stark, T.D. (2013). Memorandum: “Comments on the Draft Bridgeton Landfill North Quarry Contingency Plan – Part 1, Dated June 27, 2013.”

U.S. EPA (1999). “Municipal Solid Waste Landfills, Volume 1: Summary of the Requirements for the New Source Performance Standard sand Emission Guidelines for Municipal Solid Waste Landfills FINAL.” Publication EPA-453R/96-004, Office of Air Quality, Planning and Standards, Research Triangle Park, North Carlolina. [http://www.epa.gov/ttn/atw/landfill/lf-vol1.pdf]

U.S. EPA (2002). “Emission of Organic Air Toxics from Open Burning.” EPA-600/R-02-076, Research Triangle Park, North Carolina.

U.S. Fire Administration (1998). “Special Report: The Hazards of Associated with Agricultural Silo Fires.” USFA-TR-096/April 1998, Emmitsburg, Maryland. [http://www.usfa.fema.gov/downloads/pdf/publications/tr-096.pdf]

U.S. Fire Administration (2002). “Landfill Fires: Their Magnitude, Characteristics, and Mitigation.” May 2002/FA-225, Arlington, Virginia. [http://www.usfa.dhs.gov/downloads/pdf/statistics/fa-225.pdf]

Vasbinder, D. October 16, 2013. Depositions from Buck v. Republic Services, District Court, Eastern District of Missouri, Eastern Division. 4:13-cv-00801-TCM.

Wappett, H.L., and Zornberg, J.G. (2006). “Full scale monitoring for assessment of exothermal reactions in waste tires.” Final Report Recycled Materials Resource Center Project No. 27, 312.

Waste Age (1984). Treating Subsurface Landfill Fires.

Westlake, K. (1995). “Biological, Physical, and Chemical Processes Within Landfill.” Chapter 3, “Landfill Gas.” Chapter 4, Landfill Waste Pollution And Control, Albion Publishers, Chichester, England.

Zerlottin, M., Refisci, D., Della Zassa, M., Biasin, A., and Canu, P. (2013). “Self-heating of dried wastewater sludge.” Waste Manag. 33, 12-137.

Appendix A
Curriculum Vitae for Todd Thalhamer

Todd Thalhamer, P.E.

Waste Management Engineer
August 2015

Contact Information

Hammer Consulting Services
Cell Number 530.391.2230 e-mail:ltfire88@gmail.com

Department of Resources Recycling and Recovery (CalRecycle), 1001 I Street, Sacramento, CA, 95682
Office number 916.341.6356 e-mail:todd.thalhamer@calrecycle.ca.gov

---

Current /Past Positions

CalRecycle, Waste Management Engineer **1992 to Present**
Performing environmental engineering duties for state removal and emergency projects. Note: The California Integrated Waste Management Board (CIWMB) became CalRecycle in 2010.

Hammer Consulting Services, President **2006 to Present**
Providing practical solutions and training to landfill and tire fires outside California. Privately consulted on waste fires in Austria, Mexico, Panama, and the United States. See project list for details.

El Dorado Hills Fire District, Lieutenant **1998 to Present**
Acting as a fire officer for the El Dorado Hills Fire Department. Supervising fire crews during response.

US EPA, Region IX, Interagency Personnel Assignment **2008 to 2012**
Providing technical assessment and analysis for landfill fires and gas control systems in Region IX.

Key Waste Fire Experience

Responded to significant (level 4) landfill fire in Panama City, Panama at the request for the US Embassy and Presidential Office of Panama. Developed a suppression plan that successfully extinguished the landfill fire and reduce smoke emission impacting the City of Panama.

Established California's first multi-agency disaster incident management team. May 2011.

Performed duties as the Operations Chief at the San Bruno Pipeline Explosion, San Bruno California. Coordinated the removal of 35 residential structures and other debris; directly supervised a debris incident command team that consisted of multiple state and county agencies, contractors, waste haulers, environmental consultants, and health and safety consultants. September 2010.

