What is the status of the Lee's Lane Landfill Superfund Site?

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I. INTRODUCTION

The Lee's Lane Landfill is located in western Louisville, KY along the Ohio River (Fig. 1) [1]. The site was used as a quarry in the 1940s before being repurposed as a landfill from 1948 to 1975 (Fig. 2). At least 212,400 tons of municipal and industrial waste were disposed of in the landfill during this period. In 1980, the Kentucky Department of Hazardous Materials and Waste Management discovered approximately 400 drums of hazardous waste within the landfill; these drums were removed by the landfill owners in the fall of 1981, but the remaining drums of non-hazardous material, as well as any empty drums, were buried in place on the landfill. The buried and capped landfill waste covers an area of 112 acres. The United States Environmental Protection Agency (EPA) placed the Lee's Lane Landfill site on the National Priorities List (NPL) in 1983. Cleanup efforts concluded in 1988 and monitoring of the site has continued since.

This white paper summarizes reports published from 2013 through 2018 documenting Lee's Lane Landfill site conditions and the effectiveness of the cap and other remedies put in place to protect human health. The condition of the site must be reviewed every five years by the EPA, and those results are made available to the public in what is referred to as a Five-Year Review (FYR). The Lee's Lane Landfill FYR relies on information provided to the EPA by the Kentucky State Department of Environmental Protection (KDEP), information collected by the Lee's Lane Landfill Group, monitoring data and conclusions from the Louisville and Jefferson County Metropolitan Sewer District's (MSD) Conceptual Site Model (CSM) report, [2] and other interim communications. Using the information in these reports as well as relevant current and historical research documents, we identify questions that remain unanswered and need to be addressed in order to confirm that the contaminants present on the site do not pose a risk to public health and to

determine whether the site is ready for re-use. We conclude by proposing several next steps to fill the identified gaps in information and confirm the conclusions in the reports.

VOLATILE ORGANIC COMPOUNDS (VOCs)

The University of Louisville Superfund Research Center (ULSRC) researchers focus on accurate measurement and monitoring of and the health impacts connected to exposure to volatile organic compounds (VOCs). The research team is therefore concerned about better understanding persistent VOCs at the Lee's Lane Landfill and any possible human exposure pathways that could have adverse health impacts for individuals who live near or come onto the site on a regular basis. VOCs are organic chemical compounds that can volatilize under normal atmospheric conditions of temperature and pressure [3]. There is some level of natural VOC exposure from environmental sources, but VOCs are also emitted from anthropogenic sources such as paints, cleaners, cigarette smoke, car exhaust, and industrial releases [3-6]. As such, VOCs are nearly everywhere in both indoor and outdoor environments, and background levels of VOCs may be near or above health-based exposure limits [3]. EPA studies show that many VOCs are found at higher levels inside homes compared with levels outside regardless of whether the homes are located in urban or rural areas [7], creating a significant potential for exposure-related adverse health outcomes

A number of VOCs, including 1,3-butadiene, benzene, and chloroform, have been linked to adverse health outcomes, while others have no known health effects [7]. As with many toxic compounds, the health effects of VOC exposures depend partly upon the level and duration of the exposure. The Agency for Toxic Substance and Disease Registry (ATSDR) has ranked several VOCs on their Substance Priority List as chemicals of significant public health concern [8], and both the EPA [9] and the World Health Organization (WHO) [10] have recommended guidelines for indoor concentrations of specific VOCs. In the past, the Lee's Lane Landfill site was a

documented emission source of VOCs, specifically methane; these gases migrated to the nearby Riverside Gardens neighborhood with considerable impact [1]. The ULSRC researchers intend to offer summaries and assessments of on-going site monitoring and related decisions by KDEP and the EPA to help community members and stakeholders better understand health risks and more fully participate in determining the future of Lee's Lane Landfill.

DESCRIPTIONS OF DOCUMENTS REVIEWED

2018 FYR

When the EPA places a Superfund site on the NPL, the cleanup and ongoing monitoring of the site must be reviewed every five years. The purpose of a FYR is to evaluate the execution and performance of agreed-upon cleanup remedies for a Superfund site and determine if those remedies are and will continue to be protective of human health and the environment around the site. The report produced in August 2018 is the sixth FYR for the Lee's Lane Landfill Superfund site [1]. It provides an update of cleanup efforts and site monitoring since the 2013 FYR [11].

2016 CSM

In 2014 and 2015, the EPA and some of the potentially responsible parties—individuals, companies, or other parties that may be liable for payment of Superfund cleanup costs—met and concluded that several of the issues identified in the 2013 FYR had been completed. The Lee's Lane Landfill Group and MSD worked to assemble the new data into the 2016 CSM report [2]. This document summarizes the status of the 2013 FYR [11] and provides recommendations for necessary follow-up work. Many of the conclusions in the 2018 FYR [1] are based on data reported in the 2016 CSM.

ENTITIES INVOLVED IN SITE REVIEW AND MONITORING

EPA

The EPA is the U.S. federal agency responsible for protecting the environment. Founded in 1970, the EPA conducts environmental assessments, research, and education and is responsible for issuing and enforcing regulations that establish national standards to limit human exposure to various toxins, hazardous materials, and pollutants in air, water, and soil. In 1980, Congress established the Comprehensive Environmental Response, Compensations, and Liability Act (CERCLA), more commonly known as Superfund. The Superfund program is responsible for the cleanup and remediation of contaminated sites the EPA characterizes as posing serious human health risks and environmental damage if not contained. Part of this responsibility entails ongoing monitoring of Superfund sites and performing comprehensive reviews of those sites every five years.

EPA Region 4

EPA Region 4 covers the southeast United States and serves Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and six federally-recognized Indian tribes. Region 4's Laboratory Services and Applied Science Division, housed in Athens, GA, is responsible for providing scientific and technical expertise and environmental data for EPA offices throughout Region 4. The laboratory conducts more than 100 field investigations and analyzes over 15,000 samples collected from Region 4 EPA sites per year [12].

