IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF MISSOURI
EASTERN DIVISION

STATE OF MISSOURI ex rel.	)	Case No. 4:15-cv-01506
Attorney General Chris Koster and	)	
Missouri Department of Natural Resources,	)	
	)	
Plaintiff,	)	
v.	)	
	)	
REPUBLIC SERVICES, INC., et al.	)	
	)	Expert Report of
Defendants.	)	Paul V. Rosasco, P.E.

I. INTRODUCTION AND SUMMARY OF OPINIONS

This report presents the opinions that I, Paul V. Rosasco, P.E., anticipate providing at the trial of this matter. I have been requested to provide expert opinions in this matter on behalf of Bridgeton Landfill, LLC.

A summary of my opinions, which are based on a reasonable degree of scientific certainty, is as follows:

A. Radionuclides are present in soil that is interspersed and intermixed within the overall mass of municipal solid waste, construction and demolition fill, quarry spoils, and other soil in two separate and distinct disposal areas (Areas 1 and 2) at the West Lake Landfill.

B. Occurrences of radionculides in Areas 1 and 2 do not pose imminent, immediate or short term risks to workers, the public or the environment, but potentially could pose a long-term risk to workers if an engineered landfill cover is not installed and if commercial workers were to work full time on the surface of Areas 1 or 2.

C. The most appropriate remedial action for the West Lake Landfill is containment consisting of a new engineered landfill cover designed to prevent potential contact with or exposure to the waste materials by workers, provide protection against radiation and radon emissions, and prevent direct contact by or infiltration of precipitation and leaching to groundwater.

D. The only potential impacts if a subsurface reaction or subsurface smoldering event were to occur in Areas 1 or 2 would be a temporary, localized increase in radon emissions from the surface of Area 1 or 2.

E. There is no basis to conclude that radionuclides are present in trees at or adjacent to the site above naturally occurring levels.

F. The volatile organic compound analyses of tree samples do not provide any meaningful scientific basis to conclude that VOCs are present in soil or groundwater at the West Lake Landfill at levels of concern or that such VOCs are migrating offsite from the West Lake Landfill.

G. Plaintiff's expert's opinions regarding the directions of groundwater flow near the Bridgeton Landfill are flawed in part because they are based on data that were not obtained in accordance with accepted scientific methods and practices.

H. Plaintiff's expert's opinions regarding the need for and scope of potential remedial actions are inconsistent with EPA's requirements for evaluation and selection of remedial actions and also are inconsistent with the known conditions at the site.

This report is based on data and information available at the time it was prepared. I reserve the right to amend or revise my opinions as further information becomes available, including but not limited to deposition transcripts of the Plaintiff's, representatives, experts and fact witnesses in this matter. I also reserve the right to express new opinions in response to new information or in response to any additional opinions that may be expressed by Plaintiff's experts.

II. QUALIFICATIONS AND PUBLICATIONS

I am a geologist, hydrogeologist and civil engineer with 39 years of experience. I am also the founder and President of and a Principal Engineer with the Lakewood, Colorado based consulting engineering firm, Engineering Management Support, Inc. (EMSI). My work experience includes being responsible for the performance of Remedial Investigations ("RI"), Feasibility Studies ("FS"), Remedial Design ("RD") and Remedial Action ("RA") at Superfund sites for over 33 years including several sites where radionuclides are present. I have also been responsible for investigation and assessment of hazardous waste facilities and corrective actions at sites regulated under the Resource Conservation and Recovery Act ("RCRA") or state-equivalent Superfund, hazardous waste and solid waste corrective action programs.

My experience includes evaluation of existing data and development of scopes of work; negotiation of scopes of work, administrative orders and consent decrees; implementation and supervision of remedial investigations, treatability studies, feasibility studies, remedial designs, remedial actions, and removal actions; operations and maintenance ("O&M") of remedial and removal actions; and performance and effectiveness evaluations of O&M activities. I have performed these activities at a variety of Superfund and RCRA sites.

For the last 21 years, I have been the designated project coordinator for the RI/FS of the two areas at the West Lake Landfill that contain radionuclides that EPA has designated as Operable Unit-1 (OU-1) of the West Lake Landfill Site. I am also the designated project coordinator for the Removal Action – Preconstruction Work related to potential installation of an Isolation Barrier between the Bridgeton Landfill and Radiological Area 1. Over my 21 year involvement with the West Lake and Bridgeton Landfills, I have supervised collection of soil, groundwater and air samples, prepared or supervised preparation of numerous Work Plans, Sampling and Analysis Plans, and Quality Assurance Project Plans, site characterization and monitoring reports including the OU-1 Remedial Investigation report, evaluations of potential toxicity, exposure and risk including the OU-1 Baseline Risk Assessment, technology and remedial action alternative evaluations including the OU-1 Feasibility Study (FS), the OU-1 Supplemental Feasibility Study (SFS), and the Isolation Barrier Alternatives Analysis (IBAA) reports, and evaluation of potential impacts if a Subsurface Smolder Event (SSE) or Subsurface Reaction (SSR) were to occur in the radioactively impacted areas. Throughout these activities I have participated in numerous meetings with various government and regulatory agencies and community groups where I have provided both formal and informal technical briefings and presentations regarding the occurrences of radionuclides, potential risks that may be posed by such occurrences, potential impacts if an SSR were to occur in Area 1 or 2, potential remedial alternatives to address the occurrences of radionuclides, and the costs and benefits associated with the various remedial alternatives. My prior and continuing work related to the West Lake Landfill and adjacent Bridgeton Landfill is extensive and ongoing.

I previously have been qualified by several federal and state courts as an expert in the areas of hydrogeology, contaminant occurrence, fate and transport, remedial action technologies, site remediation, costs of remedial actions, and consistency of site investigations and remedial actions with the National Contingency Plan ("NCP"). A copy of my current curriculum vitae, including a list of publications, is included as Attachment A to this report. A listing of cases in which I have provided expert testimony during deposition or at trial during the last four years is included in Section VII of this report. I have never had a court determine that my opinions or testimony did not meet accepted standards of scientific practice or were otherwise inconsistent with expert testimony.

III. DATA AND OTHER SOURCES OF INFORMATION CONSIDERED

In addition to my education, experience and training, I specifically considered the documents listed in Attachment B in forming my opinions in this matter. I should note that having been involved with the investigation and evaluation of the West lake Landfill for 21 years, I have reviewed or authored numerous reports and documents related to the site conditions, the RIM and remedial or corrective actions for the site beyond those listed in Attachment B.

IV. STATEMENT OF OPINIONS; BASIS AND REASONS FOR OPINIONS

A. Radionuclides are present in soil that is interspersed and intermixed within the overall mass of municipal solid waste, construction and demolition fill, quarry spoils, and other soil in two separate and distinct disposal areas (Areas 1 and 2) at the West Lake Landfill.

Based on the results of numerous investigations, extensive testing and associated evaluations and reports (see Attachment B), notably the EPA-approved Remedial Investigation (RI) for OU-1 (EMSI, 2000), various naturally-occurring radionuclides primarily associated with the uranium-238 (U-238) decay series have been identified as being present in soil/waste materials in Radiological Areas 1 and 2 (also referred to more simply as Areas 1 and 2) of the West Lake Landfill (Figure 1). These radiologically-impacted materials (RIM) occur as generally thin, discontinuous lenses or layers of soil and waste materials that are interspersed and intermixed within the overall larger mass of municipal solid waste (MSW), construction and demolition debris (C&D) waste, quarry spoils, other wastes and daily, intermediate and final cover soil material that were historically placed in Areas 1 and 2. RIM is primarily present in waste materials below the ground surface (*i.e.,* in the subsurface) beneath the majority of the overall areas encompassed by Areas 1 and 2 but also occurs at or near the ground surface in much smaller extents in Areas 1 and 2. The RIM in Areas 1 and 2 occurs a relatively shallow depths in the upper or middle portions of the waste materials and as such is located above the seasonally high water table which occurs near the base of the Area 1 and 2 waste materials or in the underlying alluvial deposits.

The results of the various site investigations indicate that radionuclides occur in soil that is intermixed with and interspersed in the overall matrix of MSW, C&D fill, quarry spoils and other soil disposed in Areas 1 and 2, consistent with placement of this material as daily or intermediate soil cover of the other waste materials. The specific radionuclides contained in the RIM in Areas 1 and 2 are dominated by thorium-230 and radium-226 and their associated daughter products. Both of these radionuclides and their associated daughter products originate from radioactive decay of their ultimate parent, uranium-238 (Figure 2). The presence of elevated levels of thorium-230 and radium-226 and their daughter products combined with the generally much lower levels of uranium in the RIM indicate that the source of these materials was not high grade ores or waste materials containing high levels of uranium but rather is consistent with the presence of residues that had been subjected to extensive processing to remove uranium.

The radium-226 activity levels are not in secular equilibrium with its parent, thorium-230. Secular equilibrium is a condition where the activity level of a radioactive isotope reflects its production rate due to decay of a parent isotope. Relative to the West Lake Landfill, this means that the amount of radium-226 present in the RIM is much less than would be expected based on decay of its parent, thorium-230. This condition indicates that radium-226 had been removed from the original material in greater proportions than its parent, resulting in the amount of radium-226 in the materials being less than what would be produced by radioactivity decay from the levels of thorium-230 in the RIM. Consequently, the levels of Th-230 and Ra-226 in the RIM are not in secular equilibrium. The presence of elevated levels of Th-230 and Ra-226 and the associated preponderance of Th-230 relative to Ra-226 is demonstrated by the analytical results obtained from the numerous samples of soil/waste material collected form Areas 1 and 2.

B. Occurrences of radionuclides in Areas 1 and 2 do not pose imminent, immediate or short term risks to workers, the public or the environment, but potentially could pose a long-term risk if an engineered landfill cover is not installed and if commercial workers were to work full time on the surface of Areas 1 or 2.

As part of the investigation and evaluation of Areas 1 and 2, EMSI retained Auxier & Associates (Auxier), a nationally recognized health physics consulting firm, to prepare a Baseline Risk Assessment for OU-1. Auxier subsequently performed risk evaluations and calculations used by EMSI in the preparation of the Supplemental Feasibility Study for OU-1 and the Isolation Barrier Alternatives Analysis. Based on the calculations and evaluations performed by Auxier & Associates under my supervision and my experience with evaluation of potential risks at other Superfund or contaminated sites, it is my opinion, to a reasonable degree of scientific certainty, that the presence of radionuclides at the West Lake Landfill does not pose an imminent, immediate or short-term risks to site workers, workers at nearby facilities or the general public. The principal potential risk associated with the occurrence of radionuclides at the site is a hypothetical potential incremental cancer risk slightly above EPA's accepted risk range to a hypothetical future on-site outdoor storage worker, if such an individual were to work full time in Areas 1 and 2 with no protective measures and no additional landfill cover or fill material or other changes to the existing conditions in Areas 1 and 2.

Potential exposures to radionuclides at West Lake Landfill include radiation exposure or ingestion, inhalation or dermal contact with radonuclides. Radioactive decay produces three types of radiation, alpha, beta and gamma. Alpha radiation is blocked by clothing, something as simple as a piece of paper, or human skin. Beta radiation is blocked by plastic or glass. Gamma radiation is the most penetrating form of radiation and requires distance and/or shielding such as lead to protect humans from exposure. Another form of potential exposure would be from inhalation of radon. Inhalation of dust particles containing radionuclides, ingestion of dirt/particles containing radionuclides, or direct dermal contact with soil/waste containing radionuclides are other possible forms of potential exposure.

Based on the current land use and the presence of active controls on access to Areas 1 and 2, including the perimeter facility fencing and overall site access controls to the West Lake and Bridgeton Landfill properties, the additional fencing and warning signs around Areas 1 and 2, and the overall industrial and commercial nature of the land uses at and around the site, workers (other than specifically trained remediation workers) or other individuals (e.g., trespassers) do not have access to or otherwise access Areas 1 and 2. Therefore, exposure to radionuclides in Areas 1 and 2 by workers or other individuals does not currently exist. Furthermore, extensive prior and ongoing monitoring of radon, airborne dust, surface water, sediment, and groundwater provides data indicating that offsite migration of radionuclides is not occurring.

Based on the site characterization and monitoring results, the evaluations performed as part of the Baseline Risk Assessment indicated that under current conditions, the individual with the greatest potential exposure to radiation or the radionuclides in Areas 1 and 2 was a groundskeeper working on the former Ford Motor Credit (Ford) property adjacent to Area 2. Specifically, such an individual could be exposed to an excess risk of incurring cancer. Carcinogenic (cancer) risks are expressed as incremental probability of an individual developing cancer over a lifetime as a results of exposure to a carcinogen (EPA, 2008). Typically, the chance any individual has of developing cancer is approximately 1 in 3 (33% or 0.33) (EPA, 2008) or more specifically, slightly less than 1 in 2 (50%) for men and slightly more than 1 in 3 (33%) for women (American Cancer Society, 2015).

The risk assessment estimated that the potential incremental cancer risk for a groundskeeper working on the former Ford property was 4 x 10-5 (0.00005 or roughly 5 additional cancers per 10,000 individuals). This estimated incremental cancer risk is within EPA's range of acceptable risk (1 x 10^{-4} to 1 x 10-6 or 0.0001 to 0.000001) for Superfund sites (National Contingency Plan and EPA, 2008). I should note that since the risk assessment was completed, Ford sold the property adjacent to Area 2 and the parcel immediately adjacent to Area 2 was acquired by one of the West Lake site owners to provide a buffer between the landfill and the adjacent properties (the Buffer Zone). Furthermore, AAA Trailer, the current tenant on the property adjacent to the Buffer Zone, subsequently graded both their property and the adjacent Buffer Zone and placed gravel over these areas such that the current risks are likely less than those previously estimated by the risk assessment.

The owners of the properties that comprise the West Lake and Bridgeton Landfills previously implemented restrictions on the potential use of the site. These restrictions were developed and implemented to reflect: (1) use of the site as a solid waste disposal facility; (2) the presence of radiologically-impacted materials in Areas 1 and 2; and (3) the proximity of the site to the Lambert-St. Louis International Airport. Residential land use has been precluded at the West Lake Landfill (including Areas 1 and 2) by restrictive covenants recorded in May 1997 by each of the fee owners against their respective parcels. These restrictive covenants also prohibit use of groundwater from beneath the site. Construction activities and commercial and industrial uses have also been precluded on Areas 1 and 2 by a Supplemental Declaration of Covenants and Restrictions recorded by Rock Road Industries, Inc. in January 1998, prohibiting the placement of buildings and restricting the installation of underground utilities, pipes, and/or excavation upon its property. These covenants automatically renew fifty (50) years from the date first recorded and every twenty-five (25) years thereafter. The covenants grant EPA, the MDNR, and the property owners the right to enforce the covenants' restrictions and these land-use restrictions cannot be terminated without written approval of the then owners, MDNR and EPA. Therefore, no residential use can occur at the Site and no structures can built on Areas 1 and 2.

After careful evaluation of these restrictions it was determined that although no structures could be built on Areas 1 and 2, absent future modification of these restrictions, structures potentially could be built on portions of the site adjacent to Areas 1 and 2 in the future and occupied by businesses that could use the surface of Areas 1 and 2 for outdoor storage or other uses that could result in workers being present on Areas 1 and 2 over a normal work period (e.g., 40 hours per week, 50 weeks per year). An example might be an equipment rental facility, lumber yard or home improvement facility, or other type of commercial operation that had an office building outside of Area 1 or 2 but used one or both of these areas for storage of equipment or materials with some attendant workers that spent the majority of their time working inside Areas 1 or 2.

The RIM at the West Lake Landfill produces gamma radiation and radon emissions that if an individual were to work or otherwise be present on the surface of Areas 1 and 2 regularly for long durations (e.g., 40 hours a week for 50 weeks a year) over a long enough period of time (20 to 30 years), such an individual might experience an incremental increase in potential cancer risk. If a commercial worker were to work outdoors in Areas 1 and 2, the Baseline Risk Assessment and EPA ROD estimates that their incremental cancer risk would be up to 4×10^{-4} (0.0004) which is slightly above the upper level of EPA's acceptable risk range. This risk is due primarily to external radiation exposure from continued ingrowth of Ra-226 and its eight daughters from decay of Th-230 over the 1,000-year study period. This potential incremental cancer risk can be addressed most simply and effectively by installation of a new engineered landfill cover over Areas 1 and 2 and amendment of the existing land use restrictions to preclude use of

Areas 1 and 2 for outdoor storage or any other use that may be incompatible with the presence of waste materials in these areas or that could result in damage of or impacts to the effectiveness of the remedial actions (e.g., construction of an engineered landfill cover designed to provide sufficient shielding against gamma radiation and radon attenuation) that would be implemented to address these areas.

The Baseline Risk Assessment and EPA ROD also concluded that non-radiological contaminants are not likely to cause incremental cancer risks above EPA's acceptable risk range under the current or future exposure scenarios. Evaluation of potential adverse, systemic (non-carcinogenic) health effects indicated that non-carcinogenic risks are not expected to occur under the current or future exposure scenarios.