Performed duties as the Operations Chief at the first Cal/EPA coordinated residential structure removal project from a major wildland fire in South Lake Tahoe, CA. Developed a multi-agency debris incident management team and project specifications and scope of work for the removal of 256 structure burned by a wildfire. July 2007.

Acted as the project engineer for the CIWMB's Special Waste Division at the Tracy Tire Fire Remediation Project. Supervised and directed the remediation of the 7 million burned tires. 1999 to 2006.

Acted as the Heavy Equipment Branch Leader for both private firefighting and heavy equipment resources at the Fresno Debris Fire Incident, January-February 2003. Directly supervised two construction/removal companies and a private industrial firefighting company. January 2003.

Perform duties as the Incident Commander for the Tracy Tire Fire Suppression Project. Directed a team of firefighters, equipment operators, and safety professionals in extinguishing the longest burning tire fire in the United States, December 2000

Assist US Environmental Protection Agency's Emergency Response Team in Guam during a tire fire of 1,000,000 tires. Provided suppression guidance and remedial options to the government of Guam, January 1999.

Education **Humboldt State University** **1986-1992**
B.S. Environmental Resources Engineering with a concentration in Hazardous Waste Management.

Licenses Registered Professional Civil Engineer for the State of California, No. C055197
1996 to Present

Publications

1. *Aluminum Waste Reaction Indicators in MSW Landfill,* ASCE Journal of Geotechnical and Geoenvironmental Engineering, March 2012, Contributing Author
2. *Detection of Aluminum Waste Reactions and Waste Fires,* ASCE Journal of Hazardous, Toxic and Radioactive Waste, October 2011, Contributing Author
3. *Guidance for Conducting Emergency Debris, Waste and Hazardous Material Removal Actions Pursuant to a State or Local Emergency Proclamatio*n, California Environmental Protection Agency, October 2011, Contributing Author
4. *A New Way to Manage Structural Fire Debris from a Catastrophic Wildfire ("The Angora Protocols")*, 11th International Fire and Material Conference, San Francisco, USA, 2009, Author
5. *Landfill Fires: Their Magnitude, Characteristics, and Mitigation*, US Fire Administration May 2002, Technical Advisor
6. *Tracy Tire Fire Site Assessment of Tire-Derived Pyrolytic Oil-Affected Soil and Groundwater*, White Paper, California Integrated Waste Management Board, June 2007, Co-Author
7. *Landfill Fire Guidance Document*, White Paper, California Integrated Waste Management Board, April 2001, Author
8. *Burning Rings of Fire I and II,* California State Fire Marshal Office, 1999 and 2004 Technical committee

Presentations **Detection, Evaluation, and Suppression of Waste Fires,** Stark Consultants, Inc.
Multiple courses offered nationwide (Pennsylvania, Illinois, Indiana, Missouri) from 2008-present: *Advanced short course exploring the engineering, health, and environmental impacts of waste fires.*

Other Presentation

2015 Landfill Fire Control Detection, Evaluation, and Suppression Training, APWA Iowa Chapter, Des Moines
2014 Landfill Fire Control Workshop and Training Burn, Comox Valley Regional District and Fire Authorities
2014 Landfill Fire Control Workshop, Solid Waste Association of North American, British Columbia.
2012 Landfill Fires: Detection, Evaluation, and Suppression Training, Missouri Dept. of Natural Resources
2012 Solid Waste Association of North America Northern Lights Chapter Conference: The Cleanup: Disasters and the Aftermath of Waste, Keynote Address, " Taking Command in a Disaster,"