KDEP

KDEP's mission is to protect and enhance the environment of the Commonwealth of Kentucky. As the environment plays a vital role in public health, KDEP is also indirectly responsible for protecting the health of Kentucky's citizens. KDEP consists of six divisions: Air,

Waste Management, Water, Compliance Assistance, Enforcement, and Environmental Program Support. This last division assists the other divisions and is responsible for analyzing samples collected from Superfund sites for various toxins [13].

MSD

MSD works to provide quality wastewater, stormwater, and flood protection services to the Louisville-Jefferson County Metro in order to maintain safe, clean waterways and to protect public health. In regard to the Lee's Lane Landfill Superfund site, MSD is responsible for operation and maintenance (O&M) at the site, a task which includes performing quarterly air, gas, and groundwater monitoring as well as general maintenance of the site.

Consultants

Pace Analytical Services

Pace Analytical is a commercial analytical testing laboratory contracted by MSD for the annual analysis of groundwater samples [1]. Pace also performs analysis on soil and sediment samples collected from various sites throughout the city of Louisville in conjunction with other environmental consultants, although those services were not conducted as part of the 2018 FYR [14].

Skeo Solutions

Skeo is an environmental consulting agency that frequently works with the EPA to produce documentation, websites, and other presentation tools. Consultants from Skeo helped write and produce maps for the 2018 FYR [1].

Smith Management Group (SMG)

SMG is an environmental consulting agency which serves to help clients address environmental risks resulting from materials, products, and waste used or generated in a given

location. Throughout the early 2000s, SMG consulted with MSD to perform various O&M tasks on the Lee's Lane Landfill Superfund site, such as requesting that abandoned groundwater monitoring wells be closed and performing an evaluation of the LFG collection system in 2010 [15].

Stearns, Conrad, and Schmidt (SCS) Engineers

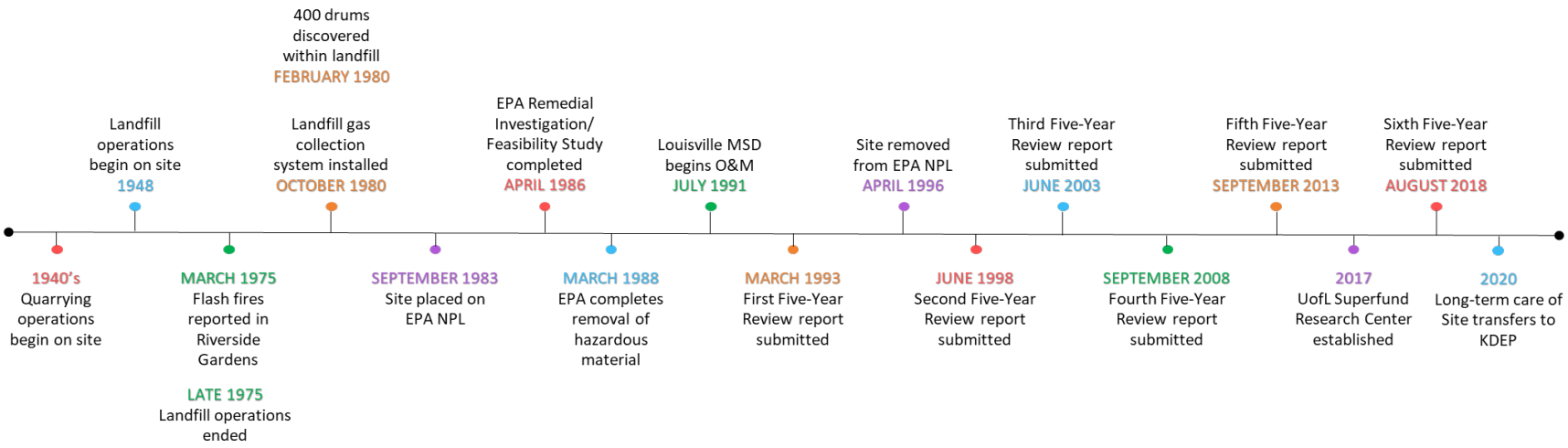
SCS Engineers is an environmental consulting and construction firm that designs and implements sustainable environmental solutions. SCS designed and provided construction oversight of the original landfill gas (LFG) collection system and provided subsequent evaluations and remedial action recommendations for the system. In 2004, SCS performed a maintenance inspection of the LFG collection system at the behest of MSD [16].

II. MAP OF SITE

Figure 1: Map Showing Location of Lee's Lane Landfill

III. TIMELINE OF SITE ACTIVITY

Figure 2: Timeline of Historical and Superfund Activity at Lee's Lane Site



IV. PROGRESS SINCE THE PREVIOUS REVIEW

The 2013 FYR posed several issues regarding ongoing site contamination and monitoring [11]. The EPA and MSD produced subsequent reports to address many of the remaining issues before the next scheduled review in 2018. We summarize the conclusions that environmental professionals and public officials involved in the site's cleanup provided in those reports and those documented in the 2018 FYR [1]. In general, representatives from the EPA, KDEP, and MSD ".... agree that the cleanup and maintenance at the site has progressed as planned [1]." While this is a positive evaluation about the process and current status of the site, several questions and issues remain regarding monitoring processes and observed contamination levels that need to be addressed by those agencies and the responsible parties before the next FYR in 2023 and before re-use of the site moves forward.

The following tables and figures pull information from the 2013 and 2018 FYRs to highlight questions that still need resolution, ongoing gaps in monitoring data collection and analysis, and potential health risks that remain if these gaps are not resolved. Table 1 organizes information and questions raised in the 2013 FYR [11] regarding the remaining contamination and potential health-related issues noted in the previous FYR. Also included are status updates for those issues based on the 2018 FYR [1]. Figures 3 and 4 show the locations of various monitors and contamination found via sampling. Table 2 provides a list of the VOCs found to be present on the site between 2012 and 2015 and indicates those that exceeded the EPA screening levels. Table 3 summarizes potential sources and health risks associated with these chemicals of concern found to be present at the site.