The Agency for Toxic Substances and Disease Registry (ATSDR) of the Center for Disease Control (CDC), a federal public health agency, recently completed a review (Health Consultation) of the site date to determine if radiological contamination at the West Lake Landfill might harm human health. With respect to radionuclides in soil, ATSDR concluded that if the landfill materials in Areas 1 and 2 are disturbed, workers could be potentially inhale dust particles that contain uranium and thorium decay products including radium-226, radon-222 and radium-228 if proper protective measures are not employed. ATSDR also determined that there is no evidence of contamination along the haul roads leading to the landfill. With respect to radon, ATSDR concluded that individual sample results of radon flux form areas 1 and 2 exceeded regulatory limits but that the overall average rate of radon flux from these areas were within regulatory limits. ATSDR further concluded that release of site-related radon will not extend beyond the site boundaries and although the outdoor radon levels near the landfill seem to be greater than typical regional and national background levels, the levels are not high enough to harm people's health. With respect to groundwater, the ATSDR concluded that radionuclides in groundwater will not harm people's health, the groundwater is not a source of drinking water, and that there is no indication that radionuclides in groundwater are migrating offsite.

Pursuant to a request from EPA, the OU-1 Respondents initiated a comprehensive air monitoring program to establish baseline air quality around Areas 1 and 2. Although only the first few months of monitoring have been performed so far and we are still evaluating the resulting data, my review of the initial data did not identify any occurrences of elevated levels of (1) radionuclides in particulate dust, (2) radon in atmospheric air, (3) gamma radiation or (4) volatile organic compounds (VOCs) around Area 1 or 2.

Humans are exposed to radiation all the time. Table 1 presents a comparison of potential risks from a variety of radiation exposures. As can be seen on Table 1, potential hypothetical worker exposure to RIM at the West Lake Landfill presents an extremely low risk compared to the risks from other types of exposure to radiation. Another way to understand the potential risks from exposure to low doses of radiation are to look at the estimated number of days of life expectancy that are projected to be lost from exposure to a low dose of radiation compared to the number of days lost as a result of various everyday activities (Table 2).

C. The most appropriate remedial action for the West Lake Landfill is containment consisting of a new engineered landfill cover designed to prevent potential contact with or exposure to the waste materials by workers, provide protection against radiation and radon emissions, and prevent direct contact by or infiltration of precipitation and leaching to groundwater.

Based on my experience evaluating potential remedial alternatives and preparing Feasibility Study reports for various Superfund sites including Superfund sites consisting of municipal solid waste landfills and sites that contain radionuclides and more importantly my experience preparing and the reasons stated in the EPA-approved FS, Supplemental Feasibility Study (SFS), and Isolation Barrier Alternatives Analysis (IBAA) reports for the West Lake Landfill, and my review of EPA's Proposed Plan, Record of Decision and Responsiveness Summary for OU-1, it is my opinion that the most appropriate remedial action for the West Lake Landfill is containment as described by EPA's Selected Remedy (EPA, 2008) hereafter referred to as the ROD-selected remedy. Specifically, the remedial action would entail installation of a new engineered landfill cover designed to meet not only the requirements for closure of a solid waste landfill, but including necessary enhancements to address potential gamma and radon emissions. In addition to a new engineered landfill cover, any soil containing radionuclides at levels above those that would allow for unrestricted use that may still be present on the Buffer Zone/Crossroad property would be removed and consolidated within the area under the new engineered landfill cover. Stormwater management would be included as part of design of the new engineered landfill cover. The remedial action would also include groundwater, landfill gas and radiation and radon monitoring. The existing institutional controls (*e.g.,* land use restrictions) would be amended to prevent land and resource uses that are inconsistent with a closed sanitary landfill containing long-lived radionuclides. Finally, a program of long-term surveillance (e.g., inspection) and maintenance of the remedy would be implemented.

On behalf of the OU-1 Respondents, I previously examined potential remedial alternatives for OU-1 and pursuant to requests from EPA, continue to examine other alternatives, notably excavation of part of the RIM (partial excavation alternatives) coupled with on-site or off-site disposal of the RIM. Most of these other alternatives entail complete or partial excavation of the RIM coupled with either on-site or off-site disposal of the RIM and regrading and capping of the remaining waste materials. All of the excavation alternatives are expected to pose significant additional short-term risks to on-site remediation workers and to the general public.

The ROD-selected remedy and any excavation and disposal alternative, whether complete or partial excavation are expected would meet EPA's criteria for long-term protection of human health, welfare and the environment. The ROD-selected remedy and the "complete rad removal" with off-site disposal alternatives appear implementable. Any potential excavation alternative and/or any alternative that includes on-site disposal are expected to have potential implementability issues caused by proximity to Lambert-St. Louis International Airport and regulatory and contractual restrictions on the disposal of putrescible solid waste near the Airport's runways. Any excavation alternative is expected to pose a greater potential bird or other wildlife hazard to aircraft and airport facilities because excavation alternatives would open up larger areas of the landfilled waste and take longer to complete than the ROD-selected remedy.

While implementation of the ROD-selected remedy and any of the potential excavation alternatives are expected to result in long-term risks within EPA's acceptable risk range, the risks (at 1,000 years) associated with a "complete rad removal" with off-site disposal alternative are expected to be less than those posed by any of the other alternatives. The short-term risks to on-site workers and to the community are worse under any of the potential excavation alternatives than under the ROD-selected remedy. The projected short-term risks to workers associated with the "complete rad removal" alternatives are outside of EPA's acceptable risk range.

The time required to implement the ROD-selected remedy is projected to be the shortest. The expected durations associated with off-site and then the on-site "complete rad removal" disposal alternatives are the longest of all of the alternatives, under some scenarios approaching 30 years to complete. Evaluations of potential partial excavation alternatives are still being performed and therefore projected durations for such alternatives have not yet been developed; however, the projected durations for such alternatives are expected to be between the durations estimated for the ROD-selected remedy and those identified for the "complete rad removal" alternatives.

The cost estimate for the ROD-selected remedy is the lowest, followed by potential on-site and then the off-site "complete rad removal" disposal alternatives (Note: Possible partial excavation alternatives are still being evaluated and therefore we have not yet developed cost estimates for these actions; however, it is reasonable to presume that the cost of such alternatives will be between the costs associated with the ROD-selected remedy and those associated with the “complete rad removal” alternatives).

Table 3 presents a summary comparison of the evaluation of the ROD-selected remedy and the “complete rad removal” alternatives relative to the NCP criteria. Because evaluation of possible partial excavation alternatives is ongoing, complete information on these alternatives relative to the NCP criteria is not yet available for these alternatives.

Although EPA has yet to complete its evaluation of possible alternatives for a potential thermal isolation barrier between the Bridgeton Landfill and OU-1 Area 1, based on the results of the Isolation Barrier Alternatives Analysis and the results of recent additional investigations (Phase 1D investigations) of the extent of RIM in the western and southwest portions of Area 1, it is my opinion that, if any remedial action is found to be necessary, the most reasonable alternative would be contingent implementation of heat removal technologies to reduce any excess temperatures associated with a possible subsurface reaction (SSR).

D. The only potential impacts if a subsurface reaction or subsurface smoldering event were to occur in Areas 1 or 2 would be a temporary, localized increase in radon emissions from the surface of Area 1 or 2.

Pursuant to a request from EPA, I performed an evaluation of potential risks if a subsurface smoldering event (SSE) or subsurface exothermic (heat generating) reaction (SSR) were to occur in Areas 1 or 2. A copy of my evaluation is included as Attachment C to this report.

My evaluation was based on a review of published literature and evaluations performed relative to the SSR in the South Quarry Landfill regarding the impacts common to SSRs and the potential effects such impacts could have on the RIM or the engineered components associated with the remedial actions previously selected by EPA for OU-1 as documented in the 2008 Record of Decision (ROD) for OU-1 (ROD selected remedy). After considering the conditions and processes known to be associated with subsurface heating events at landfills and the remedy selected by EPA in the 2008 ROD, it is my opinion, to a reasonable degree of scientific certainty, that:

- The radiologically-impacted material (RIM) disposed of in West Lake Areas 1 and 2 will not become more or less radioactive in the presence of heat. Likewise, the RIM is not explosive and will not become explosive in the presence of heat.

- An SSR does not create conditions that could carry RIM particles or dust off the site. The heat of an SSR is not high enough to ignite non-RIM wastes or chemical compounds or to cause them to explode.

- An SSR may allow radon gas to more easily rise through the ground and reach the surface of the landfill than would otherwise occur, because heat will would reduce the amount of moisture in the buried solid waste (trash) thereby increasing the amount of air between the soil particles and thus limiting the ability of the buried solid waste to retain radon below ground. Any radon gas that does make it to the surface would dissipate quickly in open air. This potential increase in the rate of release of radon gas at the surface of the landfill would be limited to the area of the SSR and would stop when the SSR ends.

- An SSR in West Lake Area 1 or 2 would create no long-term additional risks to people or the environment.

- Any short-term risks would be associated with the temporary increase in radon gas coming from the surface of the landfill if no cap is installed on the landfill, or if the cap called for by the 2008 ROD was not properly maintained.

- These short-term risks can be addressed by designing, building, and maintaining the landfill cap called for by the 2008 ROD, and by maintaining the land use restrictions already in place on the entire West Lake property, which prevent certain site uses.

- There are no additional applicable or relevant and appropriate requirements of other environmental regulations (ARARs) associated with an SSE at the West Lake Landfill.

My report was submitted to EPA and reviewed by EPA Region 7, EPA's Office of Research and Development (ORD), National Risk Management Research Laboratory, Engineering and Technical Support Center (ETSC) and Mr. Todd Thalhamer, a consultant to the Missouri Department of Natural Resources (MDNR) who has also been retained by the Missouri Attorney General's Office to provide testimony in this matter. EPA Region 7 concluded that EPA does not expect the SSE to come into contact with the

RIM. EPA also concluded that the RIM is not expected to become more or less radioactive in the presence of heat and that there is no evidence that the RIM will become explosive in the presence of heat. The ORD-ETSC comments indicated that ORD generally concurred with the three conclusions reached in the report (listed above); however, EPA-ORD did offer additional points in particular highlighting its opinion that if a SSE were to occur in OU-1 it could create the potential for additional leachate generation. This opinion was based in part on ORD's conclusion that there had been an increase in leachate generation within the South Quarry area of the Bridgeton Landfill; however, the actual data regarding leachate extraction rates do not indicate that the rate of leachate generation has increased, but instead reflect changes in the manner and locations at which leachate is being produced, extracted and managed.

Subsequently, in responses to another request from EPA, I supervised preparation and was lead author for the Isolation Barrier Alternatives Analysis (IBAA) which among other things, included evaluation of a No Action alternative relative to potential impacts if an SSE were to occur in Area 1. The IBAA report concluded it is highly unlikely that the SSE could ever migrate laterally and vertically from its location deep within the South Quarry area of the Bridgeton Landfill, into and through the North Quarry area of the Bridgeton Landfill and subsequently into Area 1. The IBAA report further concluded that the principal impact of a SSE or any increase in heat within Area 1 would be the potential increase in the amount of radon exhaled (emitted) at the surface of Area 1. Going beyond the qualitative assessment of potential changes in radon emissions described in the prior SSE Impact Evaluation, the IBAA report included a quantitative assessment of the potential increases in radon emissions that may occur if a SSE were to impact the RIM in Area 1. Based on calculated quantitative estimates of potential radon emissions, the IBAA report concluded that even with the use of conservative assumptions, the magnitude of the expected increase in radon emissions that may occur is approximately 2.9 pCi/m^2/sec above the average radon emission rate from Area 1 of 13.5 pCi/m^2/sec measured during the RI. The resultant average projected rate of radon emission from Area 1 (16.4 pCi/m^2/sec) that is estimated to occur if a SSE were to enter and move through Area 1 would not result in radon emission levels that would exceed the radon standard established under the National Emission Standard for Hazardous Air Pollutants (Radon NESHAP) of 20 pCi/m^2/sec. The IBAA report further concluded that installation of a new engineered landfill cover included in the ROD-selected remedy for OU-1 would substantially reduce the potential for any increase in radon emissions both with and without potential impacts associated with a SSE. In its review of the IBAA, EPA concluded that "The specific arguments postulated in this document [the IBAA] in relation to the heat's effect on the radiologically-impacted material (RIM) and therefore radon flux in Attachment A [of the IBAA] are well thought out and present plausible scenarios considering an event occurring is a low probability."

E. There is no basis to conclude that radionuclides are present in trees at or adjacent to the site above naturally occurring levels.

In April 2015, I accompanied and assisted three graduate student candidates from the Missouri University of Science and Technology in their efforts to collect tree core samples from trees located on Areas 1 and 2 for VOCs and radionuclide analyses. I was not advised of their intentions to subsequently collect tree cores from other areas on, adjacent to, or offsite of the West Lake/Bridgeton Landfill properties and therefore was not afforded an opportunity to observe these activities or to collect duplicate samples.

I have reviewed the "Westlake Landfill Tree Core Analysis Report" prepared by Dr. Burken and Dr. Usman and the "Report on Westlake Landfill Phytoforensic Assessment using Gamma Spectroscopy" prepared by Dr. Usman. As described in these reports, Dr. Usman analyzed the tree core samples for the presence of radionuclides. He opines that some of the samples contained radioactive material. He further opines that based on the distribution of the batches of samples that reportedly contained radionuclide, the radionuclides present in the tree samples originated from the West Lake Landfill.

Based on my observations of the tree core sampling activities, my review of the information contained his reports regarding the sampling and analytical procedures used by Dr. Usman, my knowledge of the radionuclide occurrences at the site, the soil and groundwater conditions at and near the site, and my knowledge of the results of the extensive sampling and monitoring data obtained from the various environmental media at the site (e.g., soil, surface water sediment, groundwater), I strongly disagree with Dr. Usman's opinions. It is my opinion, to a reasonable degree of scientific certainty, for the reasons discussed further below, that the data obtained by Dr. Usman do not demonstrate that radionuclides, above naturally occurring background levels, are present in the trees or that his data otherwise provide any defensible basis to conclude that there has been migration of radionuclides from Areas 1 and 2.

First, Dr. Usman himself acknowledges that "Most samples from the environment will contain low levels of radioactivity." Although he does not quantify or discuss what is meant by the term "low levels" he does acknowledge that radioactivity is naturally present in all environmental media. Unfortunately, after acknowledging this fact, he and the rest of the UM S&T team failed to collect samples from a background or reference location to assess what the naturally occurring levels of radionuclides are in trees in the St. Louis area. Instead, they resorted to obtaining background counting levels from their instrument; however, this is not a true background value. Instead, what Dr. Usman identified as "background" actually represents what is more appropriately defined as an instrument blank value, that is the random readings or "noise" level generated by the instrument in the absence of any sample. Dr. Usman then incorrectly used these results as a basis to conclude that reported activity levels above the statistically defined range associated with the instrument blank readings represented elevated levels of radionuclides in tree core samples obtained from or near the West Lake Landfill. Dr. Usman's failure to obtain and analyze samples from a reference area to develop an estimate of actual background levels in tree samples for the St. Louis area is inconsistent with his observation that radionuclides are naturally present in all environmental samples and more importantly is inconsistent with accepted scientific practice. Furthermore, Dr. Usman's failure to obtain true background data undermines the validity of his opinions relative to the potential presence of elevated levels of radionuclides in tree samples at or near the West Lake site.

In addition to his failure to obtain true background values, the procedures used by Dr. Usman to prepare and analyze the tree core samples, also severely limit the validity of the data and any conclusions that may be drawn from these data. Specifically, rather than analyzing each tree core sample separately, Dr. Usman made the decision to analyze the samples in batches; however, after making this decision, Dr. Usman had no involvement in determining which specific tree core samples were included in each batch.