2012 US EPA OSC Conference, Waste Fires, Investigation, Evaluation and Response
2011 Rubber Manufactures Association Conference on Waste Tire Fires, Colorado
2011US EPA OSC Conference, Waste Fires, Investigation, Evaluation and Response
2010 Continuing Challenge Hazmat Workshop Waste Fire, Investigation, Evaluation and Response
2010 US EPA OSC Conference, Waste Fires, Investigation, Evaluation and Response
2008 International Tire Conference, Tire pile fires and regulations
2008 Landfill Fire Workshop, British Columbia, Canada
2006 Landfill Fire Trainings, Ohio EPA
2002-05 Radiation Emergencies for 1st Responders, Awareness Course, Various Fire Departments
2002 US EPA Emergency On-Scene Coordinator Conference Speaker: "Tire Fire Lessons, History and Case Study"
2001 Continuing Challenge Hazmat Workshop Speaker and Instructor: "Heavy Equipment Operations And Associated Safety Issues"
2000 California Environmental Health Association Symposium Speaker: "Waste Tire Fire in Guam and California"
1999 US EPA Emergency On-Scene Coordinator Conference Speaker: "Nightmare on 38th Street, Site History and Perspective of the Discovered Radioactive Source"
1999 Continuing Challenge Hazmat Workshop Speaker and Instructor: "Everything You Wanted to Know about Radiation"
1998 Landfill Gas Assessment Symposium Speaker: "LF Gas Monitoring and Subsurface Fires"
1997 CAL EPA Enforcement Symposium Speaker: "Environmental Crimes Case Study"

Certifications

Cal/OSHA Hazardous Materials Incident Response Operations
Supervisors of Hazardous Waste Workers
Various Radiation Safety Courses
US EPA Introduction to Hazard Categorization and Field Screen Training
Basic Forest Firefighter Training Course 1988, Basic Fire Engine Operations
Completed the 40-Hour Hazardous Material Incident Response Course {29 CFR 1910.120} at the California Specialized Training Institute
Cal OSHA Confined Space Rescue "Awareness" (Cal OSHA Title 8, Section 5156 thru 5158)
First Responder EDH Fire Department, CPR, and American Red Cross First Aid
California Fire Service Training and Education System (CFSTES) Fire Command 1A, 1C
Various Firefighter certificates
FEMA National Incident Management System 100, 200, 300, 400 and 700
Williams Hazard Industrial Firefighting Course

Productions

MythBusters - Provided environmental compliance, safety, and fire consulting for two 2013 episodes.

Regulations

Working knowledge of solid waste and hazardous waste regulation through the Resource Conservation and Recovery Act (RCRA), Clean Air Act (CAA) and the Clean Water Act (CWA). Working knowledge of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) on how to clean up uncontrolled or abandoned hazardous-waste sites as well as accidents, spills, and other emergency releases of pollutants and contaminants into the environment. Working knowledge of California and Federal Occupational Safety and Health Administration (OSHA) regulations for work safety for both the construction and fire industries.

Standards

Working knowledge and expertise in EPA's new source performance standards (NSPS) as it relates to landfill gas and subsurface landfill fires. Working knowledge of American Society of Testing and Materials (ASTM) for soil, waste, tire, and air. Also familiar with industrial hygiene, environmental, and occupational health and safety guidelines, methodologies, protocols, and best management through the American Conference of Industrial Hygienists (ACGIH) and National Institute for Occupational Safety and Health (NIOSH).

Awards 2014 Continuing Challenge Hazardous Materials Emergency Response Workshop –Responder of the Year Award

2014 United States Coast Guard Public Service Commendation Award – Oakland Estuary Cleanup Project

2007 Sierra Business Council 2020 Vision Award – Leadership in Protecting the Environment
2008, 2005, and 2003, 2002- El Dorado Hills Fire Volunteer of the Year
2003 California Legislature Assembly Resolution, Members Resolution No. 126, Recognized and thanked for his outstanding efforts in containing the Archie Crippen Debris Fire in Fresno County
2002 City of Sonoma Proclamation for exceptional project engineering