Table 1: Status of Issues Identified in the 2013 and 2018 FYR Reports

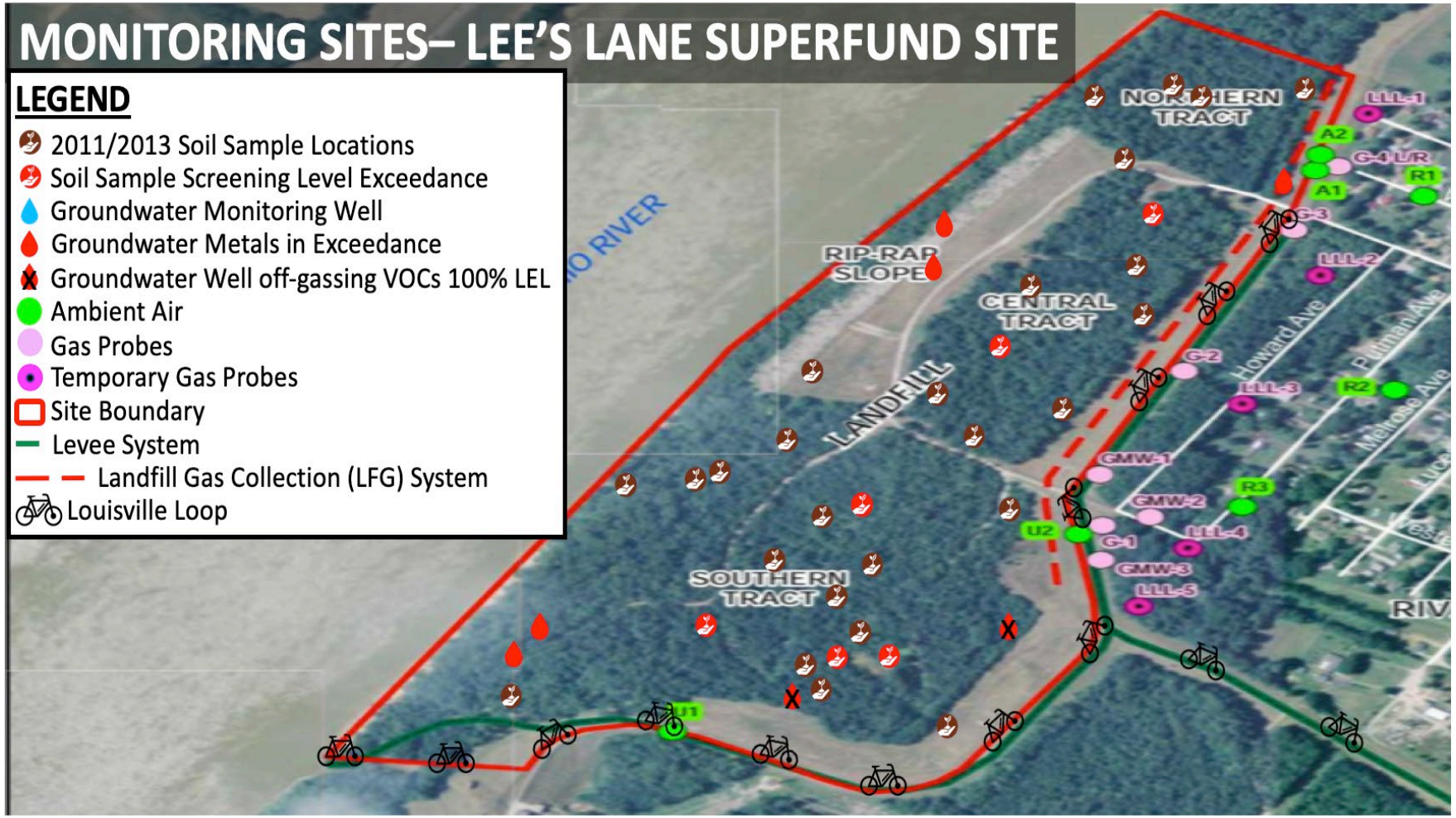
Issue	Updates since 2013 FYR	Remaining Questions	Available Data	Needs
Some soil samples still showing evidence of contamination.	● 2013: KDEP collected 31 soil samples across the site [1]. o 6 sample sites had contamination concentrations above levels deemed safe for occasional exposure. ● 2017: Detailed site inspection performed to further assess soil contamination [1]. o Contaminated spots not easily accessible, so low risk of exposure.	● Would changes driven by land re-use make these contaminated sites more accessible? ● How would land re-use change the risk evaluation for negative health outcomes?	● 2013 KDEP data [1] ● 2011 SMG data [17]	● Additional soil sampling, especially in the areas of proposed re-use where high levels of contamination were previously measured
Ambient air contains VOCs, but ambient VOC levels in the area could be elevated because of site contamination.	● MSD continues to monitor ambient air twice a year. o VOCs found naturally in ambient air, but want to confirm levels are not increased due to site. o Sept. 2013: Chloroform elevation reported at 5 monitoring stations [1]. o April 2015: Carbon tetrachloride elevation reported at 1 monitoring station [1]. ● 2013: Independent measures of ambient air noted that carbon tetrachloride levels were measured above the set reference dose, but these measures were not significantly		● Ambient air measures can be compared for Firearms training site with 5 other locations in the city. Data available in West Louisville Air Toxics Study [18]. ● MSD ambient air data from the late 2010s ● Independent ambient air measures from 2013 and 2016-	● Current on-site measures for comparison to previous years' data and to other ambient air monitors