I reviewed Dr. Usman's laboratory notes to determine which samples were included in each batch. I also reviewed the information provided by Drs. Usman and Burken regarding the locations of the various tree core samples they analyzed. I would note that the locations of the various tree core samples are confounded by inconsistencies and discrepancies in the information they provided relative to whether the specific numbers refer to the identification of actual trees or instead to specific sample vials. Figures 3 displays the locations of the various tree core samples collected by UM S&T. Figure 4 displays the locations of the tree core samples included in each batch of samples analyzed by Dr. Usman. Based on my review, the batches were assembled with little apparent logic such that the batching of the samples further obfuscates the ability to draw any meaningful conclusions from his results. For example, Batch 1 includes samples from the vacant lot located to the north of the Virbec property across St. Charles Rock Road from the Closed Demolition Landfill as well as samples obtained from the Boenker property located to the south of the southwest corner of the South Quarry area of the Bridgeton Landfill (Figure 5). Consequently, Batch 1 includes the tree cores samples from two areas that are on opposite sides of the landfill and are located approximately ¾ of mile from each other. Similarly, Batch 2 includes samples from the Virbec property located across St. Charles Rock Road from Area 1 as well as samples obtained from the southern corner of the Earth City stormwater retention pond near the inactive sanitary landfill (Figure 6). Batch 3 includes samples from the vacant lot north of Virbec, the Boenker property and near the Earth City retention pond (Figure 7). Batch 4 (Figure 8) includes samples from the south end of the Earth City retention pond, the west side of the AAA Trailer property and the Buffer Zone property (which is owned by Rock Road Industries, one of my clients and for which I was not provided any notice that UM S&T personnel would be collecting samples from this property and to my knowledge, UM S&T personnel did not receive permission from the owner or anyone else to access or obtain samples from this property). Batch 5 (Figure 9) includes samples from the northwest corner of Area 2, the central portion of Area 2 and also a sample obtained offsite from the south end of the Earth City retention pond. Batches 6, 7 and 8 include only samples from Area 2 (Figure 10 -12). Batch 9 includes samples from Area 1 and Area 2 (Figure 13). Batch 10 includes samples from Area 1 (Figure 14). Batch 11 (Figure 15) includes samples from Area 1 as well as samples from along both the east and west sides of the Closed Demolition Landfill (some of which appear to have been obtained from property owned by Bridgeton Landfill/Rock Road Industries and again for which I was not provided any notice regarding sample collection from this area and to my knowledge, UM S&T personnel did not receive permission to access or obtain samples from this property) and a sample obtained from the commercial area located across St.

Charles Rock Road from Area 2. Batch 12 included samples obtained from the Boenker property, from near the south corner of the Bridgeton Landfill, from the Earth City property adjacent to the South Quarry area of the Bridgeton Landfill and from Area 2 (Figure 16). Batch 13 included samples from the Earth City property adjacent to the South Quarry and a sample from the Boenker property (Figure 17). Batch 14 includes samples obtained from the Earth City property offsite from the South Quarry and a sample from Area 2 (Figure 18). The locations of the samples including in the remaining batches are shown on Figures 19 – 30) and also display rather inexplicable groupings of samples within the various batches.

Furthermore, in examining Dr. Usman's own notes regarding which tree core samples were included in each of the batches, I discovered that his batches of tree core samples not only include actual tree core investigative samples, but for some unexplained reason, the various sample batches also include quality assurance/quality control (QA/QC) samples such as duplicate samples, field blank samples and trip blank samples (Table 4). Because the purpose of collecting and analyzing QA/QC samples is to provide data needed to evaluate the quality of the analytical results, it is standard scientific practice to analyze QA/QC samples separately from investigative samples. By not separating these samples out of the batches, Dr. Usman failed to obtain data necessary to evaluate the overall precision, accuracy, representativeness, comparability and completeness of his data. I also discovered that his notes indicate that a sample vial number 155 was included in Batch 22; however, review of the tree core sample forms completed by the graduate students during collection of the samples indicates that no such sample was ever collected.

No discussion of the rationale used to select which samples were included in which batch is provided in either Dr. Usman's report or the "Westlake Landfill Tree Core Analysis Report" prepared by Dr. Burken and Dr. Usman. I do not understand why they simply did not combine all of the samples from a particular area such as from the Virbec property and/or the vacant lot adjacent to the Virbec property together into one or two batches, all of the samples from Boenker property into one or two batches, all of the samples from the south end of the Earth City retention pond into one batch, all of the samples from the Earth City property adjacent to the South Quarry into one batch, and so forth. Furthermore, I can see no rationale reason as to why samples obtained from Areas 1 and 2, the supposed source areas of the radionuclides, were included in batches that also contained samples obtained from offsite areas.

The "Westlake Tree Core Analysis Report" prepared by Drs. Burken and Usman states "Net Count in 4 analyzed batches of 16 samples were found to be more than 3σ of background radiation corresponding to a 99.73% confidence level." In his report, Dr. Usman states "However, five batches (batch number 1, 3, 4, 5, and 6) had exhibited counts where the gamma counts were statistically higher than background, warranting further investigation." (Note: as previously discussed, the value Dr. Usman used for comparison was not background but rather was the instrument blank level.) No explanation is provided for the discrepancy in the number of batches purportedly containing elevated counts (*i.e.,* four versus five batches) discussed in the two reports. Neither report presents the results of his initial screening of the 16 batches listed in the "Westlake Tree Core Analysis Report" or for all 23 tree core sample batches with results reported in the additional documentation provided by Dr. Usman. Similarly, although his report describes the methodology he used to develop his "background" level, neither report presents the actual "background" results he obtained or his specific calculations used to develop the 3σ value of background radiation corresponding to a 99.73% confidence level he used for his "background" level.

Dr. Usman's graphical portrayals of the results of his analyses of the batches of samples are incorrect and misleading, as demonstrated by review of the values presented on Figures 5 – 7 of the "Westlake Tree Core Analysis Report." These figures purportedly display the locations of batches of tree core samples that contain elevated levels of radionuclides against the values contained in Appendix B of the same report.. Figure 5 of the "Westlake Tree Core Analysis Report" is titled "Geographic Distribution of Elevated Count Samples – U238" and although the legend to this figure indicates that the results represent "Uranium 238 counts in Tree Core Analyses", the values shown on the legend are identified as "Net rad counts" and do not correspond with any of the results presented in "Appendix B: Radiological Sample Batches and Counts for Significant Peaks" of the "Westlake Tree Core Analysis Report". Specifically, Figure 5 states that the U-238 result for Batch 1 had a Net Rad Count 159679; however, this value is not listed for any of the results presented in Appendix B and does not correspond with the U-238 result of 1,759 listed in Appendix B. Similar inconsistencies exist between the results presented on

Figure 5 and those listed in Appendix B for the U-238 results for all of the other 4 batches (3, 4, 5 and 6) that Dr. Usman identifies as containing “elevated” levels of radionuclides. In particular, Figure 5 lists values for Batches 4 and 5 which according to the results presented in Appendix B did not contain detectable levels of U-238. Similar problems exist with Figures 6 and 7. Of particular note are the results for Batch 5, which Figure 6 indicates contained a net count of 5,520 for U-235 and Figure 7 indicates contained a net count of 6,849 for Th-232; however, Appendix B indicates that the results for these isotopes, indeed the results for the entire U-235 and Th-232 decay chains were non-detect for Batch 5. Despite the complete absence of Th-232 and any of its decay products in Batch 5, Dr. Usman’s displays results and identifies Batch 5 as containing elevated levels of U-235 and Th-232 on Figures 6 and 7 of the “Westlake Tree Core Analysis Report”.

Per his report, the highest levels of Uranium-238 were reported to occur in Batch 1 which as discussed above included only offsite samples obtained from the Boenker property and from the vacant lot located to the north of the Virbac facility. Batch 3 included samples from these same two areas plus on additional sample from the south end of the Earth City retention pond. The highest levels of Uranium-235 were also reported to occur in Batch 1. The highest levels of Thorium-232 were obtained from Batch 6 which include samples from Area 2.

Although Dr. Usman concluded that his data indicate one or more of the samples in batches 1, 3, 4, 5 and 6 contain radioactive material, he never discusses the results associated with each of these batches but instead switches to discussing the results in terms of clusters that are formed when he plots the result of these batches on an aerial photograph where he identifies four clusters including a northwest, northeast, southwest and southeast clusters. He opines that the results obtained from his Northwest cluster, which includes results from portions of various batches that included tree samples obtained from Area 2 and adjacent to the west side of the AAA Trailer property derived from Batches 4, 5 and 6, suggest that radioactive material may have migrated to reach the root tips of plants in this area. What he fails to acknowledge is that these same batches include samples from other areas and that several other batches that only contained samples from the area he identifies as his northwest cluster, such as Batches 7, 8, and 9, did not display elevated levels of radionuclides. He further opines that higher counts observed in batches that include samples from his northeast cluster could have receive some radioactive material from migration of leached material that migrated underground to this area. He again fails to acknowledge that these same batches include tree core samples from other areas, and that several of his sample batches, notably Batches 2, 22 and C, include samples from his northeast cluster did not display what he defines as elevated radionuclide levels. Furthermore, his northeast cluster is located offsite and upgradient from both Area 1 and Area 2 so there is no mechanism for any possible migration of radionuclides underground from Area 1 or 2 to this area. Lastly, he states that the presence of radioactivity in what he identifies as his southwest and southeast clusters was “rather unexpected”, so much so that he ran separate batches composed of just samples from these two areas which again reportedly contained elevated levels of radionuclides even though, as he states, these two clusters are not in the proximity of any radiological site (presumably he was referring to Areas 1 and 2). Ultimately, he concludes "Because of the batching we are unable to pin point the source of this possible contamination."

Overall, because the data used to identify his clusters of purportedly elevated levels of radionuclides are based on analyses of composite batches of samples that include some samples located within the areas of his identified clusters and some samples from elsewhere, combined with the absence of "elevated" radionuclide levels in other batches obtained from these same cluster area, no meaningful conclusions can be drawn regarding the possible presence of radionuclides above naturally occurring levels can be made from his tree core results.

Furthermore, Dr. Usman' results indicate that the highest levels of radionuclides occur in samples obtained offsite rather than from samples obtained directly from Areas 1 and 2. In fact, with respect to Area 1, Dr. Usman concluded "However the samples <*sic*> the Radiological Area 1 showed no traces of U238, U235 or Th232." Relative to the absence of radionuclides in tree core samples obtained from Area 1, Dr. Usman offers the following:

> "This observation suggests that the top soil and tree root tips may be in geological isolation of the underlying radioactive material in the area. In other words, the tools and techniques put in place to prevent upward

migration of the radioactive material seem to perform well to prevent upward migration and limit availability."

This opinion is at best speculative and lacks any foundation because there is no geological isolation in Area 1. Instead the trees in Area 1 are growing directly in the radioactively-impacted material. Furthermore, no "tools or techniques" or any other protective measures have been implemented in Area 1. The logical protective measure for Areas 1 and 2 would be to installed the new engineered landfill cover over these areas as described in EPA's ROD (the ROD-selected remedy). However, in 2009 EPA instructed the OU-1 Respondents to stop all work related to implementation if the ROD-selected remedy.

When asked at his deposition to explain what "tool and techniques" he was referring to it became apparent that he was referring to the presence of landfill cover and gas extraction wells on the Bridgeton Landfill that have nothing to do with conditions in Area 1. Unfortunately, Dr. Usman's complete lack of knowledge of the site and the site conditions and his desire to provide an explanation regarding why the trees growing in the RIM in Area 1 do not show elevated levels of radionuclides resulted in him reaching conclusions and offering opinions that are completely contradictory to the facts. Because he believes that the reported "elevated" levels of radionuclides had to originate from Areas 1 and 2 but because he did not observe "elevated" radionuclide levels in trees actually growing in Area 1, he was forced to come up with a reason for this condition that was consistent with his hypotheses that the trees in the area have elevated levels of radionuclides rather than going back and questioning the validity of his basic hypothesis. Simply stated, he is guilty of confirmation bias, that is he tended to look for information that conformed to his hypothesis and overlook, or in this case develop totally unsubstantiated reasons to discount or ignore information that is inconsistent with his hypothesis.

Another example of the effects of Dr. Usman's lack of site knowledge can be seen in the specific radionuclides he identifies as being elevated, U-238, U-235 and Th-232. As discussed in my earlier opinion, the radionuclides of primary concern at the West Lake site are Ra-226 and Th-230 and their related daughter products that resulted from disposal of residues that contained only very low levels of uranium. Review of the results of the extensive soil and groundwater sampling performed at the West Lake Landfill, indicate that uranium is generally not present at levels above background or regulatory criteria except in a very few soil/waste samples that contain significantly elevated levels of Ra-226 and Th-230. This observation is consistent with the radioactive materials disposed of at the West Lake Landfill having been subjected to extensive processing to remove uranium prior to be taken to the West Lake Landfill. Furthermore, occurrences of Th-232 are extremely rare in any of the soil and groundwater samples obtained from the West Lake Landfill and where present occur at only trace levels consistent with background levels. Instead of reviewing or at least considering even the most basic information regarding the conditions and radionuclide at the West Lake Landfill, Dr. Usman instead relied on a report of leaching of radionuclides from soil at the St. Louis Airport site (SLAPs) as the basis for his opinion that uranium is the likely contaminant at the site. Although one of the materials (leached barium sulfate residue or LBSR) that was stored at the SLAPs site for a period of time was ultimately disposed of at the West Lake Landfill, a variety of other substances, some which were later sold for further processing for recovery of uranium, that were also stored at SLAPs were never taken to or otherwise have any relationship whatsoever to the radioactive materials at the West Lake Landfill. Consequently, Dr. Usman's opinions, which focus on purported "elevated" levels of uranium and Th-232 are inconsistent with the actual conditions at the West Lake Landfill and likely again originate from confirmation bias. Specifically, he found what he believes to be "elevated" levels of uranium and Th-232 in tree core samples and therefore, opined incorrectly that such occurrence must be coming from Areas 1 and 2. Instead of questioning his fundamental hypotheses that the testing was intended to address, specifically, is there any basis to conclude that trees at the West Lake Landfill have taken up radionuclides that are present at the West Lake Landfill (which include Ra-226 and Th-230 and not uranium or Th-232 as indicated in Dr. Usman's report), Dr. Usman arrives at a fallacious opinion that because there are what he believes to be elevated levels of radionuclides in trees, and radionuclides are present at West Lake Landfill, West Lake Landfill must be the source of the radionuclide occurrences in the tree core samples.

Finally, I must point out that Dr. Usman himself acknowledges he did not obtain actual quantitative data on the radionuclide levels in the trees but instead his results were intended only for screening purposes. According to Dr. Usman, his screening level data only serve to suggest that "there is sufficient merit to warrant careful analysis and in-depth examination. Despite the fact that he believes a "careful analysis and in-depth examination" of the possible presence of radionuclides in trees needs to be performed, he as offered opinions that radionuclides are present in trees and that radionuclides have migrated from the West Lake Landfill. The absence of a careful analysis and in-depth examination of his data is clearly evidenced by the points I have identified above. Furthermore, the absence of such careful analysis and in-depth examination is inconsistent with accepted scientific practice.

I should also note that in March 2009, my firm retained the services of a local St. Louis health physicist to collect 23 samples of vegetation from Areas 1 and 2 and have those samples analyzed to make an initial determination if the vegetation contained radionuclides. This work was performed in anticipation of implementation of remedial design investigations that would necessitate removal of the vegetation in order to access Areas 1 and 2 and to obtain more accurate topographic maps to be used to prepare grading plans. The results of this sampling indicated that elevated levels of radionuclides were not present in leaves, twigs or ground litter in Areas 1 and 2. A copy of this report is included as Attachment D.

As opposed to Dr. Usman's development and reliance on qualitative, screening level data, the vegetation samples that were collected from Areas 1 and 2 in March 2009 were submitted for quantitative analyses for the presence of radionuclides and the specific activity levels associated with any radionuclides that were reported to be present. The March 2009 sample results indicated that the levels of radionuclides in all of the vegetation samples were less than the criteria established for “complete rad removal” from soil; that is the combined levels of Ra-226 plus Ra-228 were less than 7.9 pCi/g (criteria of 5 pCi/g plus background of 2.9 pCi/g) and were less than the combined levels of Th-230 plus Th-232 (7.9 pCi/g) that, through radioactive decay and ingrowth, could result in combined radium levels above the EPA criteria for unrestricted use.

Despite all of the stated limitations of his data (screening level, not quantitative); lack of true background values, inconsistencies between his results and his fundamental hypothesis, and lack of correlation of his results with known monitoring results and site conditions, Dr. Usman nevertheless opines that his results indicate offsite migration of RIM. For all of the reasons discussed above, I do not agree with Dr. Usman’s opinions or conclusions. For the reasons stated above, it is my opinion, to a reasonable degree of scientific certainty, that Dr. Usman’s results do not provide a scientifically-defensible basis to conclude either that “elevated’ levels of radionuclides are present in tree core samples at or near the West Lake Landfill or that any offsite migration of radionuclides have occurred.

F. The volatile organic compound analyses of tree samples s do not provide any meaningful scientific basis to conclude that VOCs are present in soil or groundwater at the West Lake Landfill at levels of concern or that such VOCs are migrating offsite from the West Lake Landfill.

I have reviewed the “Westlake Landfill Tree Core Analysis Report” prepared by Dr. Burken and Dr. Usman and the “West Lake Landfill Organic Pollutant Phytoforensic Assessment” prepared by Dr. Burken. As described in these reports, Dr. Burken analyzed tree core samples for the presence of volatile organic compounds (VOCs).

Based on the results of the VOC analyses of tree core samples Dr. Burken opines that "Findings indicate contamination on-site for the WLL area, and the distribution of pollutants in the vegetation at the WLL and surrounding properties is highly indicative of off-site migration."

Dr. Burken further opines "Two off-site areas of indicate <*sic*> a high probability for off-site pollutant transport." He goes on to state "The ClVOCs were detected most frequently in the northwest area of WLL property near the closed demolition landfill and OU1, and off property to the north-northeast across St. Charles Rock road from the entrance to the WLL. The second area was near South Quarry and West OU2 to the southwest along and across the Old St. Charles Road and the closed section of the Old St. Charles road near the water district impoundments."