Civil Cases **John Michael Abicht, et al., Plaintiffs vs. Republic Services of Ohio, Defendants.** Waste fire expert for the Plaintiffs, Weitz and Luxenberg .
State of Texas vs. Zumwalt, Helotes Debris Fire**.** Waste fire expert for the State of Texas, Office of the Attorney General of Texas and the Department of Environmental Quality
State of California vs. Crippen, GOH Debris Fire. Waste fire expert for the State of California, Office of the Attorney General and CalRecycle
State of Idaho, Dept. of Environmental Quality Enforcement Case. Waste fire expert for the State of Idaho, Office of the Attorney General

US EPA Cases **USEPA and DOJ vs. Republic, Forward Landfill,** Waste fire expert for the US EPA and Department of Justice, Sacramento Office
USEPA and DOJ vs. Waste Management, Waimanalo Gulch Landfill, Waste fire expert for the US EPA and Department of Justice, San Francisco Office
USEPA and DOJ vs. County of Maui, Central Maui Landfill, Waste fire expert for the US EPA and Department of Justice, San Francisco Office

Depositions:

Buck v. Republic; September 3, 2013
Albicht v. Republic; November 8, 2012
Admiral Insurance Company v. Crippen; July 2, 2004

Waste Disaster Projects

- 2012 - Keynote Address "Taking Command in a Disaster," at the Solid Waste Association of North America Northern Lights Chapter Conference: The Cleanup: Disasters and the Aftermath of Waste
- 2010 - San Bruno Pipeline Disaster: Client: Cal/EPA, CalRecycle. Lead the recovery team at the San Bruno Pipeline Disaster. Performed duties as the Operations Chief and coordinated the removal of residential structure debris, hazardous waste, and asbestos. Developed project specifications and scope of work for the removal of 34 structures and other debris destroyed by 30 inch natural gas pipeline.
- 2007 - Angora Structural Fire Debris Removal. Client: Cal/EPA, CIWMB. Performed duties as the Operations Chief at the first Cal/EPA coordinated residential structure removal project from a major wildland fire in South Lake Tahoe, CA. Developed project specifications and scope of work for the removal of 256 structures burned by a wildfire.

Waste Fire Projects (Evaluations, Investigations, Publications, Presentation)

- 2015 WCA Landfill, Texas. Provide emergency response consultation.
- 2015 Black Oak Landfill, Missouri. Provide consultation on a possible subsurface smoldering event for MDNR.
- 2014 Lake County Wood Debris Fire, Emergency Response to implement an fire suppression plan and fire break, Lake County Solid Waste District, Montana.
- 2014 Iqaluit Dump Fire, Iqaluit, Canada. Provide initial consultation on suppression options, foam usage, health and safety issues and air emission related to smoldering solid waste and associated dioxin release.
- 2014 Pasco Sanitary Landfill, Washington. Provide initial consultation to both the responsible party and the State of Washington on the impacts and issues with fire suppression at landfills.