	different from levels measured in other ambient air samples collected from throughout Louisville (unpublished data).		2019 (unpublished data)	
Soil gas monitoring shows high levels of VOCs.	● MSD monitors soil gas twice a year. o There are both permanent and temporary gas probes in place for monitoring. o A number of VOCs exceeded the screening level between 2012 and 2015 [1]. ● 2016: Site inspection recommended evaluation to determine source of specific VOCs [2].	● What are the sources of carbon tetrachloride and the 1,3-butadiene?	● MSD soil gas data from the late 2010s o Only for specific compounds	● Current on-site measures for comparison to previous years' data and to determine the source of specific VOCs
Gaseous contaminants were identified along site perimeter at levels that could pose a health risk if found at same levels in residential homes.	● June 2013: Soil gas probes noted high levels of VOCs at site perimeter [1]. ● 2014-2015: 33 homes tested for levels of VOCs intruding from site [2]. o No unacceptable health risks due to levels found in residential homes.	● What health risks could arise if more vapors migrated from the site towards residences? ● Could vapor intrusion pathways exist yet remain undetected due to inconsistent sampling?	● 2014-2015 EPA Vapor Intrusion Study data [2]	● Repeated vapor intrusion study to measure gas levels at all points within the home to complete the exposure pathway at a single time point ● Stronger exclusion criteria for homes included in the study to exclude participant activities that may contaminate

				VOC samples (e.g., smoking)
Groundwater could potentially be contaminated, but new wells are needed to gather proper data.	● 2014: 5 new groundwater wells installed [1]. ● July 2016: EPA agreed to continue groundwater monitoring for five contaminants of concern: arsenic, manganese, iron, barium, and lead [1]. o Each of these metals continues to be routinely detected in groundwater samples	● Why are wells not being tested for specific contaminants of concern if their concentrations in previous years have exceeded the health-risk based limit? ● How might seasonality and river levels influence these measures?	● MSD groundwater data from the 2000s and 2010s	● Potential interest in measuring contamination in water flowing into the Ohio River ● Current on-site measures for specific contaminants of concern, specifically ones that are missing data points
Gas monitors placed next to some of the groundwater wells off-gassing VOCs at very high levels.	● 2013: Independent measure of air space in monitoring wells showed levels of carbon tetrachloride above the reference dose (unpublished data). ● 2016: KDEP Groundwater Report stated that 2 groundwater monitoring wells continue to off-gas VOCs at 100% of the lower explosive limit (LEL) [1, 19]. o A bladder pump was used to make measurements rather than an electronic monitor to avoid potential explosion.	● Which VOCs were measured above the LEL? ● Where are the VOCs at these wells coming from, and what can be done to stop their release?	● Independent measures from 2013 (unpublished data)	● Data regarding which VOCs were being off-gassed and at what levels ● Current on-site data regarding VOC source and containment

The landfill gas (LFG) collection system is currently not working as designed.	● 2004 [16] & 2010 [15]: Engineering studies report LFG system is inoperable. ○ Models show methane levels have decreased since initial measures. ● Current FYR states that LFG will be shut down as it is no longer necessary [1].	● How accurate are the measured methane levels if it is unknown whether or not the LFG system has been working properly?	● None	● Current on-site data of "safe" methane levels ● Possible testing of LFG to determine its functionality
Despite site security, trespassing is becoming more frequent.	● Trespassing can result in soil erosion and waste exposure as well as unintentional exposures that could negatively impact health. ● 2012-2014: MSD has placed a number of signs regarding site security and have tried to obstruct easy access to the site and to on-site trails [1].	● What can be done to keep people from coming onto the site without permission? ● What was the basis for re-estimating the number of days it was safe to be on the site as a trespasser or for recreational use?	● Anecdotal data regarding incidences of trespassing and photographic evidence of unauthorized access and activity [1]	● Clarification regarding new estimation of the number of days it is safe to be on site ● Additional efforts to keep unauthorized individuals off the site (fences, cameras, etc.)

Figure 3: Monitoring Sites at the Lee's Lane Landfill Superfund Site [2]



Abbr: LEL, lower explosive limit; **LFG,** landfill gas; **VOCs,** volatile organic compounds.

Figure 4: Vapor Intrusion Study Evaluation Sites at Lee's Land Landfill Superfund Site (2014) [2]