Although the above statements regarding the areas he believes elevated levels of VOCs in tree core samples indicate offsite migration are somewhat unclear, based on review of his entire report and in particular his figures it appears that he is opining that occurrences of elevated levels of chlorinated VOCs (ClVOCs), principally trichloroethene (TCE) and tetrachloroethene also referred to as perchloroethene (PCE) and of benzene, toluene, ethyl benzene and xylenes (BTEX) in tree core samples, indicate two areas of contamination. The first area he identifies is the northwest portion of Area 2 and offsite on the east side of St. Charles Rock Road across from the landfill entrance (which he apparently considers to be one area). The second area he identifies is to the southwest of the Inactive Sanitary Landfill and the South Quarry.

I disagree with Dr. Burken's conclusions and opinions for the several reasons. First, Dr. Burken failed to examine and understand the site conditions, in particular the results of the extensive soil and groundwater monitoring data obtained from the site and to compare these data to his results to assess the overall validity of his hypotheses. Second, Dr. Burken failed to evaluate other facilities in the vicinity of the site with known releases that could, and as discussed further below, do impact the overall validity of his conclusions.

The Superfund investigation, site characterization and monitoring of the West Lake Landfill has been ongoing for over 20 years. During that time extensive numbers of soil and groundwater samples have been obtained and analyzed for VOCs. With respect to soil or more appropriately waste materials in Areas 1 and 2, samples were obtained and analyzed for VOCs during the OU-1 RI as part of the drilling and sampling of soil borings located in Areas 1 and 2. PCE, TCE and benzene were generally not detected in these soil samples, or if detected were found to occur at concentrations below any levels that would result in them being identified as potential chemicals of concern. Toluene, ethyl benzene and xylenes were only detected at concentrations above trace levels (parts per billion) in three samples including one sample of the contents of a 5-gallon container encountered during drilling of the soil borings. Regardless, the presence of such limited occurrences of these compounds in soil/waste is consistent with the fact that the site was used for waste disposal and that some of the waste materials, including simple household solid wastes, contain these chemicals. The fact that some of these constituents were detected in tree cores growing directly in the waste materials does not provide any basis to indicate that these constituents have or are migrating but rather reflects the fact that the trees are rooted and growing in the waste materials.

With respect to groundwater, most recently, at the request of EPA, I directed efforts to collect samples from every monitoring well at the site (at last count numbering 85 wells) during four separate events and to have the resultant samples analyzed for VOCs, trace metals, inorganic compounds, radionuclides, field parameters and during the first event for semi-volatile organic compounds. During these four groundwater monitoring events, PCE and TCE were only detected in one monitoring well (S-61) located within the West Lake Landfill. Even this well, which is located within Area 2 and is drilled directly through the waste materials into the underlying alluvium just below the waste materials, only contained 0.40 to 1.2 micrograms per liter (ug/L) of PCE and 1.0 ug/L of TCE, which was detected only once in the four monitoring events. These results are below the State and EPA drinking water and groundwater standards of 5 ug/L for these compounds. PCE and TCE were not detected in any of the other 84 monitoring wells, including monitoring wells located downgradient of S-61 and completed in the same shallow alluvial zone as well S-61. Although the tree sampling results (Figures 31, 32 and 33) may have detected PCE, TCE and to a much lesser extent 1,2-dichloroethene (DCE) in trees located in the vicinity of this well, the presence of PCE or other chlorinated VOCs in any other tree core samples does not indicate and does not provide a scientific or any other basis to conclude that PCE or other chlorinated VOCs are present in groundwater above regulatory levels, levels that would pose any risk to the public, or that would require any form of remedial action other than possibly installation of engineered landfill cover as originally selected by EPA. Furthermore, although PCE, TCE, and DCE may have been detected in tree core samples obtained from other areas, based on the actual groundwater data, the tree core sample results cannot be used as a basis to conclude that PCE, TCE or other chlorinated VOCs occur in groundwater in any other area, that PCE, TCE, or other chlorinated VOCs occur in any groundwater, either onsite or offsite, at levels above EPA and Missouri standards, or that PCE, TCE, or other chlorinated VOCs are migrating in groundwater off of the site.

With respect to Dr. Burken's opinion regarding the presence and offsite migration of benzene in what he identifies as his northwest area (essentially Area 2), although the groundwater monitoring results obtained from monitoring wells in and around Area 2 during all four of the recent comprehensive groundwater monitoring events did, in some instances detect the presence of benzene near Area 2 (Figure 34), none of the reported detections were at concentrations at or above the EPA and State groundwater and drinking water standards (Figure 35). Therefore, although the tree core sampling results for benzene (Figure 36) may have the ability to define areas potentially containing benzene in groundwater, the presence of benzene in tree core samples provides no meaningful basis to conclude that benzene is present in the underlying groundwater at concentrations of concern (i.e., at concentrations greater than EPA or State standards) or that benzene is migrating in groundwater off of the site.

Results of the recent groundwater monitoring indicated that toluene was only detected at concentrations greater than the EPA and State groundwater and drinking water standards (1,000 ug/L) in two wells, PZ-104-SD and MW-1204. Both of these wells are located adjacent to the South Quarry in areas where water quality has been affected by the SSR in the South Quarry. Although Dr. Burken's tree sample results (Figure 37) may have detected the presence of toluene in tree cores elsewhere at the site and offsite, the presence of toluene in tree core samples provides no meaningful basis to conclude that toluene is present in the underlying groundwater at concentrations of concern (i.e., at concentrations greater than EPA or State standards) or that toluene in is migrating in groundwater off of the site.

Results obtained from the recent comprehensive groundwater monitoring events indicate that ethyl benzene and xylenes are not present in groundwater anywhere at or near the site at concentrations anywhere near the groundwater and drinking water standards. The highest level of ethyl benzene was 140 ug/L in well PZ-205-AS, which is substantially below the drinking water/groundwater standard of 700 ug/L. The highest levels of xyelenes detected in any of the groundwater samples were 190 to 240 ug/L in PZ-303-AS and 140 to 480 ug/l in PZ-205-AS which are substantially less than the groundwater and drinking water standard of 10,000 ug/L. Although Dr. Burken's tree sample results may have detected the presence of ethyl benzene (Figure 38) and xylenes (Figure 39) in tree core samples at the site and offsite, the presence of ethyl benzene and xylenes in tree core samples provides no meaningful basis to conclude that ethyl benzene or xylenes are present in the underlying groundwater at concentrations of concern (i.e., at concentrations greater than EPA or State standards) or that ethyl benzene or xylenes are migrating in groundwater off of the site.

In addition to the complete lack of correlation between the tree core results and any actual occurrences of chemical in groundwater at levels above EPA or State groundwater or drinking water standards, I also consider Dr. Burken's opinions to be invalid as a result of his failure to consider the results and impacts to groundwater from other facilities near the West Lake Landfill that are known to be sources of release of many of the same constituents Dr. Burken identified as being present in his tree samples. I will give Dr. Burken credit for identifying the occurrences of benzene in tree core samples obtained from the northern portion of the Crossroad development as likely originating from potential sources other than the West Lake Landfill; however, I find it surprising that he did not investigate, consider or otherwise was made aware by his client of other potential sources in the vicinity of the West Lake Landfill.

For example, the Virbac (former PM Resources or Purina Mills facility) located the east side across St. Charles Rock Road from the landfill entrance. Per MDNR records and readily available documents regarding this facility, it is well known that this facility generated, stored and handled hazardous wastes and that releases of hazardous materials, including VOCs occurred at this facility.

A variety of hazardous wastes were produced and stored in a 16,000-gallon underground storage tank (UST), located along the east side Purina Mills/PM Resources building. A 1200-gallon concrete spill catchment tank was also installed at the offloading area to collect and contain spills. Purina Mills/PM Resources operated the storage tank and catchment basin under two hazardous waste permits, one issued by the MDNR and one issued by EPA, both effective May 25, 1987. In September, 1994, PM Resources removed the spill catchment/tank system. During removal, it became apparent that a release of hazardous chemicals had occurred at this location. Initial investigations revealed relatively high concentrations of ethylbenzene, xylenes and TPH in the soil immediately surrounding the 1,200-gallon tank and catchment area. MDNR accepted PM Resources/Purina Mills' closure report for the 12,000-gallon UST in 1998. MDNR reportedly has not accepted the closure certification as of yet. The tank was closed in place and was referred to corrective action for soil and groundwater investigation related to the tank. Low concentrations of miscellaneous volatile organic compounds were identified along the perimeter area of the former hazardous waste UST. In 1999, PM Resources/Purina Mills entered into a Consent Judgment with the EPA. The Consent Judgment and permit issued to Purina Mills required them to investigate and clean up releases of hazardous waste and hazardous constituents to the environment at their facility resulting from present and past hazardous waste handling practices. In 2001, PM Resources submitted a Remedial Action Plan to address the issues raised during past subsurface investigations surrounding the former catchment tank, hazardous waste UST and hazardous waste above-ground storage tanks (ASTs). Groundwater monitoring was also included in the Remedial Action Plan. Groundwater monitoring identified the presence of a large number of chemicals of concern at concentrations greater than water quality standards/risk-based levels including BTEX, acetone, carbon disulfide, chlorobenzene, nitrobenzene, methyl tert-butyl ether (MTBE), and tetrahydrofuran along with various phenol compounds, polynuclear aromatic hydrocarbons (PAHs), other

SVOCs, as well as various pesticides and one herbicide (Risk Assessment and Management Group, Inc., 2005 and PM Resources, 2003). In 2006, PM Resources proposed to construct a new building over the location of the 16,000-gallon UST. The facility submitted a work plan to investigate the soil and groundwater in the vicinity of the tank. The tank and approximately 213.5 tons of impacted soil were removed and properly disposed of off-site.

In the 2008 OU-2 ROD, EPA identified the PM Resources facility as a known source of groundwater contamination from which groundwater flows toward the landfill and as a result some of the contaminants detected as part of the OU-1 and OU-2 investigations may be attributable to this facility. Impacts to groundwater quality at the former PM Resources facility have extended offsite across St. Charles Rock Road and impacted groundwater quality beneath a portion of the West Lake Landfill Superfund Site, most notably in monitoring well PZ-114-AS (Herst & Associates, 2005b, 2004a and 2004b).

The Hussman facility is located at 12999 St. Charles Rock Road, across St. Charles Rock Road and to the east of the West Lake Landfill Superfund Site. Hussmann is a manufacturer of commercial refrigeration parts. A release of paint thinner was discovered during closure of USTs at the facility. Hussmann believes the release was from older, unregulated tanks removed in 1989. Petroleum hydrocarbons have been detected in both soil and groundwater at the Hussmann property. Hussman is addressing the contamination through the Missouri Brownfields Voluntary Cleanup Program.

A leaking underground storage tank (LUST) was also operated in conjunction with the asphalt plant at the West Lake Landfill. The OU-2 RI report indicates that the asphalt plant LUST investigation began in 1993. Soil sampling conducted during removal of a 10,000 gallon underground storage tank (UST) that had been used to contain diesel fuel yielded Total Petroleum Hydrocarbon (TPH) concentrations as high as 13,270 milligrams per kilogram (mg/kg), with benzene, toluene, ethylbenzene and xylenes (BTEX) also present (Herst & Associates, 2005a). Soil concentrations exceeded soil cleanup levels (Herst & Associates, 2005a). By the end of 1993, groundwater monitoring wells had been installed in the asphalt plant area and some of the wells exhibited floating free product on top of the groundwater (Herst & Associates, 2005a). Groundwater TPH concentrations were as high as 748,593 milligrams per liter (Herst & Associates, 2005a). Measured floating product thickness has exceeded 3.7 feet (Herst & Associates, 2005a). Limited floating product recovery occurred beginning in 1993 and extending through at least 2004 (Herst & Associates, 2005a). These data clearly indicate that the asphalt plant LUST is a major source of petroleum hydrocarbons including BTEX compounds at the West Lake Landfill that also impacts water quality at the adjacent Bridgeton Landfill.

In the 2008 OU-2 ROD, EPA identified the PM Resources facility as a known source of groundwater contamination from which groundwater flows toward the landfill and as a result some of the contaminants detected as part of the OU-1 and OU-2 investigations may be attributable to this facility. EPA further determined that groundwater near the southwest corner of the Inactive Sanitary Landfill was impacted by petroleum hydrocarbons and volatile organic hydrocarbons, the potential source of which may be the LUST (*i.e.,* the asphalt plant LUST) that lies between the Inactive Sanitary Landfill and the Former Active Sanitary Landfill (*i.e.,* the Bridgeton Landfill)

Given that all of these facilities are known to MDNR, it is surprising that Dr. Burken either was not aware of these sources of chemical releases to soil and groundwater in the areas he was collecting tree core samples or that he otherwise failed to consider the potential impacts these facilities would have on his tree core sample results. As discussed above, Dr. Burken identified two areas that he believes indicate a high probability for offsite pollutant transport. The first area he defines is located to the north-northeast area across St. Charles Rock Road from the landfill entrance where ClVOCs and BTEX were detected most frequently in his tree core samples. The tree core samples in Dr. Burken's north-northeast area were obtained from or adjacent to the Virbec (former PM Resources) facility immediately downgradient of the UST and catchment areas where hazardous wastes, including VOCs had been released to the ground and groundwater from this facility. The second area identified by Dr. Burken was near the South Quarry and west side of the Inactive Sanitary Landfill extending to the southwest across Old St. Charles Rock Road which includes the area around and downgradient from the LUST. Dr. Burken's failure to acknowledge or otherwise consider conditions associated with these facilities, with their known impacts to soil and groundwater, during the evaluation of his tree core results is surprising, and more importantly is entirely inconsistent with accepted scientific practice.

G. Plaintiff's expert's opinions regarding the directions of groundwater flow near the Bridgeton Landfill are flawed in part because they are based on data that were not obtained in accordance with accepted scientific methods and practices.

Plaintiff's expert Mr. Price offers opinions regarding the directions of groundwater flow and offsite groundwater quality. For the reasons discussed below, I disagree with Mr. Prices opinions on these topics.

Mr. Price opines on p. 4 of his report that "Groundwater flow within this [alluvial] aquifer is generally west-northwest at the BSLF site. However, the flow direction can change depending on Missouri River stage. During high river stage, the alluvial groundwater elevation can rise and groundwater gradients can temporarily reverse or change directions." I disagree with his opinion that the groundwater gradients can temporarily reverse or change directions. Although changes in water levels can be observed in response to changes in river stage, such changes reflect the temporary propagation of increased head, not a change in groundwater flow direction.

A similar statement to that of Mr. Price was made in a report submitted to EPA by the Missouri Coalition for the Environment. That report stated that "The water table in the alluvial aquifer is known to rapidly respond to river stage as well as to the delivery of recent precipitation, with groundwater rapidly moving either toward or away from the river, depending upon river stage." The U. S. Geological Survey (UGSG), in particular Mr. John Schumacher was asked to review this report. The November 25, 2013 USGS review of the report concluded that the statement that groundwater moves rapidly either toward or way from the river, depending on the river station was incorrect. The USGS concluded that rapid changes in water levels measured in alluvial aquifer wells associated with changes in river stage does not indicate rapid movement of the water itself, but rather the propagation of a pressure head. The large hydraulic conductivity of the alluvial aquifer leads to rapid propagation of head changes in alluvial wells in response to river changes, but not the actual movement of water within the aquifer.

Mr. Price's report also discusses potentiometric levels in the vicinity of five bedrock monitoring wells installed by the State of Missouri on private properties adjacent to the BSLF site. Based on his interpretation of the water level data, he concludes that groundwater flow directions in the vicinity of these wells is away from, or in some cases sub-parallel to, the Bridgeton Landfill. However, some of the water level data used by Mr. Price for his analyses are not representative and were not obtained in accordance with accepted scientific practice. Specifically, Mr. Price's opinions are based in part of water levels obtained from the five new State of Missouri wells, that had been installed only one to two weeks before the water level measurements were obtained, therefore introducing uncertainty regarding the stability and representativeness of the water level data. More importantly, as stated by Mr. Price in his report, "Water levels were measured in the State of Missouri wells on August 25 and 28, following sampling on August 20 and 21." Accepted scientific practice requires water level data that are to be used to evaluated static potentiometric levels be collected prior to any activities that would change the water level, such as groundwater sampling, that could cause the water level to not be representative of the static (non-stressed) potentiometric level at a well. Mr. Price himself acknowledges that change in water level in well MO-1-SDR between the measurements obtained on August 25 and August 28, 2015 indicates that the water level was still recovering from sampling of the well on August 21, 2015.

Mr. Price's reliance of water level data collected after sampling of the State of Missouri wells and his subsequent portrayal of these water level data, that were known to be unstable or potentially unstable, to derive conclusions regarding the general direction of groundwater flow is inconsistent with accepted scientific practices.