- 2014 George Town Landfill Fire, Cayman Islands. Press inquiry (Cayman Free Press=) on the toxicity and hazards of a landfill fires.
- 2014 Harrelson Materials Management, Louisiana. Press (www.shreveporttimes.com) inquiry on subsurface smoldering events and impacts to the community.
- 2014 to 2012 –Bridgeton Landfill Smoldering/Oxidation Event, St Louis Area, Missouri. Client: Missouri Department of Natural Resources. Provided an evaluation and review of a reported subsurface oxidation event. [Hammer Consulting Services]
- 2013-Cerro Patacon Landfill Fire, Panama. Client: Government of Panama. Provided emergency response services, technical oversight, and firefighting services for the Panamanian Waste Officials during landfill fire.
- 2012 - Contributing Author *Aluminum Waste Reaction Indicators in MSW Landfill,* ASCE Journal of Geotechnical and Geoenvironmental Engineering
- 2012 to 2009 - Forward Landfill Fire and Gas Issue. Client: US EPA, Region IX. Provided technical review, comments, and legal support for the landfill fire and gas control issue.
- 2012 to 2007 - Waimanalo Gulch Landfill Heating Event, Hawaii. Client: US EPA, Region IX. Provided technical review and comment to the heating event along the liner.
- 2012 to 2007- Central Maui Landfill Fire and Heating Event, Hawaii. Client: US EPA, Region IX. Provided technical review and comment to the fire and heating event.
- 2012 to 2010 - Azusa Tire Monofill Fire, California. Client: CalRecycle. Provided a review of the fire and evaluation of future expansion plans.
- 2010 - Instructor for Waste Fires, Investigation, Evaluation and Response, US EPA, Florida
- 2010 - Instructor for the Continuing Challenge Hazmat Workshop - Waste Fires, Sac, California
- 2010 - Contributing Author of "Aluminum Waste Reaction Indicators in MSW Landfill" ASCE Journal of Geotechnical and Geoenvironmental Engineering, October 2010
- 2009 - Philippines Landfill Fire Discussions, Technical Assistance, World Bank
- 2009 - Instructor for Waste Fires, Investigation, Evaluation and Response, US EPA, Florida
- 2009 - Instructor for Waste Fire Course, Short Course on Detection, Evaluation, and Suppression, Client: Paid Training, Indianapolis, Indiana
- 2009 - Instructor for Waste Fire Course, Short Course on Detection, Evaluation, and Suppression, Client: Paid Training, Chicago, Illinois
- 2009 to 2007 - Kailua-Kona Landfill Fire Suppression Project, Hawaii. Client US EPA, Region IX. Provided technical review and comment to the suppression plan.
- 2008 - Instructor for Waste Fire Course, Short Course on Detection, Evaluation, and Suppression, Client: Paid Training, Hershey, PA
- 2008 - Instructor for Landfill Fire Seminars, B.C., Canada
- 2008 - Instructor for International Tire Conference, San Diego California 2008 - Instructor/Presenter
- 2008 - Instructor/Presenter for International Tire Conference. Client: Cal/EPA, CIWMB. Presented information on tire storage, tire regulations, and tire fire response.
- 2008 to 2007 - Lawson Illegal Disposal Site Subsurface Debris Fire, Torres Martinez Reservation, California. Client: Cal/EPA, CIWMB and US EPA, Region IX. Provided technical review and comment to the operation and site investigation.
- 2008 to 2006 - Countywide Landfill Fire Issue, Ohio. Client: Ohio EPA. Discussions concerning landfill fire issues, review of infrared surveys, landfill operations including gas tuning logs, data trend analysis, and site recommendation.
- 2007 - City of Kingston Landfill Fire, Jamaica. Client: Solid Waste Authority for Jamaica. Provided technical assistance to a landfill fire.
- 2007 - Helotes Debris Fire, San Antonio, Texas. Client: City of Helotes and Bexar County Commissioners Court. Provided technical review of the incident. Also provided a presentation of a previous debris fire and discussed site issues and risk associated fire suppression.
- 2006 - Landfill Fires Guidance Document Final, CIWMB
- 2006 - Candlestick Point Subsurface Fire, San Francisco, California. Client: Cal-EPA, CIWMB. Performed duties as the incident commander for the suppression project. Project included representatives from San Francisco Fire Department, US EPA, Region IX, California Department of Parks and Rec, and San Francisco Health Department