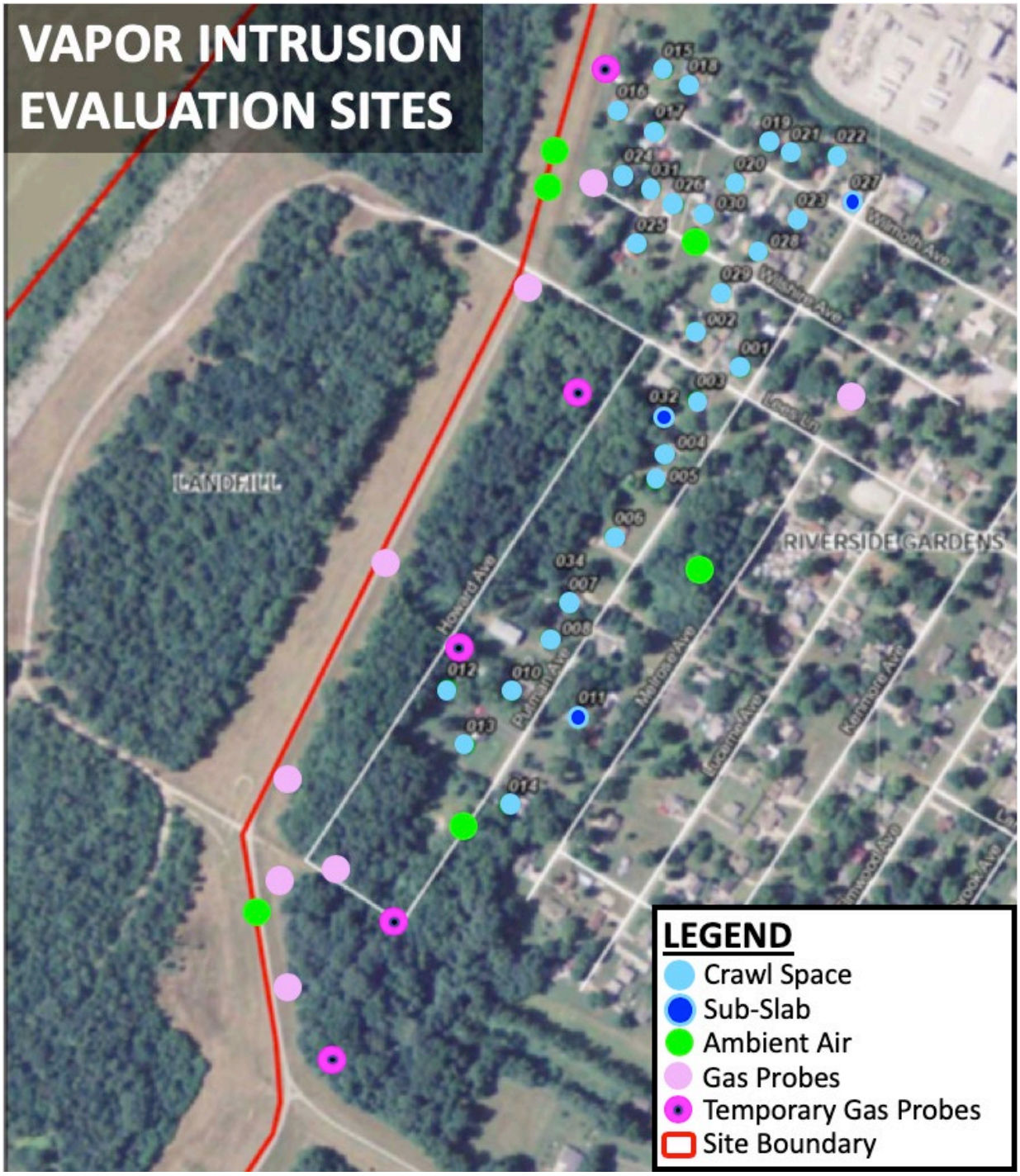


Table 2. Volatile organic compounds present at Lee's Lane Landfill site (2012-2015)

VOCs in Exceedance	VOCs Not in Exceedance
1,3-Butadiene[I, SG, VI]	1,1,1-Trichloroethane
1,4-Dichlorobenzene[VI]	Chloromethane
1,2-Dichloroethane[VI]	Dichlorodifluoromethane
Benzene[VI]	Ethylbenzene
Carbon tetrachloride[AA, I, SG, VI]	Methylene chloride
Chloroform[AA, I, SG]	Toluene
Methane[SG]	Trichloroethene
Tetrachloroethene[I, SG]	Trichlorofluoromethane
	Vinyl chloride
	o-, m-, & p-Xylene

Type of sample(s) showing exceedance indicated. **Abbr.: AA,** ambient air; **I,** industry; **SG,** soil gas; **VI,** vapor intrusion; **VOCs,** volatile organic compounds.

Table 3: Potential Sources and Known Health Effects of Contaminants of Concern

Abbr.: CNS, central nervous system; **CS,** cigarette smoke; **CVD,** cardiovascular disease; **GI,** gastrointestinal; **PAH,** polycyclic aromatic hydrocarbon; **PVC,** polyvinyl chloride; **VOC,** volatile organic compound.

Contaminant	*Potential Sources*	*Known Health Effects*
VOC		
1,3-Butadiene	CS, Industry, Rubber manufacturing, Gasoline exhaust	Respiratory irritation, CVD, Cancer
1,4-Dichlorobenzene	Plastic production, Pesticides, Deodorant	Skin irritant, Cancer, Liver damage, Kidney damage
1,2-Dichloroethane	PVC production, Upholstery, Chemical manufacturing	Eye and throat irritant, Cancer
Benzene	Natural sources, CS, Industry, Gasoline exhaust, Plastics	GI disturbances, Difficulty breathing, Cancer
Carbon tetrachloride	Old fire extinguishers, Refrigerants, Dry cleaning	Liver damage, Kidney damage, Cancer
Chloroform	Chemical manufacturing, CS, Water chlorination	Respiratory irritation, Cancer, Kidney damage, Liver damage, CNS depression
Methane	Natural gas, Organic materials, Industry	Generally non-toxic
Tetrachloroethene	Industry, Dry cleaning, Lubricants, Cleaning products	Skin irritation, CNS depression, Cancer
Heavy Metals		
Arsenic	Natural sources, Industrial processes, CS	Skin lesions, Cancer, Pulmonary disease, CVD
Manganese	Natural sources, Steel production, Paints	CNS disturbances, Impaired fertility, Kidney stones
Iron	Natural sources, Foods	Liver disease, CVD, Diabetes
Barium	Natural sources, Drill lubrication, Rubber production	GI disturbances
Lead	Natural sources, Leaded gasoline, Lead paint, Coal combustion	CNS disturbances, Anemia, Impaired fertility, Slowed mental development
Other		
PCB-1248 (Aroclor1248)	Electrical transformers, Hydraulic fluids, Paints, Metal coatings	Acne-like rash, Liver damage, CNS damage, Respiratory irritation
Bis(2ethylhexyl)phthalate	PVC production, Building product, Plastics	Cancer
PAH		
Benzo(a)pyrene	Wood burning, Gasoline exhaust, CS, Burnt food	Cancer
Dibenzo(a,h)anthracene	Gasoline exhaust, Smoked foods, CS	Genetic mutation, Cancer

V. DATA REVIEW

This section summarizes data collected and resulting conclusions drawn by KDEP, MSD, and the environmental contractors after the 2013 FYR. We highlight explanations for those conclusions using a critical lens that suggests there are gaps in knowledge about the site condition and potential impacts on the surrounding residential areas.