H. Plaintiff's expert's opinions regarding the need for and scope of potential remedial actions are inconsistent with EPA's requirements for evaluation and selection of remedial actions and also are inconsistent with the known conditions at the site.

Plaintiff's expert, Mr. Hemmen, prepared a feasibility study (FS) report of potential alternatives for groundwater remediation at the Bridgeton Landfill. Although Mr. Hemmen's report was structured to address the National Contingency Plan (NCP) requirements for a FS, the content of Mr. Hemmen's report does not meet the NCP requirements relative to the evaluations required, specifically, evaluation of the threshold criteria regarding the overall protectiveness of public health and the environment. Furthermore, although Mr. Hemmen's report is purportedly focused on potential groundwater remediation alternatives for the Bridgeton Landfill (*i.e.,* the North and South Quarry areas), Mr. Hemmen actually proposes remedial alternatives that encompass the entire West Lake Landfill. The West Lake Landfill is a National Priorities List (NPL) site, also referred to as a Superfund site. Only EPA, not the State, has the authority to determine what remedial actions, if any, may be required for a Superfund site. In addition, the scope of Mr. Hemmen's proposed remedial actions, and therefore the cost of his proposed actions, are inconsistent with the actual groundwater conditions at the site.

Congress, under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA also commonly known as Superfund) and the associated Superfund Amendments and Reauthorization Act (SARA), established the requirements for selection of remedial actions as Superfund sites. CERCLA §104 Paragraph (b) (4) states that the "The President shall select remedial actions to carry out this section [Response Authority] in accordance with section 121 of this Act (relating to cleanup standards)". EPA has been authorized to implement CERCLA in all 50 states and U.S. territories. EPA developed a set of regulations, the NCP, to implement the requirements established by Congress for selection of remedial actions as Superfund sites.

CERCLA, the NCP, and related EPA guidance on the performance of Remedial Investigations/Feasibility Studies (RI/FS) at Superfund sites established nine criteria for evaluation of potential remedial alternatives and selection of remedial actions at Superfund sites. The first of these criteria is that the various remedial alternatives must be protective of public health and the environment. Congress and EPA identified this as a threshold criteria that must be met by any remedial action to be undertaken at a Superfund site.

Mr. Hemmen acknowledges this criterion on p. 11 of his report; however, in performing his evaluations he repeatedly states that "Conclusions about this criteria are deferred due to lack of off-site groundwater data." Mr. Hemmen himself acknowledges that his evaluations are limited due to what he perceives to be a lack of adequate Site characterization data and a lack of risk assessment information including ecological risk making it difficult to evaluate remedial alternatives, risks and costs. The failure of Mr. Hemmen's report to evaluate and make a determination regarding the overall protectiveness of his remedial alternatives makes his evaluation deficient in terms of the NCP criteria.

Mr. Hemmen states on p. 6 of his report that "VOCs and, in particular benzene, is a main focus for potential groundwater remediation at the site." Mr. Hemmen's report does not contain any discussion of where or at what concentrations benzene is present in groundwater other than to state that benzene was detected in 18 monitoring wells at concentrations greater than its water quality standard of 5 micrograms per liter.

Mr. Hemmen's report does not identify any specific numerical objective for his proposed remedial actions provides any specific evaluation of the ability of any of his proposed remedial alternatives to achieve any particular numerical standard. Review of Appendix B to his report indicates that it appears he set forth a scope for one of the vendors he contacted for cost information based on an assumption that the level of benzene in groundwater at the site was 1 milligram per liter (mg/L) which is equal to 1,000 ug/L and that the remedial action objective for benzene in groundwater is 5 ug/L.

Based on these criteria, Mr. Hemmen developed remedial alternatives and associated cost estimates for engineering systems that extend from 4,600 to 8,700 ft around and nearly fully encompassing the entire West Lake Landfill. However, the scope of the remedial alternatives proposed by Mr. Hemmen and therefore their associated costs are entirely inconsistent with the actual site data.

Mr. Hemmen's FS fails to examine the occurrence and distribution of benzene occurrences at concentrations greater than his proposed remediation criteria. Figures 31 and 32 summarized the benzene results obtained from the four comprehensive groundwater monitoring events recently performed as part of the OU-1 investigations. Review of these figures indicates that the only consistent occurrences of benzene at concentrations greater than 5 ug/l are located in alluvial deposits along the west side of the southern portion of the Inactive Sanitary Landfill (*i.e.,* downgradient of the LUST site) and bedrock along the southwest and eastern portions of the South Quarry. Only one site well (PZ-104-SD) has reported benzene concentrations in the range of 1 mg/L, and this well is not located near the proposed alignments of any of the remedial alternatives developed by Mr. Hemmen. Furthermore, the majority of benzene concentrations along the proposed remedial alternative alignments are non-detect and where benzene is present at concentrations above the MCL along the alternative alignments, it occurs in the range of 10 to 50 ug/l, not 1,000 ug/l

Consequently, the scope and extent of the remedial alternatives developed by Mr. Hemmen are grossly and inappropriately over stated. Specifically, the lengths of remedial alternatives are grossly exaggerated. For example, the stated length of Alternative 3 is 4,600 ft (however, upon checking his figures the distance actually appears to be 5,760 ft). No specific distance or length is cited in his report for his

Alternative 4; however, based on the alternative descriptions and objectives, it is assumed to be the same as Alternative 3. The stated length for Alternative 5 is 8,700 ft (my check indicates that this distance is actually 8,570 ft). In contrast, the actual length of occurrences of benzene in alluvium along the site boundary at concentrations greater than 5 ug/L is only 1,325 ft.

Setting aside whether any of the remedial alternatives proposed by Mr. Hemmen are actually necessary and would meet all of the NCP criteria, the grossly exaggerated lengths associated with Mr. Hemmen's alternatives results in extreme over-statement of the costs to construct and implement such alternatives.

V. EXHIBITS SUPPORTING OPINIONS

Exhibits supporting or summarizing my opinions are included in Attachment E. These exhibits are preliminary as I may change the format of the exhibits and/or add to or update the information depicted on the above exhibits. I may also develop exhibits based on information drawn from the materials and documents considered in forming my opinions (Attachment B) or to better illustrate the data and information shown in these documents. I may also use additional demonstrative exhibits at trial.

VI. COMPENSATION

I am being compensated at the rate of $175/hour for my work evaluating the various documents and data in this matter, preparing this expert report, preparing for deposition and other activities plus expenses at cost plus 7.5%. I am to be compensated at the rate of $350 per hour for my time spent testifying in a deposition or during the trial in this matter.

VII. OTHER TESTIMONY

The other cases in which I have provided expert testimony during deposition or at trial within the past four years are as follows:

Name of Case	**Court**	**Trial or Deposition Testimony**
City of Livingston, et al. v. BNSF Railway Company, et al.	Montana Sixth Judicial District Court, Park County, DV-07-141	Deposition
Graham, et al. v. BNSF Railway Company, et al.	United States District Court for the District of Montana, CV-12-145-M-DWM	Deposition
Asarco LLC v. NL Industries, Inc., et al.	United States District Court Eastern District of Missouri, Case No. 4:11-CV-000864-JAR	Deposition
Asarco LLC v. Atlantic Richfield Company and American Chemet Company	United States District Court for the District of Montana, Case No. CV-12-53H-DLC	Deposition

I declare under penalty of perjury that the foregoing is true and correct.

Executed on October 30, 2015.

Paul V. Rosasco, P.E.

October 30, 2015

at the rate of $350 per hour for my time spent testifying in a deposition or during the trial in this matter.

VII. OTHER TESTIMONY

The other cases in which I have provided expert testimony during deposition or at trial within the past four years are as follows:

Name of Case	Court	Trial or Deposition Testimony
City of Livingston, et al. v. BNSF Railway Company, et al.	Montana Sixth Judicial District Court, Park County, DV-07-141	Deposition
Graham, et al. v. BNSF Railway Company, et al.	United States District Court for the District of Montana, CV-12-145-M-DWM	Deposition
Asarco LLC v. NL Industries, Inc., et al.	United States District Court Eastern District of Missouri, Case No. 4:11-CV-000864-JAR	Deposition
Asarco LLC v. Atlantic Richfield Company and American Chemet Company	United States District Court for the District of Montana, Case No. CV-12-53H-DLC	Deposition

I declare under penalty of perjury that the foregoing is true and correct.

Executed on October 30, 2015.

Paul V. Rosasco, P.E.

October 30, 2015

Attachment A

Curriculum Vitae of Paul V. Rosasco

PAUL V. ROSASCO, P.E.

Engineering Management Support, Inc.
7220 West Jefferson Avenue, Suite 406
Lakewood, CO 80235

(303) 940-3426

paulrosasco@emsidenver.com

Mr. Rosasco has 39 years' experience in providing supervision, management, and technical review for geological, hydrogeological, and engineering projects. He has designed and implemented geological, hydrogeological and geophysical investigations and environmental monitoring programs for sites ranging from 0.5 acres to over 300 square miles. Mr. Rosasco has extensive project management and technical experience in a wide variety of waste disposal and environmental contamination projects. He has provided design, site engineering, and construction management services and served as owner's representative for surface and subsurface remediation projects. He has also been involved in a variety of geotechnical, geologic hazard, and water supply evaluation projects.

Mr. Rosasco has 33 years of experience with all aspects of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and National Priorities List (NPL) site projects where he has worked at over 40 Superfund Sites. His experience includes evaluation of existing data and development of scopes of work, negotiation of scopes of work, administrative orders and consent decrees, implementation and supervision of remedial investigations, feasibility studies, remedial designs, remedial actions, removal actions and performance and effectiveness evaluations of operation and maintenance of removal and remedial actions.

Mr. Rosasco also has 32 years of experience with Resource Conservation and Recovery Act (RCRA) facilities where he has performed characterizations of generator and treatment, storage, and disposal sites, assessed the nature and extent of contamination, and evaluated, designed and implemented corrective measures. He has participated in the development and review of RCRA Part B applications, ground-water monitoring and corrective measure programs and closure plans. Mr. Rosasco has also developed operations plans and designed and facilitated permitting for solid and liquid waste disposal sites.

Mr. Rosasco has provided expert testimony related to groundwater occurrence, flow and chemical transport, the nature, extent and sources of environmental contamination, the necessity and appropriateness of various remedial actions, consistency of response actions with the National Contingency Plan (NCP) and other environmental regulations, and allocation of response costs. He has been qualified by several federal courts as an expert in the areas of hydrogeology, contaminant occurrence, fate and transport, remedial actions, cost allocation and National Contingency Plan (NCP) consistency. He has also provided expert testimony on the role of environmental issues and site remediation related to property valuation and condemnation proceedings. He has testified at numerous regulatory hearings and public meetings on issues ranging from site selection and the design and operations of waste disposal facilities, environmental contamination and remediation, and water quality standards. He has also provided expert assistance related to construction claims and disputes.

In addition to expert testimony, Mr. Rosasco has provided expert assistance in support of litigation in a wide variety matters including hydrogeological characterization, nature, extent and causation of contamination, and remedial actions at regional groundwater contamination sites such as the San Gabriel Valley – Baldwin Park Operable Unit, the Suburban Operable Unit and the former Fairchild Industries facility in southern California; the former Lockheed facility in Redlands, CA; regional mining districts including Leadville, CO, Bunker Hill, ID, Crede, CO, and Jamestown CA; petroleum refineries, bulk plants, and retail outlets; and various manufacturing and commercial facilities throughout the country. Mr. Rosasco served as an independent arbiter during settlement negotiations for a leaking underground storage tank site in Colorado and served as the 30-B6 representative relative to the claimed releases from adits, tunnels and portals in the upper portion of the Coeur d'Alene Basin.

EDUCATION

M.E., Engineering Geology, Colorado School of Mines, 1985

B.S., Geology, University of Oregon, 1976

REGISTRATIONS

Professional Engineer – Colorado
Professional Engineer – Washington
Professional Engineer – Illinois (retired status)

EMPLOYMENT HISTORY

1994 – Present Engineering Management Support Inc.
President
Principal Engineer

1985 - 1994 Harding Lawson Associates
Member of Board of Directors
Senior Vice President
Director of Program Development
Consulting Vice President
Director of RCRA and CERCLA Services
Northeast Regional Manager
Mid-continent Operating Officer
Rocky Mountain Regional Manager
Principal in Charge - Denver Office
Associate in Charge - Denver Office

1981 - 1985: Fox Consultants, Inc.
Hydrogeology group manager
Project geological engineer and Rock mechanics supervisor

1979 - 1981: Department of Energy/Office of Nuclear Waste Isolation, Colorado School of Mines
Project geologist and Assistant project manager

1978 - 1979: Colorado School of Mines
Research assistant

1977 - 1978: Kennicott Copper Co./Bear Creek Mining Co.
Assistant geologist

1976 - 1977 Lane County Community College
Mathematics Instructor

COMMUNITY SERVICE

Former Member - Jefferson County, Colorado Planning Commission (member and former Chairman [twice] and Vice-Chairman [twice] 1994 - 2004)

MEMBERSHIPS

American Society of Civil Engineers
Association of Groundwater Scientist and Engineers

PUBLICATIONS

1995 Weaver, Jeffrey, D., Digel, Robert, K., and Rosasco, Paul V., Performance of a Post-audit of Groundwater Flow Models Used in Design of a Groundwater Capture/Containment System, in Symposium on Subsurface Fluid Flow (Ground-Water) Model, American Society for Testing and Materials.

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Attachment B

List of Documents Reviewed and Relied On

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Attachment C

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

January 2014

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

Prepared for

The United States Environmental Protection Agency Region VII

Prepared on behalf of

The West Lake Landfill OU-1 Respondents

Prepared by

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January 14, 2014

EXECUTIVE SUMMARY

In a July 3, 2013 letter, the United States Environmental Protection Agency (EPA) asked the West Lake Landfill Operable Unit 1 (OU-1) Respondents to expand the risk analysis section of the December, 2011 Supplemental Feasibility Study (SFS) to consider risks from a subsurface smoldering event (SSE), either originating in the Bridgeton Landfill portion of Operable Unit 2 (OU-2), or developing within West Lake Areas 1 or 2 (OU-1). EPA requested a qualitative assessment that takes into account how the remedy design for OU-1 would address the presence of an SSE, should one occur. EPA also indicated that the evaluation should discuss potentially applicable or relevant and appropriate requirements (ARARs) associated with a possible SSE. This SSE Evaluation Report presents that expanded risk analysis, potential ARARs identification, and the EPA Record of Decision (ROD) remedy design evaluation.

After considering the conditions and processes known to be associated with subsurface heating events at landfills and the remedy selected by EPA in the 2008 ROD, this Report concludes that:

- The radiologically-impacted material (RIM) disposed of in West Lake Areas 1 and 2 will not become more or less radioactive in the presence of heat. Likewise, the RIM is not explosive and will not become explosive in the presence of heat.

- An SSE does not create conditions that could carry RIM particles or dust off the site. The heat of an SSE is not high enough to ignite non-RIM wastes or chemical compounds or to cause them to explode.

- An SSE may allow radon gas to more easily rise through the ground and reach the surface of the landfill than would otherwise occur, because heat will would reduce the amount of moisture in the buried solid waste (trash) thereby increasing the amount of air between the soil particles and thus limiting the ability of the buried solid waste to retain radon below ground. Any radon gas that does make it to the surface would dissipate quickly in open air. This potential increase in the rate of release of radon gas at the surface of the landfill would be limited to the area of the SSE and would stop when the SSE ends.

- An SSE in West Lake Area 1 or 2 would create no long-term additional risks to people or the environment.

- Any short-term risks would be associated with the temporary increase in radon gas coming from the surface of the landfill if no cap is installed on the landfill, or if the cap called for by the 2008 ROD was not properly maintained.

- These short-term risks can be addressed by designing, building, and maintaining the landfill cap called for by the 2008 ROD, and by maintaining the land use restrictions already in place on the entire West Lake property, which prevent certain site uses.

- There are no additional ARARs associated with an SSE.

Table of Contents

List of Acronyms

AIT	Auto Ignition Temperature
ARAR	Applicable or Relevant and Appropriate Requirements
BOD	Biological Oxygen Demand
C&DD	Construction and Demolition Debris
C	Centigrade
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CO	Carbon monoxide
cm/sec	centimeters per second
EMSI	Engineering Management Support, Inc.
EPA	United States Environmental Protection Agency
F	Fahrenheit
FEMA	Federal Emergency Management Agency
FML	Flexible Membrane Liner
GCCS	Gas Collection and Control System
MCL	Maximum Contaminant Level
MDNR	Missouri Department of Natural Resources
MSW	Municipal Solid Waste
NRC	Nuclear Regulatory Commission
OSTRI	Office of Superfund Technology Research and Innovation
OU	Operable Unit
RIM	Radiologically Impacted Material
ROD	Record of Decision
SFS	Supplemental Feasibility Study
SSE	Subsurface Smoldering Event
UMTRCA	Uranium Mill Tailings Radiation Control Act
USACE	United States Army Corps of Engineers
USDOI	United States Department of the Interior

1. INTRODUCTION

In a July 3, 2013 letter, the United States Environmental Protection Agency (EPA) requested that the West Lake Landfill Operable Unit-1 (OU-1) Respondents expand the risk analysis section of the Supplemental Feasibility Study (SFS) (EMSI, 2011) to include risks associated with a subsurface smoldering event (SSE) reaching OU-1 from the Bridgeton Landfill portion of OU-2, or a new SSE originating within OU-1 (EPA, 2013). EPA requested a qualitative assessment that would consider how the remedy design would address the presence of an SSE, should one occur. EPA also indicated that the evaluation should include a discussion of potentially applicable or relevant and appropriate requirements (ARARs) of other environmental regulations associated with a possible SSE. Engineering Management Support, Inc. (EMSI), on behalf of the OU-1 Respondents, prepared a Work Plan (EMSI, 2013) for this evaluation that was approved by EPA on July 30, 2013.