- 2006 - Minimize Landfill Fire and Losses, Audio Conference, Client: Solid Waste Report, Speaker, Washington D.C.
- 2003 to 2006 - Tracy Tire Fire Remediation Project, San Joaquin County, California. Client: Cal-EPA, CIWMB. Supervised and directed the remediation of a tire fire site, in which 7.5 million tires burned. The project included the excavation and transportation of 387,000 tons of hazardous waste and contaminated soils.
- 2006 - Landfill fire, Australia, Pollution Response Agency. Client: Australia Pollution Response Agency and US EPA Region IX. Provided technical assistance with the landfill fire.
- 2004 - Chalan Pago Kajiyama Hardfill Facility Fire, Guam. Client: Guam EPA. Provided technical and suppression guidance on the debris fire.
  2003 - Yulupa Elementary Playground Tire Chip Fire Removal, Santa Rosa, California. Client: Cal-EPA, CIWMB and Bennett Valley Union School District. Supervised and directed the removal of burnt tire chips from a playground. Also collected samples and coordinated responsible agencies for the district.
- 2003 - Crippen (GOH - Fresno Debris) Debris Fire, Fresno, California. Client: Cal-EPA, CIWMB. Acted as Heavy Equipment Branch Leader for the suppression project. Supervised both municipal and private fire fighters during the suppression efforts. Also acted as a technical lead to the City of Fresno, County of Fresno, and US EPA, Region IX.
- 2003 - Woodlake Sanitary Landfill, Loretto, Minnesota. Client: Foth & Van Dyke and Assoc., Inc. and the State of Minnesota. Provide an evaluation of a rapid oxidation subsurface event at the landfill. [Hammer Consulting Services]
- 2003 - Idaho Tire Recovery Pile Evaluation, Lincoln County, Idaho. Client: State of Idaho, Office of the Attorney General. Provided an assessment of a number of tire piles and evaluated the fire hazards and environmental impact from a potential tire fire. Prepared an assessment report as a technical expert for tire fires.
- 2002 - Cogen Dump Los Angeles County Subsurface Fire, Closed Facility, California. Client: US EPA Region IX - Richard Martyn, OSC. Provide a review of LFG data and provided technical support to determine if a subsurface fire was present.
- 2002 - Greenhill Road Illegal Landfill/Debris Fire, Johnston, Rhode Island. Client: US EPA, Region I. Consulted and analyzed site data from the subsurface fire. Provided recommendation for monitoring probes, suppression techniques, and health and safety procedures and protocols. [Hammer Consulting, private venture]
- 2002 - Superior Greentree Landfill Fire, Kersey, Pennsylvania. Client: Superior Greentree Landfill, LLC. Consulted and analyzed site data concerning a rapid oxidation subsurface event. [Hammer Consulting Services]
- 2002 - Instructor/Presenter for Tire Fire Response, US EPA On-Scene Coordinator (OSC) Readiness Conference, Tampa, Florida. Client: US EPA.
- 2002 - Naco Landfill Fire, Naco, Mexico. Client: US EPA, Region IX, Emergency Response. Provided technical guidance on the suppression project to US EPA.
- 2001 - Developed a Response to Landfill Fire Guidance Document, Internal Document. Client: Cal-EPA, CIWMB.
- 2001 - Hunter’s Point Landfill, US Navy, San Francisco, California. Client: Cal-EPA, CIWMB and US EPA, Region IX. Provided technical review of a suppression plan for the subsurface fire and provided site recommendations.
- 2001 - Shredded Tire Facility in Ohlsdorf, Austria. Client: Strauss Investor Services, Inc. and Austria Environmental Protection. Provided observations and recommendation on the smoldering rubber waste pile. [Hammer Consulting Services]
- 2000 - Tracy Tire Fire Suppression Project, San Joaquin County, California. Client: Cal-EPA, CIWMB. Acted as Incident Commander for the suppression project. Supervised and directed the suppression of the longest burning tire fire in United States history.
- 2000 - Instructor/Presenter for Environmental Suppression Workshop, Sacramento County, California. Client: Various Fire Departments and Regulatory Agencies.
- 2000 - Andersen Air Force Base Landfill Cap Evaluation, Guam, USA. Client: US Air Force. Performed a site investigation and evaluation of a suspected landfill fire. [Hammer Consulting, private venture]