Soil & Soil Gas

The 2013 FYR [11] reported that possible soil contaminants on the site had not been adequately identified. KDEP consequently performed soil sampling in 2013 and collected 31 soil samples from 28 locations across the site (see Figure 3). Of those samples, six exceeded concentrations deemed safe for occasional exposure. Many of these samples showed elevated levels of benzo(a)pyrene, and some showed elevated levels of lead, dibenzo(a,h)anthracene, polychlorinated biphenyls, and bis(2-ethylhexyl) phthalate. A more detailed site inspection conducted in 2017 and reported in the 2018 FYR [1] further assessed the locations of soil contamination. Although the results indicated that contamination was still present, the inspection concluded that the risk of human health was low because the locations were not deemed physically accessible to the general public.

MSD monitored levels of soil gas from both temporary and permanent gas probes on and adjacent to the site; this monitoring occurred twice a year. According to the 2016 CSM [2] and the 2018 FYR [1], several VOCs, including 1,3-butadiene, carbon tetrachloride, chloroform, methane, and tetrachloroethene, were found to be in exceedance of EPA regional screening levels between 2012 and 2015 (see Table 2). The EPA sets these standards based on the carcinogenic risk of exposure to specific compounds. They can be modified for different routes of exposure, whether by inhalation, ingestion, or dermal contact. In particular, measures of carbon tetrachloride and

chloroform were above the screening levels during every sampling event between September 2012 and April 2015 at one and two wells, respectively. The exceedances in other VOC measures were more sporadic, occurring during different sampling events or at different wells. Importantly, both the 2016 CSM [2] and the 2018 FYR [1] recommend further evaluation in order to determine the source(s) of these VOCs, particularly 1,3-butadiene and carbon tetrachloride, as these VOCs exceeded screening levels at gas probes directly adjacent Riverside Gardens.

Ambient Air

Although VOCs are found naturally in ambient air, MSD monitors ambient air levels at the site twice a year to ensure that VOC levels in the area are not above background levels. Between 2013 and 2015, the reported monitoring data show that although there were elevated levels of specific VOCs, such as carbon tetrachloride and chloroform, at some monitoring stations, these levels were not sustained for extended periods. Independent measures of ambient air conducted by Russell Barnett, the director of the former Kentucky Institute for the Environment and Sustainable Development, in 2013 (unpublished data) also found elevated levels of carbon tetrachloride. However, these levels were not significantly higher than levels measured in ambient air samples collected throughout Louisville, suggesting that the carbon tetrachloride was unlikely to be emanating from the landfill and indicating that it would be impossible to determine ultimate sources.

Groundwater & Groundwater Gas

The 2013 FYR [11] stated that groundwater on the site could be contaminated, but additional wells were needed to gather enough data to determine whether contamination existed. KDEP installed five additional groundwater wells at the site in 2014, bringing the total number of monitoring wells up to seven. Between 2013 and 2017, many of the wells routinely detected one

or more of the five contaminants of concern (arsenic, manganese, iron, barium, and lead), although no increasing or decreasing trends in the concentrations of these contaminants were documented. There are missing measurements in the October 2017 well monitoring data for one or more of the five contaminants of concern that exceeded screening levels at each well in previous monitoring events. This suggests a lack of thorough testing for each of these wells. MSD installed additional groundwater wells adjacent to the site in December 2018, and updated monitoring data from these wells should provide additional information regarding potential contamination before the 2023 FYR.

Furthermore, the 2018 FYR reports that, according to the 2016 KDEP Groundwater Report [19], two of the groundwater monitoring wells were off-gassing VOCs at 100% of the lower explosive limit (LEL). As a result, those and subsequent years' measurements at these wells were made using a bladder pump rather than an electronic device to prevent the possibility of an explosion. As the report does not identify which VOCs were off-gassing at these levels, it is unknown whether the levels at which they are released are hazardous to human health. The 2018 FYR identifies these VOCs as an issue that could affect future protectiveness of the site and indicates the need to determine their source(s).

Vapor Intrusion

In June 2013, soil gas probes along the site perimeter reported levels of seven contaminants at levels that, if found within residential homes, would pose a health risk. To ensure that these contaminants were not migrating into nearby residential homes, the EPA conducted vapor intrusion sampling in 33 homes in Riverside Gardens between June 2014 and July 2015, with results reported in the 2016 CSM [2]. The EPA collected soil samples from outside the homes in the study and air samples from the basements, sub-slabs, crawl spaces, and first floors of these

homes for VOC measurements in order to identify the level and source of the VOCs. The analysis could not identify a complete vapor intrusion pathway between the site and the interior of the tested residences, and although some elevated levels of VOCs were detected, the EPA concluded that these were likely not attributable to the site because of their inability to detect a vapor intrusion pathway. The report concludes that there was "no unacceptable health risks from vapors migrating from beneath homes to indoor air [1]."

Landfill Gas (LFG) Collection System

In 1980, SCS Engineers, under the direction of the Jefferson County Department of Public Works, installed the landfill gas (LFG) collection system to address the potential migration of gases from the site to nearby residential areas. Engineering studies in 2004 [16] and 2010 [15] determined that the LFG system was inoperable and had exceeded its 25-year useful life. Gas probe data over a 22-year period (1993 to 2005) showed continuous decreases in methane levels and confirmed that there had been no new releases of methane from the site. The 2016 CSM [2] stated that methane concentrations on the site had not exceeded the LEL (5% methane) at any probe since 2007. The CSM also reported low levels of methane from samples collected in 2013 from 18 gas probes located between the site and Riverside Gardens. The vapor intrusion study in 2014-2015 also confirmed that methane was not migrating from the site to Riverside Gardens [2]. The 2018 FYR thus noted the imminent closure of the LFG system and indicated that KDEP would continue to monitor methane levels for two years to ensure there is no increase. The shutdown of the LFG system occurred in September 2019 [20]. No additional action is required as long as methane levels remain below the LEL.