The West Lake Landfill is a 200 acre, closed solid waste disposal facility that accepted wastes for on-site landfilling from the 1940's or 1950's through 2004. Operable Unit-1 (OU-1) addresses two disposal areas (Areas 1 and 2) where radionuclides are mixed within landfilled soil and solid waste materials, plus an adjacent area (the Buffer Zone/Crossroad Property) where erosion from Area 2 deposited radiologically-impacted materials (RIM). Operable Unit-2 (OU-2) consists of the remainder of the site including areas never used for landfilling, several inactive fill areas containing sanitary waste or demolition debris which were closed prior to state regulation, and a permitted sanitary landfill currently undergoing closure under the State of Missouri's solid waste regulatory program.

The site was used for limestone quarrying and crushing operations from 1939 through 1988. Beginning in the late 1940s or early 1950s, portions of the quarried areas and adjacent areas were used for landfilling municipal refuse, industrial solid wastes, and construction/demolition debris. In 1973, 8,700 tons of leached barium sulfate residues, (a remnant from the Manhattan Engineer District/Atomic Energy Commission project) were reportedly mixed with approximately 39,000 tons of soil from the 9200 Latty Avenue site in Hazelwood, Missouri, transported to the West Lake Landfill, and used as daily or intermediate cover material. Prior investigations have determined that these radiologically-impacted materials (RIM) were disposed in portions of two separate disposal areas at the site that have subsequently been identified as Radiological Area 1 and Radiological Area 2, or simply Area 1 and Area 2 (Figure 1). As a result of the original use of the radiologically-impacted soil as daily and intermediate landfill cover material and the natural decomposition and consolidation of the refuse which had been covered by the radiologically-impacted soil, the RIM is intermixed with and interspersed within the overall matrix of landfilled refuse, debris and fill materials, and unimpacted soil and quarry spoils in Area 1 and Area 2. In some portions of Areas 1 and 2, RIM is present at the surface; however, the majority of the radiological occurrences are located in the subsurface beneath these two areas.

Landfill activities conducted after 1974 within the quarry areas (part of what is classified as the West Lake OU-2) were subject to permits obtained from the Missouri Department of Natural Resources (MDNR). In 1974 landfilling began in the portion of the site described as the North

Quarry Pit (Figure 1). Landfilling continued in this area until 1985, when the landfill underwent expansion to the southwest into the area described as the South Quarry Pit (Herst & Associates, 2005). Together, the North and South Quarry pit landfills make up the permitted Bridgeton Sanitary Landfill. In December 2004, the Bridgeton Sanitary Landfill stopped receiving waste pursuant to an agreement with the City of St. Louis to reduce the potential for birds to interfere with airport operations. The Bridgeton Sanitary Landfill is inactive and closure activities are proceeding under MDNR supervision.

In December 2010, Bridgeton Landfill detected changes in the landfill gas extraction system; specifically, elevated temperatures and elevated carbon monoxide levels (Bridgeton Landfill, LLC, 2013a). Further investigation indicated that the South Quarry Pit landfill was experiencing an exothermic subsurface smoldering reaction or event – an "SSE" (Bridgeton Landfill, LLC, 2013a). As a consequence of the SSE, the South Quarry Pit Landfill has experienced an increase in fugitive emissions and odors, elevated waste temperatures, and accelerated decomposition of the landfilled solid waste (Bridgeton Landfill, LLC, 2013a). The property owner has performed various evaluations and mitigation activities relative to this event (Bridgeton Landfill, LLC, 2013a, 2013b and 2013 c; MDNR, 2013; and Thalhamer, 2013).

This report provides an evaluation of the potential impacts if an SSE were to occur within Areas 1 or 2 at the West Lake Landfill, both before and after construction is complete for the remedy selected by EPA in the Record of Decision (ROD) (EPA, 2008). More specifically:

- Section 2 of this report presents a general overview of the conditions and processes associated with subsurface heating events at landfills.

- Section 3 summarizes the engineering components of the ROD-selected remedy.

- Section 4 presents an evaluation of potentially applicable or relevant and appropriate requirements (ARARs) of other environmental regulations relative to an SSE in West Lake Areas 1 or 2.

- Section 5 presents an evaluation of the possible impacts relative to potential release and/or migration of radionuclides from the RIM if an SSE were to occur in West Lake Areas 1 or 2.

- Section 6 presents an evaluation of potential impacts on the effectiveness and performance of the ROD-selected remedy if an SSE were to occur in West Lake Areas 1 or 2 post-construction. This section also describes how the design of the ROD-selected remedy would address the presence of an SSE. In accordance with EPA's letter, a qualitative evaluation of the potential impacts of an SSE has been performed based on published literature combined with an understanding of the site conditions, the ROD-selected remedy, and basic scientific principles and processes.

- Section 7 provides a summary and conclusions regarding the evaluations of the potential impacts relative to the occurrence of an SSE in West Lake OU-1 and the impacts of an SSE on the ROD-selected remedy.

- Finally, Section 8 lists the reference documents considered in these evaluations.

2. SUBSURFACE HEATING EVENTS

In accordance with EPA's letter and the Work Plan, this section outlines a review of published scientific and regulatory agency literature on subsurface heating events in general. EMSI took a comprehensive approach to the review, recognizing that the scientific literature in this area is in development, and that some articles cited do not apply to the specific conditions at the Bridgeton Landfill portion of OU-2.

2.1 Combustion and Pyrolysis (smoldering)

Subsurface heating events are described by many terms, such as subsurface fire, smoldering fire, slow pyrolysis, glowing combustion, subsurface oxidation, and reaction (Ohio EPA, 2011). For purposes of this evaluation, a subsurface heating event will be considered to include any and all of the above listed events.

Combustion or fire is a process involving rapid oxidation of material at elevated temperatures accompanied by the evolution of heated gaseous products of combustion, and the emission of visible and invisible radiation (e.g., heat and/or light) (Biffa et al., 2008). Four elements are necessary for a fire to occur, including fuel or combustible material, sufficient heat to raise the material to its ignition temperature, oxygen to sustain combustion, and an exothermic chemical chain reaction (Biffa, et al., 2008, and Fire Safety Advice Centre, 2011). Combustion is described as a self-sustained, exothermic reaction between fuel and oxidizer, while ignition can be defined as a rapid transition process by which an exothermic reaction and self-supported combustion is initiated (Moqbel et al., 2010). Combustion can occur in two modes, the flaming mode or the non-flaming mode (Biffa, et al., 2008). In the flaming mode, solid and liquid fuels are vaporized, and it is this volatile vapor from the solid or liquid fuels that is visually observed as actually burning in the flaming mode (Biffa et al., 2008). The non-flaming mode involves smoldering or glowing embers. Smoldering is the slow, low-temperature, flameless form of combustion sustained by the heat produced when oxygen directly attacks the surface of a condensed-phase fuel (Rein, 2009). The fundamental difference between smoldering and flaming is that in the former, the oxidation reaction and the heat release occur on the solid surface of the fuel or porous matrix, and in the latter, these occur in the gas phase surrounding the fuel (Rein, 2009).

Although sometimes referred to as landfill fires, subsurface heating events at landfills are not fires in the normal sense of that word, because there are no flames associated with a subsurface thermal event. Deep-seated landfill fires do not 'burn;" instead, these fires are a form of combustion known as pyrolysis, under which the thermal reaction takes place in an oxygen-starved environment and the combusting material is consumed very slowly and at relatively low temperatures (Foss-Smith, 2013). Most subsurface "fires" are thought to exist at the smoldering stage of combustion (Biffa, et al., 2008) and generate heat in the absence of gaseous flames (Dehaan and Icove, 2011). Biffa et al. (2008) define a subsurface fire as the sustained pyrolysis and rapid oxidation of carbon based material at elevated temperatures accompanied by the evolution of heated gaseous products of combustion and the emission of visible and invisible radiation (light and/or heat).

Regarding the existing SSE in the Bridgeton South Quarry Landfill, MDNR states that a reaction associated with an SSE event occurs slowly without a visible flame or quantities of smoke and may be deep within the landfill (MDNR, 2013). MDNR further states that normally, an actual flame will not be observed, and the only time this type of event results in a visible flame or smoke is when the subsurface event is excavated and exposed to the atmosphere.

2.2 Causes of an SSE

A subsurface heating event may occur at any solid waste or construction and demolition debris (C&DD) landfill (Ohio EPA, 2011). Examples of some of the causes of subsurface heating events include (Ohio EPA, 2011):

- Aerobic microbiological decomposition of waste (this cause is often associated with an operational failure such as poor cover or the over-application of vacuum on a gas extraction well);

- Chemical reaction (e.g. oxidation) in the waste material. Examples are:
  - Spontaneous combustion, which can occur in such common household wastes as oily rags, paints, solvents, batteries, and pool chemicals.
  - Exothermic reaction when water is combined with certain wastes, such as aluminum production waste, municipal solid waste, ash, lime, iron waste, steel mill waste, and other metal wastes.
  - Oxidation of cellulose and plastics to form peroxides which have a low ignition temperature.

- "Hot loads," such as cooking charcoals, ashes, or smoking materials that are buried but not extinguished.

The most common cause of an SSE is an increase in the oxygen content of the landfill, which increases aerobic (oxygen-based) bacterial activity and raises temperatures (FEMA, 2002). Improper operation of a landfill gas extraction system can include under-pulling or over-pulling. Under-pulling can result in excess emissions of landfill gas to the atmosphere and gas migration (LandTec, 2005a). Over-pulling of a landfill gas extraction system can result in intrusion of atmospheric air (oxygen) into the landfill which disrupts the anaerobic (low- or no-oxygen) decomposition and increases aerobic degradation resulting in increased heat generation and potentially resulting in an SSE (LandTec, 2005a and 2005b and USACE, 2013).

The primary cause of an SSE is spontaneous combustion (Moqbel et al., 2010). Spontaneous combustion is defined as combustion of material in the absence of an externally applied spark or flame (Moqbel et al., 2010). Landfills are complex systems where various interrelated biological and chemical reactions result in waste degradation (Moqbel et al., 2010). An increase in solid waste ambient temperature causes an increase in the oxidation rate and concomitant heat generation (Moqbel et al., 2010). The presence of heat, oxygen and fuel (i.e. solid waste) in the landfill produces the necessary elements of a fire (Moqbel et al., 2010). If this heat is not dissipated, the temperature continues to rise until it reaches the auto-ignition temperature (AIT) of the solid waste, causing a fire (Moqbel et al., 2010).

Methane often has been suspected to initiate spontaneous subsurface fires in a landfill (Moqbel et al., 2010). However, a combustible mixture of methane and oxygen requires a very high temperature to ignite (>500 °C / 900 °F) (Moqbel et al., 2010). Studies conducted by Moqbel et al., (2010) showed that spontaneous fires are initiated by solid materials with lower ignition points. FEMA (2002) reports that municipal solid wastes produced in the United States in 1999 (prior to recycling) consisted of 38% paper materials. Although testing conducted by Moqbel et al., (2010) indicated that the auto-ignition temperature of paper and cardboard was in excess of 300 °C / 572 °F, excess heat generation from exothermic reactions (self-heating) occurs in paper at temperatures slightly below 100 °C / 212 °F; however, these values reflect conditions for dry materials and were greatly affected by the presence and nature of moisture (e.g., water vs. leachate) within the paper. These same studies concluded that the presence of moisture in solid wastes can generally promote self-heating by lowering the solid waste permeability, thereby decreasing heat dissipation, and by increasing the absorption of energy in the solid waste as the liquid evaporates (Moqbel et al., 2010). These studies also concluded that heat generated from chemical oxidation plays a major role in the spontaneous combustion of solid waste (Moqbel et al., 2010).

2.3 Indications of an SSE

The following are events or features that could indicate the presence of an SSE in a landfill (CalRecycle, 2013, De Havilland, undated, FEMA, 2002, Ohio EPA, 2011):

- Substantial settlement over a short period of time;
- Smoke, steam or smoldering odor emanating from the gas extraction system or landfill;
- Elevated levels of carbon monoxide (CO);
- Combustion residue in gas extraction wells or headers;
- Occurrences of odors, in particular new odors, odors that smell "hot" or "burning," or odors of volatile fatty acids or sulfur compounds such as mercaptans;

- Increase in gas temperature in the extraction system;
- Excess temperatures in the landfill mass;
- Changes in landfill gas quality; such as a rapid or localized reduction in methane content or an increase in the ratio of carbon dioxide to methane concentrations indicating the inhibition of biological activity, or an increase in oxygen, nitrogen or balance gas concentrations reflecting over-pulling in the landfill gas extraction systems;
- Excessive liquid (leachate or condensate) generation that cannot be attributed to seasonal variability or operation/construction activities;
- A change in leachate quality; and/or
- Stressed vegetation cover or patchy snow melt.

It is important to note that while this is not an exclusive list, not all of these conditions may be present at a landfill that is undergoing an SSE, and some of these conditions can be caused by factors other than an SSE. The simultaneous occurrence of many of the above factors at a particular landfill is a strong indication of an SSE.

In the case of the Bridgeton South Quarry Landfill, the primary manifestations of an SSE include the following (Bridgeton Landfill, LLC, 2013a):

- Curtailment of methane production in portions of the waste mass where temperature is elevated above 160° F / 71 ° C (which exceed conditions generally considered favorable for the bacteria responsible for methanogenesis);
- Elevated temperatures in the landfill mass which require special construction materials for gas and liquid handling features;
- Production of hydrogen, carbon dioxide, volatile organics, and carbon monoxide, some of which migrate outward and away from the reacting waste materials;
- Creation of odorous emissions;
- Generation of pressure within the waste mass resulting from the phase change of liquid entrained in the waste mass to vapor phase and resulting settlement;
- Increased gas capture complexity due to the pressure increases at depth that release upward within the waste mass due to the increasing density of the waste with depth;
- Heating of waste which results in a steam/water vapor front moving out, up, and away from the SSE, which then condenses in the cooler surrounding waste mass and gas extraction wells resulting in higher localized leachate generation;

- Leachate characteristic changes including elevated constituents such as biological oxygen demand (BOD), volatile organic compounds, and dissolved and suspended solids that result from liberation of constituents from the as-received waste material and from the thermal degradation of biological material;

- Greater than normal settlement at the location of and/or adjacent to reacting waste mass resulting from the significantly reduced volume of waste mass; and

- Soot/tar-like materials that accumulate on Gas Collection and Control Systems (GCCS) components (flame arrestors, KOP, demister pads, well pumps, and small diameter hoses and lines).

Once waste temperatures begin to rise and are sustained within a landfill, the heating “front” may move further into the landfill (Ohio EPA, 2011). Subsurface smoldering events caused by reactions within a landfill begin at a point of origin, and then spread slowly into adjacent areas until conditions cease to be favorable for the SSE to continue (Bridgeton Landfill, LLC, 2013a). Factors affecting propagation include oxygen (air) intrusion, moisture, waste type/size, and void space (Ohio EPA, 2011).

3. ROD-SELECTED REMEDY

EPA selected a containment remedy for OU-1 that would protect human health and the environment by providing source control and institutional controls for the landfilled waste materials. A description of and reasons for selection of this remedy are presented in EPA’s ROD for OU-1 (EPA, 2008). The source control and institutional control methods prevent human receptors from contacting the waste material. The source control method mitigates contaminant migration to air and restricts infiltration of precipitation into the landfill, which contributes to the protection of groundwater quality.

The components of the ROD-selected remedy include the following:

1. Install landfill cover meeting the Missouri closure and post-closure care requirements for sanitary landfills, including enhancements consistent with the standards for uranium mill tailing sites (i.e., armoring layer and radon barrier). The engineered landfill cover would consist of the following layers (from top to bottom):

    - A one-foot thick layer of soil capable of sustaining vegetative growth;

    - A two-foot thick infiltration layer of compacted USCS CL, CH, ML, MH, or SC soil-type with a coefficient of permeability of 1 x 10^{-5} cm/sec or less; and

    - A two foot thick bio-intrusion/marker layer consisting of well-graded rock or concrete/asphaltic concrete rubble.