- 1999 - Illegal Green Waste Pile, Guam USA. Client: Guam, EPA and state fire department. Consulted and recommend suppression options for the fire.
- 1999 - Cajon Illegal Landfill Fire, San Bernardino County, California. Client: San Bernardino County Fire (State funded project through CIWMB). Provided consultant oversight for air monitoring and sampling. Also recommended a suppression/remediation plan for the site.
- 1998-1999 - Hawaiian Island Landfill Fires, Hawaii. Client: State of Hawaii Public Works. Provided general training via the Internet on subsurface fires and suppression options.
- 1998 - Ordot Tire and Landfill Fire, Guam, USA. Client: US EPA Region IX, Emergency Response. Performed site investigation and evaluation on the concurrent tire and landfill fire. Provided suppression options and recommendations to the incident commander. Confirmed the present of a subsurface fire and developed a suppression plan.
- 1998 - Tracy Tire Fire, San Joaquin County, California. Client Cal-EPA, CIWMB. Acted as a state responder to the tire fire and provided suppression options and recommendations to the incident commander.
- 1997 - Westley Tire Fire, Stanislaus County, California. Client Cal-EPA, CIWMB. Acted as a state responder to the tire fire and provided suppression options and recommendations to the unified command.
- 1997 - Lone Pine Landfill Fire, Inyo County, California. Client: County of Inyo, Department of Environmental Health Services (State funded project through CIWMB). Performed a site investigation and evaluation of a subsurface fire. Consulted and recommended suppression options for the fire.
- 1996 - Panoche Tire Fire, Fresno County, California. Client: Cal-EPA, CIWMB. Acted as site responder and engineer and to the tire fire and subsequent remediation project. Also assisted US EPA Region IX, Emergency Response in recommending fire suppression options.
- 1996 - Simi Valley Landfill Subsurface Oxidation Event, Ventura County, California. Client: Cal-EPA, CIWMB. Reviewed and commented on the actions the facility was taking to reduce the oxidation event.
- 1995 - San Marcos Landfill, Underground Landfill Fire, San Diego, California Client: Cal-EPA, CIWMB. Conducted a joint preliminary investigation to determine if an underground fire was present.
- 1995 - Calexico Landfill Fire, Imperial County, California. Client: Cal-EPA, CIWMB. Reviewed and concurred with a consultant's report concerning the successful suppression of a landfill fire. Determination was made based on carbon monoxide results.
- 1995 - Kepco Pinedale Landfill Fire, Fresno County, California. Client: Cal-EPA, CIWMB. Provided comments to the Remedial Action Plan for the landfill fire investigation.
- 1995 - Chateau Fresno Sanitary Landfill Fire, Fresno County California. Client Cal-EPA, CIWMB. Reviewed and commented on a work plan for the phase I of a landfill fire investigation
- 1994 - Gillespie Landfill Fire, San Diego County, California. Client: County of San Diego Public Work Department. Provided regulatory oversight for the suppression and air monitoring plan.
- 1993 - City of Sunnyvale Landfill Fire, Santa Clara County, California. Cal-EPA, CIWMB. Performed a site visit and provide technical oversight.
- 1992 - Coyote Canyon Landfill, Orange County California. Client: Cal-EPA, CIWMB. Reviewed the "Evaluation of Mitigation Methods for Elevated Subsurface Temperatures and Fires" report and observed injection of liquid nitrogen to control the multiple landfill fires.
- 1992 - Berry Street Mall Landfill Fire, Sacramento County, California. Client: Cal-EPA, CIWMB. Acted as site engineer and provided oversight for the subsurface landfill fire and suppression project.

Appendix B
Site Observation Reports for Todd Thalhamer
Provided Separately

Appendix C
Field Video of Gas Migration
Dated July 2015
Provided Separately

Appendix D
Hazard Awareness Presentation for First Responders – Updated
August 2015
Provided Separately