Trespassing

Despite MSD's continued efforts to prevent unauthorized access to the site, there continues to be frequent trespassing on the site. Steps taken to discourage trespassing include additional signage, new security gates, and decreased ease of access to on-site trails to recreational vehicles. Trespassing results in surface erosion and personal exposure that could lead to adverse health outcomes. Continued efforts must aim to discourage unauthorized access to the site.

VI. KEY CONCLUSIONS FROM EXPERT INTERVIEWS

The 2018 FYR [1] includes interviews with four experts on site-related matters. The notable observations and conclusions from these interviews are summarized below.

- Donna Seadler- Remedial Project Manager for the EPA
    - Stated the current cleanup is sufficient to manage the human health and ecological risks of the site
    - Reported that MSD has taken several steps to deter trespassing, but that these efforts have not been entirely successful due to the site's size and location
    - Remarked that "…very little is heard from the community anymore [1]."
    - Stated that no more work is needed under Superfund to limit site access
    - Proposed "positive re-use for this Site so that the community can move forward [1]"
- Kevin Koprec- Toxicologist for the EPA
    - Said cleanup and maintenance of the site have progressed as planned
    - Proposed site re-use that involves an owner or tenant to be at the site regularly to deter trespassing
    - Concluded that there should be no site-related adverse health effects for people who occasionally (once per month) trespass onto the site off of the paved asphalt trails

- Stated that trespassing has caused some soil erosion of vegetation/soil cover over areas of buried waste
- Proposed institutional controls preventing the development of the site for residential use or another use that would have people on the landfill on a daily, chronic basis
- Proposed controls preventing the use of on-site groundwater
- Supported periodic inspections to look for erosion in areas of buried waste caused by trespassing

- Jim Kirby- Environmental Scientist with KDEP
  - Did not find the site ready for reasonably anticipated re-use at this time: inadequate access control measures, lack of an engineered cap on most of the site, unknown efficiency of LFG system
  - Requested further assessment of the LFG collection system
  - Reported numerous complaints from residents at public meetings and via emails
  - Proposed an Environmental Covenant be in place for the site
- Heather Dodds- Professional Engineer with Louisville MSD
  - Found that cleanup projects have successfully improved site conditions
  - Concluded that the project is protective of human health and the environment
  - Reported that MSD conducted site-specific inspections monthly and quarterly
  - Said that MSD O&M staff report issues when observed during routine site visits
  - Reported no significant changes made in site O&M since the previous FYR
  - Stated that site security continues to be an issue

VII. MOVING FORWARD

Despite the wealth of data and the somewhat positive outlook of the site and its current conditions, there are still a number of unresolved issues and questions that need to be addressed to reduce uncertainty and confirm that the current site conditions protect human health. These should be addressed before initiating substantive discussions regarding re-use since the nature of their resolution may limit safe re-use options.

Because the soil and soil gas sampling were not comprehensive (lack of testing due to inaccessibility and undetermined sources of VOCs measures in soil gas), any plans for re-use cannot thoroughly assess health risks associated with any particular re-use plan. For example, redevelopment might increase human access to inadequately tested areas. Therefore, the implementation of a more comprehensive soil testing plan and soil gas monitoring efforts could reduce any lingering uncertainty about site safety and allow for the creation of appropriate environmental covenants or deed restrictions. A more accurate image of current soil contamination, or lack thereof, can be generated in part by using the most recent monitoring data collected by KDEP and the EPA. However, additional sample collection and analysis would provide a more accurate and useful picture of site condition and contamination.

Potential risks from ambient air are largely unknown because of a lack of current data. Systemic ambient air measurements in Riverside Gardens need to be collected to better understand which airborne VOCs come from the site and which come from other sources such as nearby industry. Similarly, the potential risks from groundwater are unidentified as there is a lack of data that would permit an examination of the impact of the site location on levels of and exposure to groundwater-associated VOCs. The Lee's Lane Landfill site sits directly adjacent to the Ohio River and within the river's 100-year floodplain. Fluctuations in the river's water levels impact

groundwater levels on the site, and these changes could force contaminants, particularly gaseous contaminants such as VOCs, through cracks and openings they may not usually reach, potentially creating new pathways of exposure. This possibility is particularly concerning as explosively high levels of VOCs were measured at two groundwater monitoring wells, though the review does not specify which VOCs these were, does not identify a source, and does not include groundwater levels as a factor in the results.

The potential for new infiltration pathways for VOCs and other gaseous contaminants from the site may also impact vapor intrusion into Riverside Gardens. Other research has worked to identify alternate vapor intrusion pathways that have the potential to impact human health [21-23], such as migration through sewer pipes, and it may be critical to examine these alternate pathways to ensure that there is no migration of vapors from the site into nearby residences. Determining what impact the non-functioning LFG may have on the accuracy of methane measurements would result in more accurate estimates of the potential for methane migration into homes. The methodology of the vapor intrusion study was not adequate to rule out vapor intrusion pathways. Although samples were collected from multiple places inside and around the homes, collection occurred at varying times throughout the year rather than in a single sampling. Therefore, a complete intrusion pathway may have existed at some point yet remained undetected due to the inconsistent nature of the sample collection. Furthermore, many of the residents of the homes included in this study were smokers, and as cigarette smoke is a known source of VOCs, possibly compromising samples, this could again mean that an intrusion pathway existed but remained undetected. A more vigorous vapor intrusion study taking into account the aforementioned issues to avoid confounding the results would confirm the absence of a vapor intrusion pathway attributable to the Lee's Lane Landfill. Additional studies could also possibly better identify

alternate sources of VOCs. This information would allow residents to decide if and how vapor barriers are needed in their homes to mitigate exposure regardless of whether the VOCs originate from the landfill or other sources.