2. Consolidation of radiologically contaminated surface soil from the Buffer Zone/Crossroad Property to the containment area;

3. Apply groundwater monitoring and protection standards consistent with requirements for uranium mill tailing sites and sanitary landfills;

4. Surface water runoff control;

5. Gas monitoring and control including radon and decomposition gas as necessary;

6. Institutional controls to prevent land and resource uses that are inconsistent with a closed sanitary landfill site containing long-lived radionuclides; and

7. Long-term surveillance and maintenance of the remedy.

The description and basis for the selected remedy was documented in the ROD.

Performance standards for each of the remedy components are specified in the ROD. As a result of subsequent discussions between EPA Region 7 and EPA's Office of Superfund Remediation and Technology Innovation (OSRTI), the following additional performance standards were identified for the ROD-selected remedy:

- The proposed cap should meet Uranium Mill Tailing Radiation Control Act (UMTRCA) guidance for a 1,000-year design period including an additional thickness to prevent radiation emissions.

- Air monitoring stations for radioactive materials should be installed at both on-site and off-site locations.

- Groundwater monitoring should be implemented at the waste management unit boundary and also at off-site locations. The groundwater monitoring program needs to be designed so that it can be determined whether contaminants from the landfill have migrated across the waste management unit boundary in concentrations that exceed drinking water Maximum Contaminant Levels (MCLs). The groundwater monitoring program needs to measure for both contaminants that have historically been detected in concentrations above MCLs (e.g., benzene, chlorobenzene, dissolved lead, total lead, dissolved arsenic, total arsenic, dissolved radium and total radium), and broader indicators of contamination (e.g., redox potential, alkalinity, carbonates, pH and sulfates/sulfides).

- Flood control measures at the site should meet or exceed design standards for a 500-year storm event under the assumption that the existing Earth City levee system is breached.

Evaluation of how the ROD-selected remedy addresses these additional performance standards and a refined description and evaluation of the containment remedy selected by EPA and documented in the ROD was presented in the Supplemental Feasibility Study (SFS) (EMSI, 2011).

4. POTENTIAL ARARS RELATIVE TO AN SSE

The Comprehensive Environmental Response Compensation and Liability Act (CERCLA) requires that remedial actions be analyzed for compliance with applicable or relevant and appropriate requirements (ARARs) of other environmental laws and regulations. ARARs are divided into three categories:

- Chemical-specific ARARs;
- Location-specific ARARs; and
- Action-specific ARARs.

Descriptions of ARARs, the criteria used to identify whether a requirement is potentially applicable or relevant and appropriate, and identification of potential ARARs for OU-1 are provided in the FS report (EMSI, 2006). Additional evaluations of ARARs as they relate to the "complete rad removal" alternatives are provided in the SFS report (EMSI, 2011).

These prior evaluations identified the various potential ARARs including chemical-specific ARARs associated with the chemicals observed to be present at the site, the location-specific ARARs (e.g., requirements associated with the proximity of the site to Lambert-St. Louis International Airport and to the Missouri River), and action-specific ARARs associated with the presence of radionuclides and a municipal solid waste (MSW) landfill at the site. No additional potential ARARs associated with the potential occurrence of an SSE in OU-1 Areas 1 or 2 or possible interactions between an SSE and the radiologically-impacted materials were identified during this current evaluation. The previously identified ARARs describe the requirements associated with the design and maintenance of a landfill cover, including installation of an engineered cover over the RIM, landfill gas management, odor control, and other aspects of the engineering controls for the site.

5. POTENTIAL IMPACTS OF AN SSE ON THE RIM

Based on a review of published literature and evaluations performed relative to the SSE in the South Quarry Landfill (see prior discussions in Section 2), the impacts common to SSEs that could possibly result from an SSE at West Lake OU-1 could include the following:

- Increased temperatures in the waste mass, landfill gas and possibly leachate;

- Generation of increased vapor (gas) pressure within the waste mass resulting from the phase change of liquid entrained in the waste mass to the vapor phase;

- Changes in landfill gas production and quality;

- Changes in leachate and condensate production and quality;

- Increased emissions of odors, smoke or steam;

- Elevated levels of carbon monoxide, hydrogen, carbon dioxide, and volatile organics;

- Reduction in the volume of the waste mass from pyrolysis of the waste resulting in greater than normal settlement over and adjacent to the reacting waste mass;

- Damage to landfill infrastructure elements, after and to the extent they are installed;

- Slope failure; and

- Groundwater and surface water contamination.

Of these possible impacts, this evaluation will consider the physical and chemical conditions of the RIM at West Lake in order to assess what possible impacts could result in a potential release, emission or migration of radionuclides contained within the RIM. Based upon this, the possible impacts to be evaluated include:

1. Combustion;

2. Increased subsurface temperature;

3. Waste consolidation and pore space reduction; and

4. Vaporization of entrained moisture resulting in potential increases in radon emissions.

As discussed below, any effect of these possible impacts on radon release are expected to be limited because the rate of radon generation and emanation would remain the same – temperature does not change the radium decay rate which produces radon gas. While the impacts might increase the rate at which radon is released from the ground, these effects are expected to be localized given that the heat and steam fronts associated with an SSE event would be localized to the perimeter of the SSE and would stop when the SSE reaches the waste mass boundary. These impacts would also be temporary since they would stop when the SSE ends.

Other impacts identified above, such as increased odors, are associated solely with solid wastes and have no effect on the RIM in West Lake Areas 1 and 2. Some of the other impacts identified above, although not expected to directly affect the RIM, could affect the performance of one or more of the ROD-remedy components and are discussed in the next section of this report.

None of these possible impacts would affect the rate of radon generation (creation of radon from radium decay). However,, some of the impacts could affect the rate of radon emanation (the release of radon from the mineral grain), or the rate of radon exhalation (the release of radon at the ground surface).

5.1 Combustion

As discussed in Section 2, subsurface heating events at landfills typically do not include flaming combustion but rather persist at the smoldering stage of combustion. These fires are more likely to burn slowly without visible flame or large quantities of smoke (Thalhamer, 2013). Flames or smoke do not occur with smoldering events unless the subsurface fire is excavated or otherwise exposed to the atmosphere (Thalhamer, 2013). Therefore, the release of radionuclides through gaseous emissions by flaming would not occur with a subsurface smoldering event.

Also, as discussed in Section 2, a combustible mixture of methane and oxygen requires a very high temperature to ignite (>500 °C / 932 °F) (Moqbel et al., 2010). Temperatures typically associated with subsurface smoldering events are reported to range from 212 or 250 °F (100 or 121 °C) up to 450 °F (232 °C) (Thalhamer, 2013). Therefore, although temperatures could reach the levels where smoldering combustion of paper and other materials could occur, the temperatures that are expected to occur in conjunction with an SSE should not reach the levels necessary for ignition and explosion of methane within the landfill mass. Furthermore, methane production often decreases during a subsurface heating event because methane-producing microorganisms are inhibited by high temperatures (Ohio EPA, 2011). Methane generation in waste is also dependent upon the age of the waste, and the wastes at OU-1 are at least 30 years old or older. Finally, methane production also decreases significantly when temperatures are elevated above 160 °F / 71 °C (Bridgeton Landfill, LLC, 2013a). Consequently, the conditions necessary for a methane explosion and a corresponding explosive release of radionuclides from Area 1 or 2 at the landfill will not occur.

5.2 Increase in Subsurface Temperature

As set forth above, temperatures typically associated with subsurface smoldering events are reported to range from 212 or 250 °F up to 450 °F (100 or 121 to 232 °C) (Thalhamer, 2013). In the South Quarry Landfill, downhole temperatures near the SSE range from approximately 175 to 185 °F (79 to 85 °C). Monitoring locations within the waste mass in the area of the SSE have measured temperatures slightly above 300 °F / 149 °C and another displayed a temperature of approximately 225 °F / 107 °C (Bridgeton Sanitary Landfill, 2013d). At the Hunter's Point Landfill in California, a vent gas temperature of 480 °F / 249 °C associated with an SSE was reported (Thalhamer, 2013). The RIM at the site consists of leached barium sulfate residue mixed with soil. The melting point of barite (barium sulfate) is reported to be greater than 1,300

°C / 2,372 °F (Chem Alert 2, 2007) or 1,580 °C / 2,875 °F (Chemnet, 2013, and Chemicalland, 2013). Therefore, the heat that has been observed and/or could be generated within the landfill materials within West Lake Areas 1 and 2 could not approach the amount of heat necessary to melt or otherwise disrupt the stability of the RIM.

Additionally, the dissipation of heat through the landfill surface would greatly limit the potential for a buildup of heat in the uppermost portion of the landfill mass. Because of the relatively low thickness of the surrounding and overlying waste materials in West Lake Areas 1 and 2 compared to the deep waste materials surrounding and overlying the materials fueling the SSE at the South Quarry Landfill (Attachment 1), the waste environment in West Lake Areas 1 and 2 would not create the same insulation effect as is created in the South Quarry Landfill, and any generated heat in West Lake Areas 1 and 2 would dissipate into the surrounding overburden and native soil and rock. In addition, the relatively low thickness of the surrounding and overlying waste materials in West Lake Areas 1 and 2, as compared to the substantial depth of the Bridgeton quarry-fill environment, results in substantially lower loading (pressure) on the waste materials and therefore less consolidation and lower waste densities than likely occur in the Bridgeton South Quarry Landfill, where the waste column is 250 feet or more deep (Attachment 1). DeHavilland (2011) has theorized that the weight of the disposed material and the resulting overburden pressure may be a contributing factor to the buildup of excess heat and possible ignition of landfill materials. Consequently, the lower overall thickness of the waste deposits in West Lake Area 1 or 2 should result in lower amounts of pressure, lower heat accumulation, and therefore lower temperature increases than those observed in the substantially thicker and consequently denser refuse deposits present in the Bridgeton South Quarry Landfill.

In addition, any increase in temperature would have no effect on radioactive decay of the RIM in Areas 1 and 2. Radioactive decay is a function of time and the half-lives of the various radionuclides. Radioactive decay is independent of temperature or pressure conditions (MIT, 2009), and therefore increases in temperature or pressure will not increase or otherwise affect the rates of radioactive decay within the RIM. Therefore, evaluation of the possible effects of an SSE on the RIM will primarily focus on potential changes that could affect the rates of radon release.

Intuitively, one might posit that radon flux (migration) and resultant radon exhalation would increase with increasing temperature because diffusion is directly proportional to temperature; however, there are conflicting reports about the degree to which temperature affects radon exhalation (ORISE, 2011). Increasing temperatures can affect the amount of moisture within the waste and soil and consequently affect the rates of radon migration and radon exhalation. These effects are discussed further below.

5.3 Waste consolidation and pore space reduction

Pyrolysis of the waste in conjunction with an SSE produces a reduction in the waste mass, a reduction in total void spaces (or pore spaces), and potentially a reduction in the porosity of the waste materials. Reducing the total void space and possibly the waste porosity should theoretically result in a reduction in the radon emanation rate (the rate at which radon is released from the RIM to the air and liquids within the pore spaces). Radon emanation rates are a function of pore size and overall porosity (Sun and Furbish, 1995). If the pore space is very small and the opposing surfaces are close, the radon might embed into an adjacent surface instead of staying in the water or air phase within the pore space (Sun and Furbish, 1995). The radon which attaches to a nearby solid is considered embedded (Sun and Furbish, 1995). Thus, only the radon within the pore space, that is therefore available for migration and subsequent release, is considered as emanated (Sun and Furbish, 1995). Therefore, a reduction in porosity would decrease the radon emanation rates (release from the mineral grain) and consequently result in a decrease in the radon exhalation rates (release from the ground surface).

5.4 Vaporization of Entrained Moisture

An increase in subsurface temperatures could result in vaporization of entrained moisture and subsequent reduction in the moisture content of the buried waste and soil. Reduction in waste/soil moisture can have several effects, some of which could result in a decrease in the amount of radon emanation (release of radon to the pore spaces) and some of which could result in an increase in radon exhalation (release of radon at the ground surface). Specifically, a reduction in waste/soil moisture could lead to a reduction in the rate of radon emanation (release of radon from the mineral grains). Conversely, vaporization of entrained moisture could release radon that is dissolved within the soil moisture resulting in a slight increase in radon mass within the landfill and a resultant temporary increase in the amount of radon available for exhalation (release at the ground surface). Vaporization of entrained moisture could also result in creation of a steam front that could result in localized increases in vapor pressure which could also increase radon migration and emission (exhalation) rates. In addition, reduction in waste/soil moisture could also lead to increased soil permeability resulting in increased radon migration and exhalation (radon emission at the ground surface). Each of these effects is discussed further below.

5.4.1 Effect of moisture vaporization on radon emanation

Radon is generated by the decay of radium within a mineral grain. In order for radon to be released, it must move from within the mineral grain to the outside of the solid mineral grain (radon emanation) where it has a potential for migration and release from the ground (Al-Ahmady 1995). The transition process controlling this transfer from inside to outside the solid mineral grain is called radon emanation (Salimitari, et al., 1996). For most soils containing radium constituents, only 10-50 percent of the radon generated within the mineral grain actually is released (emanates) from the mineral grain and enters the pore volume of the soil (USDOI, 1992). There is at least one study indicating that radon emanation rates from radium-bearing rocks decrease with increasing temperature (Garver and Baskaran, 2004).

Studies (Rogers, et al., 1984, Sun and Furbish, 1995) have indicated that the presence of moisture within the pore spaces increases radon emanation because radon emanation rates are greater for liquid than for air. Among the factors that influence radon emanation, soil moisture content has been demonstrated to have a significant impact (Strong & Levins 1982). Fluid-filled soil pores contain most of the soil moisture (Salimitari, et al., 1996). When the content of water in the pore space increases, the direct radon emanation coefficient component is increased, because a greater fraction of the recoil radon atoms are trapped in the pore space (Salimitari, et al., 1996). Trapping of recoiled radon atoms generated from radioactive decay of radium in the pore space is profoundly reduced when capillary water surrounding solid mineral grain is reduced or eliminated (Salimitari, et al., 1996). This means that radon moves more easily from the grain into surrounding water, but when surrounding water is unavailable there is less tendency for the radon to move from the mineral grain into the pore space (emanate). Therefore, a reduction in soil moisture content as a result of vaporization of entrained moisture could result in a reduction in radon emanation and an attendant reduction in the amount of radon available for exhalation (release from ground surface, discussed below).

5.4.2 Release of radon dissolved in soil moisture

Vaporization of entrained moisture could potentially result in a slight, temporary increase in radon emission (exhalation) due to the release of radon dissolved in the entrained moisture (i.e. radon that had been emanated from the mineral grain into surrounding moisture). Although radon is a gas, it is slightly soluble in water. Vaporization of entrained moisture could result in a temporary release of that portion of the radon that is dissolved within the entrained moisture.

Radon is subject to retrograde solubility: that is, the solubility decreases with increasing temperature. Therefore, an increase in temperature could result in an increased release of radon that is dissolved in moisture entrained in the RIM and waste, as opposed to radon entrained within the mineral grain itself. This effect could potentially result in a slight, temporary increase in radon emission (exhalation) at the ground surface due to the release of radon dissolved in entrained moisture.

The RIM and any entrained moisture that contains radon is in equilibrium with the air in the pore spaces in the RIM and adjacent refuse. Therefore, radon entrained in the soil moisture will naturally transfer to the gas phase within the pore spaces and consequently the mass (amount) of radon contained in the entrained moisture is expected to be small. Still, some very small fraction of the generated radon could be present in the entrained moisture. If an SSE were to occur, one of the effects would be for the advancing heat front to vaporize the entrained moisture (i.e., a steam front). Vaporization of the entrained moisture within the RIM would result in transfer of whatever radon was dissolved in this moisture from the liquid phase to the vapor phase.

Because the amount of entrained moisture is finite and the rate of radon generation is independent of the soil moisture content, any release of radon from entrained moisture would be a temporary effect. Therefore, vaporization of entrained moisture could potentially result in a slight, temporary increase in radon release at the surface in the immediate area of the increased heat front associated with an occurrence of an SSE in West Lake Area 1 or Area 2. This increase is expected to be small due to the small amount of radon that would be dissolved in the interstitial moisture. This effect will also be temporary due to the finite amount of moisture entrained within the RIM and associated refuse. This effect is also expected to be localized due to the localized nature of the heat front associated with an SSE.

5.4.3 Increase in vapor pressure

The presence of elevated temperatures resulting from an SSE can cause vaporization of moisture entrained within the landfill mass. In the vicinity of the heat front around an SSE, vaporization of the entrained moisture within the refuse and RIM could result in an increase in interstitial vapor pressure as a result of the conversion of the entrained moisture from liquid to vapor (i.e., a steam front). The waste which previously held moisture entrained in cellular structures, voids or other means of stable entrapment shrinks, making it smaller and more dense, and this reduction in the waste volume (and increase in the waste density) can result in increased liquid saturation levels within the remaining waste mass until such time as the free moisture either flows away or evaporates.