The task of the ULSRC is to study the health impacts of VOC exposures, and it therefore follows that our research should inform the community members of Riverside Gardens. The residents of Riverside Gardens have long been concerned about health effects due to site-related contaminant exposure and have asked whether they experience an excess burden of disease because of their proximity to the site. The Riverside Gardens Community Health Assessment (2017-2018) [24] addresses this question. Preliminary data show that although cancer morbidity in the neighborhood is not above the expected levels, prevalence estimates of musculoskeletal, respiratory, cardiovascular, and mental health conditions significantly exceed local, state, or national estimates [24]. Although many VOCs measured on-site have been linked to cardiopulmonary irritation or disease (Table 3), nearby industries have also reported the release of several of these compounds [25]. Additional research could determine whether the adverse health effects seen in Riverside Gardens are due to exposure to VOCs from the site or from other sources. Similarly, promoting environmental health literacy and protective measures to Riverside Gardens residents and other residents of nearby communities is necessary work for reducing adverse health effects regardless of the source of the VOCs.

VIII. BIGGER PICTURE

Why is research at Superfund sites necessary, and why is it imperative for objective researchers to provide critical reviews of federal, state, and local government-produced site data?

In October 2019, the United States Government Accountability Office presented a report to Congress showing that approximately 60% of nonfederal Superfund sites overseen by the EPA

are in areas that could be impacted by natural disasters such as wildfires, flooding, storm surges, and rising sea levels [26]. Studies show that climate change can exacerbate these types of disasters, increasing the likelihood that these sites will pose a human and environmental health hazard regardless of their current legal status. As part of the EPA's charge to manage human and environmental risks from these Superfund sites, accounting for l climate change associated effects at these locations will be crucial.

Despite the EPA's efforts to incorporate such analysis into their research and actions, the agency is limited in scope by statutes and by decreased funding and increased public distrust [27, 28]. However, new sites continue to be added to the NPL as states, tribes, or citizens ask for agency assistance and scientific research continues to become more sophisticated regarding the health risks of exposures to hazardous materials. EPA's limited scope, capacity, and resources available to address Superfund sites could result in less thorough monitoring and enforcement of protections at best and rushed or incomplete site cleanups in order to delete sites from the NPL at worst. The results could be catastrophic in terms of both acute and chronic exposure risks.

Furthermore, the EPA have recently been increasing pressure on state and local governments and other stakeholders to accelerate the re-use and redevelopment of existing Superfund sites [29-34]. These sites often represent significant acres of land that could present beneficial opportunities for local communities once cleanup is completed. Across the country, former Superfund sites have been redeveloped into residential and commercial areas, parks and recreational spaces, and wildlife habitats, among other uses [29]. Re-use or redevelopment may, in part, be determined by controls put in place to prevent further exposure, but in general, the re-use of Superfund sites is promoted when the property can be used safely and when re-use will not affect the protective remedies in place at the site. Regarding the Lee's Lane Superfund site, re-use

is limited by the presence of the landfill cap, and several researchers have called for institutional controls or an Environmental Covenant to prevent certain types of re-use [1]. Additional sampling and study are needed to determine whether these controls are necessary. One re-use option being explored by both the Commonwealth of Kentucky and the city of Louisville is a solar installation. A solar feasibility study was completed in 2017 to explore the advantages and disadvantages of this type of redevelopment [35]. Discussions about the solar installation are still on-going and at the time of this publication, there is no definitive redevelopment plan for the Lee's Lane Superfund site.

A federal push to accelerate the re-use of Superfund sites creates the potential for increased risks to human and environmental health unless it is accompanied by increased resources to maintain regulatory clean-up standards, monitoring standards, and stakeholder engagement in clean-up and end-use decisions. There are growing opportunities for professional and citizen scientists alike to deploy sophisticated experimental methods and technology in exposure research, especially through the National Institutes of Environmental Health Sciences (NIEHS) Superfund Research Program. However, there are often gaps in knowledge, whether through lack of access to data or through an inadequate understanding of technical language, that inhibits communication between regulators, researchers, and those in the community. Independent review and translation of conclusions based on monitoring data collected and analyzed by local, state, and federal agencies can fill some of those gaps and ultimately help assure public safety and reduce uncertainty related to site re-use options. Additionally, this type of public review and summary of monitoring data can be used to inform environmental and health policies and improve communication of scientific data to those who may be most directly impacted by exposures. Ultimately, improving the public's and policymakers' understanding of their roles in the future of Superfund sites creates

the opportunity for building awareness of exposure risk and related health effects to ensure protecting human health is prioritized in clean-up, monitoring, and re-use decisions.

LIST OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

AA	Ambient air
ATSDR	Agency for Toxic Substances and Disease Registry
CERCLA	Comprehensive Environmental Response, Compensations, and Liability Act
CNS	Central nervous system
CS	Cigarette smoke
CSM	Conceptual Site Model
CVD	Cardiovascular disease
EPA	United States Environmental Protection Agency
FYR	Five-Year Review
GI	Gastrointestinal
I	Industry
KDEP	Kentucky Department for Environmental Protection
LEL	Lower explosive limit
LFG	Landfill gas
MSD	Louisville and Jefferson County Metropolitan Sewer District
NPL	National Priorities List
O&M	Operation and maintenance
PAH	Polycyclic aromatic hydrocarbon
PVC	Polyvinyl chloride
SG	Soil gas
SCS	Stearns, Conrad, and Schmidt
SMG	Smith Management Group
ULSRC	University of Louisville Superfund Research Center
VOC	Volatile organic compound
VI	Vapor intrusion
WHO	World Health Organization

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