A SSE could also increase landfill gas generation from decomposition of the destroyed (pyrolyzed) waste volume by the SSE. Such an increase in landfill gas generation would be localized to the area of the SSE. An increase in landfill gas generation could result a temporary increase in radon migration to the surface due to the increase in landfill gas pressure gradients and landfill gas flux.

An increase in vapor pressure could potentially result in a slight, temporary increase in radon migration rates due to the increased interstitial vapor pressure gradients in the immediate area of the increased heat front associated with an occurrence of an SSE in West Lake Area 1 or Area 2. An increase in radon migration rates would decrease radon attenuation (reduction from natural radioactive decay of radon) because the radon vaporized within the steam would move more quickly through the subsurface. This would allow less time for natural degradation before reaching the surface and therefore could result in a temporary increase in radon exhalation (release at the surface). Such potential, temporary increases in radon migration and exhalation rates are expected to be localized due to the localized nature of the heat/steam fronts.

The possible effects that could result from vaporization of entrained moisture are expected to be temporary. Because the rate of radon generation is limited by the rate of radon decay, the total amount of radon generated will not increase. Therefore, the effect of increased vapor and landfill gas pressures and fluxes are expected to result in only a temporary, potential increase in radon release at the surface. These effects are also expected to be localized given that the heat and steam fronts associated with an SSE event would also be localized to the perimeter of the SSE. The short decay time for radon gas will result in a further limitation on the duration and extent of any effect since radon released from the site would be expected to decay within a limited time from release.

5.4.4 Increase in waste/soil permeability

Reduction in the moisture content of the refuse deposits and soil could result in a localized increase in waste/soil permeability. Any increase in subsurface permeability could potentially increase rate of radon migration through the refuse and soil because there is more space within the waste mass through which the radon can migrate towards the surface. An increase in radon migration rate would reduce the amount of time available for radon decay and therefore potentially could result in an increase in radon exhalation (release at the surface). An increase in the permeability of the soil cover over the waste deposits could result in a further increase in the radon exhalation rate (release at surface). Conversely, as previously discussed, pyrolosis of the waste materials produces a reduction in the waste mass and as a consequence, a reduction in the porosity (amount of void space) of the waste materials. A reduction in the porosity of the waste materials should result in a reduction in the permeability of the waste, thereby reducing radon migration rates.

In addition to vaporization of entrained moisture within or adjacent to the RIM, the advancing heat front could also vaporize entrained moisture within the refuse and associated soil located above and around the RIM. Because migration of radon in the subsurface is strongly affected by the degree of water saturation of the soil and refuse (Antonopoulos-Domis, et al., 2009, NRC, 1989, Papchristodoulou, et. al., 2007, Papchristodoulou, et. al., 2009, Rogers, et al., 1984, Rogers and Nielson, 1988), a decrease in entrained moisture could potentially result in a decrease in radon attenuation (reduction due to natural radioactive decay of radon) and consequent increase in radon exhalation rate (release at surface) if an SSE were to occur in West Lake Area 1 or 2.

Because radon generation is limited to the rate of radioactive decay, the total amount of radon generated will not increase; however, a reduction in the soil moisture content could reduce the amount of attenuation (decay) of the radon within the landfill mass before it reaches the landfill surface thereby resulting in a potential increase in radon exhalation (surface emission of radon). Such an increase is expected to be temporary, lasting only as long as the SSE heat front sustains vaporization of moisture entrained within the waste/soil materials. With cessation or lateral migration of an SSE heat front and subsequent infiltration of precipitation, the moisture content of the refuse/soil should increase, returning to near the levels that existed prior to passage of an SSE through a particular area.

6. POTENTIAL IMPACTS OF AN SSE ON THE ROD-SELECTED REMEDY

As noted above, there are numerous potential impacts which could result from the presence of a heating event. In addition to assessing the impact of a heating event on landfills in general and the RIM specifically, as discussed above, this evaluation also considered what impacts would be relevant to the components of the ROD-selected remedy. A potential SSE within West Lake Area 1 or 2 could result in three possible impacts to the components of the ROD-selected remedy. These include direct combustion of the engineered components, thermal damage to the engineered components, and differential settlement of the engineered components. However, as discussed below, it does not appear that any such impacts alter the effectiveness of the ROD-selected remedy and, specifically, any radon emissions.

6.1 Direct Combustion

The design of the ROD-selected remedy is based on use of natural materials (soil and rock) which are not subject to any type of combustion (either flaming or smoldering). Therefore the selected materials of the ROD-selected capping system would not be directly affected or damaged by the presence of either a smoldering or flaming fire within the landfill mass. As such, the performance of those components would not be adversely affected.

6.2 Thermal Impacts

In addition to vaporizing entrained moisture within the landfill mass, the increased temperature associated with an SSE has the potential to drive moisture out of the landfill cover materials. A reduction in the moisture content of the low permeability layer within the engineered landfill cover could increase the overall permeability of the cover system. Although no specific studies of the impacts of heat on low permeability soil layers within landfill covers systems have been found, studies of landfills with heat generating events have reported that the long-term efficiency of composite liners at the base of the landfills was imperiled by desiccation and subsequent cracking of the mineral liner (e.g., bentonite layer) below the geomembrane (Doll, 1997; and Southen and Rowe, 2011). Therefore, it is likely that the occurrence of elevated temperatures within the upper portions of a landfill could have a similar effect on the efficiency of low permeability layers composed of compacted soil, or composite layers consisting of a mineral (e.g., bentonite) layer.

Because the primary purpose of the low permeability layer is to reduce infiltration of precipitation into the landfill and to reduce radon release, an increase in the permeability of the landfill cover could result in an increase in leachate generation (due to infiltration) and radon exhalation rates (greater release at the surface due to reduced attenuation). Such impacts may be partially mitigated, and thus potentially of a temporary nature, because infiltrating precipitation would subsequently act to raise the moisture content of the low permeability layer. Depending upon the amount and nature of the clay content of the low permeability layer, some residual damage to the low permeability layer may occur. If the low permeability layer is primarily composed of silts or non-expansive clays, desiccation cracks could form in the cover and persist even if subsequent infiltration were to increase the moisture content of the low permeability layer. If the low permeability layer contains expansive clay, the re-wetting and resultant swelling of the clay minerals should act to seal such cracks.

At an extreme, the presence of elevated temperatures could damage or possibly destroy the vegetative cover over those portions of the landfill that are subject to an SSE. A reduction in moisture content of the vegetative layer could kill the vegetation. The purpose of the vegetative cover is to reduce potential infiltration of precipitation and to protect the underlying low permeability layer from erosion or freeze-thaw damage. Because any potential damage to the vegetative cover can be easily identified through visual observation and repaired through re-seeding/revegetation efforts, such an impact is expected to be only temporary. Ongoing routine inspection and maintenance of the landfill cover, as required by the ROD-selected remedy, would result in the identification and repair of such a condition.

The ROD-selected remedy calls for inclusion of a minimum two-foot thick rock layer at the base of the engineered landfill cover immediately over the existing landfill surface.
The primary purposes of this rock layer are to serve as a marker layer, to provide protection in the event that significant erosion were to occur to the landfill cover, and to reduce the rate of radon migration and thereby contribute to radon attenuation. The rock layer will not be adversely impacted by increased temperature. Additionally, this rock layer will provide insulation and isolation between any potential heating that may occur within the underlying waste mass and the overlying low permeability layer of the engineered landfill cover. Therefore, the current conceptual design of the ROD-selected remedy includes components (included for other purposes) that would also serve to reduce potential thermal impacts to the engineered landfill cover if an SSE were to occur in West Lake Area 1 or 2.

As such, the design and required maintenance of the ROD-selected remedy are sufficient to mitigate any potential thermal impacts and permit the ROD-selected remedy to continue to function as expected.

6.3 Differential Settlement

The most likely and most significant impact of a potential SSE on the ROD-selected remedy components would be the effects of SSE-driven waste consolidation and the resultant differential settlement of the engineered landfill cover system. If the reduction in the volume of waste materials were significant, it could lead to settlement of the overlying waste materials. Consolidation and settlement of the waste materials could lead to subsidence and differential settlement of the engineered landfill cover. Differential settlement of the engineered landfill cover would likely result in damage to the cover system which could negatively affect the performance of the landfill cover through desiccation, creation of cracks, or in the extreme, complete disruption resulting in offsets in the cover system layers. Such impacts could result in increased radon release at the surface, and increased precipitation infiltration into the underlying waste mass.

Any occurrences of differential settlement of the engineered cover would be readily identifiable by visual inspection of the landfill surface because such disruptions would be manifested at the ground surface in the form of depressions, cracks, or stressed or dead vegetation. Ongoing routine inspection and maintenance of the landfill cover, as required by the ROD-selected remedy, would result in identification and repair of such a condition. Consequently, the design and required maintenance of the ROD-selected remedy are sufficient to mitigate any potential negative effects of differential settlement and permit the ROD-selected remedy to continue to function as expected.

7. CONCLUSIONS

In the unlikely event of an SSE within Areas 1 or 2 of the West Lake Landfill OU-1, the heat generated by this theoretical event would not combust, melt or alter the stability of the RIM. Further, an SSE would not increase the production of radon, because the rate of radon generation within the waste is a constant based on the amount of source material and the rate of radioactive decay. An SSE might affect the rate of radon exhalation (the release of radon at the ground surface), because the exhalation of radon is a function of the migration of radon through the surrounding waste materials and engineered landfill cover over the relatively short time frame between radon generation and decay.

An occurrence of an SSE could potentially result in a temporary, localized increase in radon exhalation (release at the surface of the landfill cover), but would not result in any long-term increases in radon emissions from the landfill. Further, any such temporary, localized increases in radon release would be mitigated by the ROD-selected remedy.

As detailed above, conditions in the subsurface are not anticipated to have any substantial or lasting impacts on the conditions or performance of the engineered landfill cover near the ground surface. Engineered components of the ROD-selected remedy consist of rock and soil, which do not burn and are not subject to reaction or oxidation. Therefore, they would not be affected by an SSE, and the ROD-selected remedy would continue to function as a barrier to both infiltration of precipitation and release of radon gas to the surface.

Furthermore, the ROD-selected remedy directs ongoing monitoring, maintenance and use controls that would mitigate any impact from any short term increase in the rate of radon release.

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FIGURE

Source: MyTopo.com Date of Photograph 8/9/2007

Figure 1

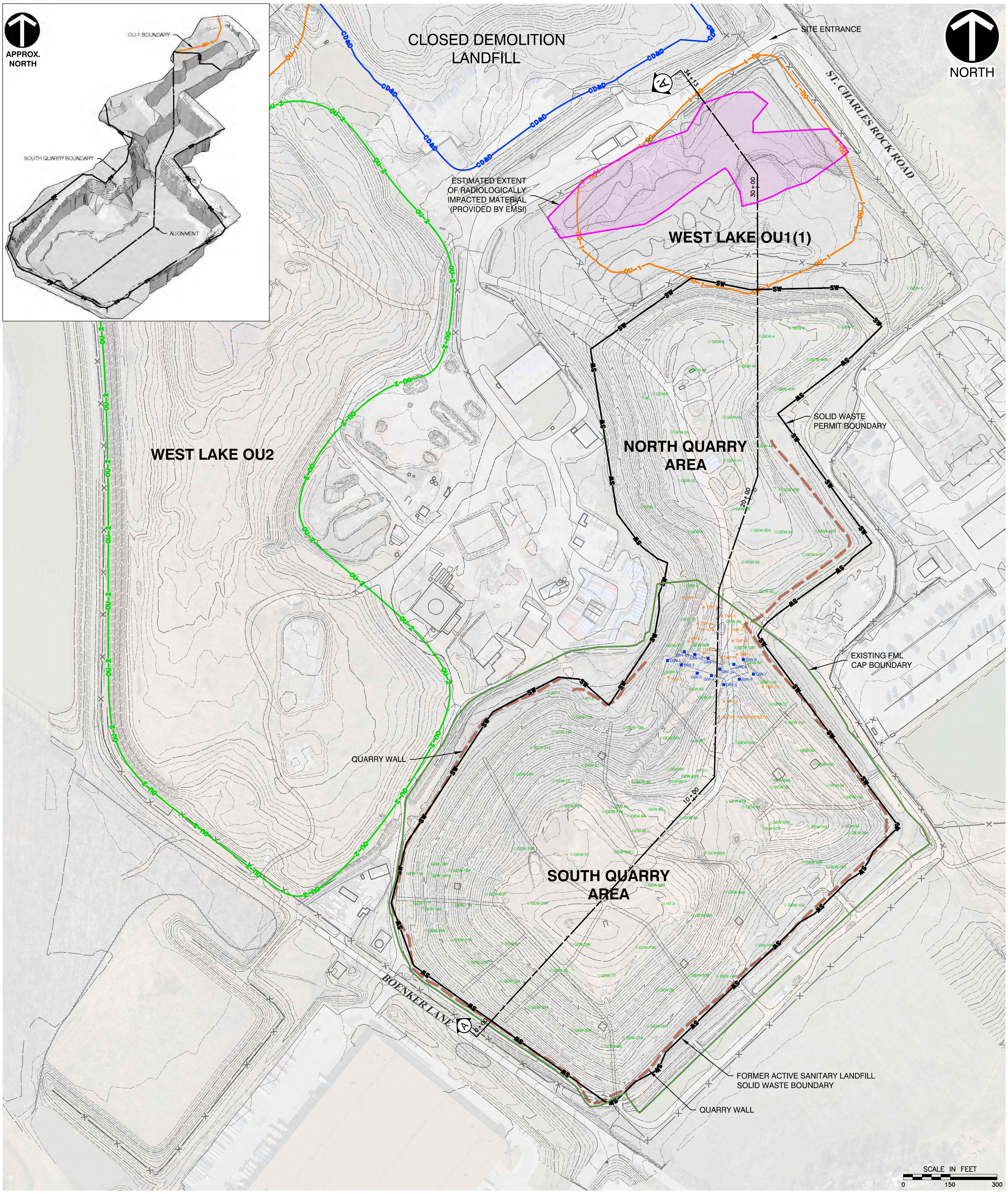
West Lake Landfill Features

West Lake Landfill OU-1 Additional Fencing and Signage

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2013\Fencing\WL-Fig-1-Site Features.dwg plotted: 05/15/2013

ATTACHMENT

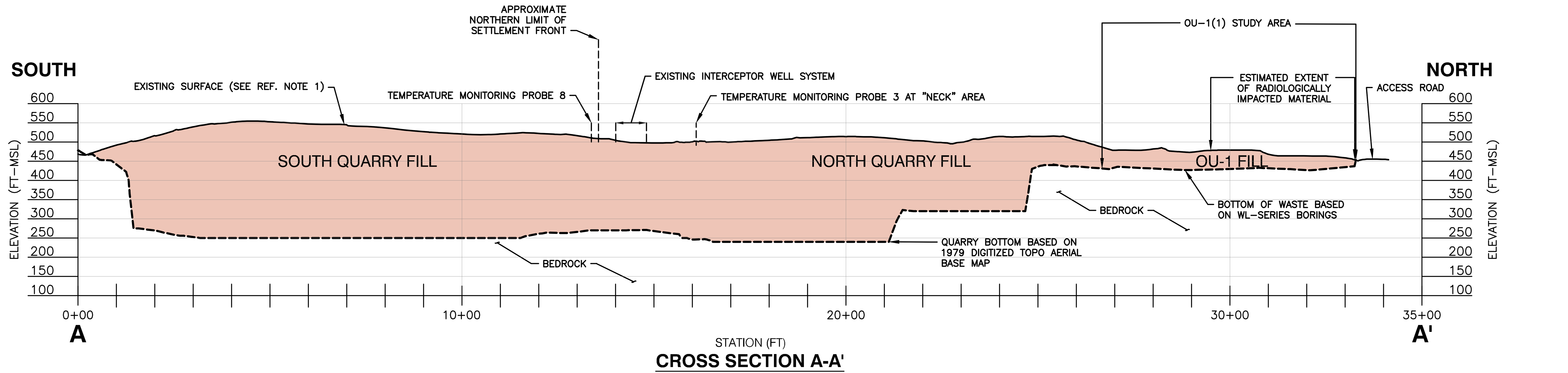


LEGEND

SW	EXISTING SOLID WASTE PERMIT BOUNDARY
OU-1	EXISTING OU1 STUDY AREA BOUNDARY
OU-2	EXISTING OU2 BOUNDARY
CD&D	EXISTING CLOSED DEMOLITION BOUNDARY
	EXISTING QUARRY HIGHWALL
	EXISTING FML CAP BOUNDARY
GEW-81	EXISTING LFG EXTRACTION WELL (GEW)
TMP-8	EXISTING TEMPERATURE MONITORING PROBE (TMP)
GIW-10	EXISTING GAS INTERCEPTOR WELL (GIW)

REFERENCE

1. TOPOGRAPHIC INFORMATION BASED UPON BRIDGETON LANDFILL-DTM.DWG PROVIDED BY COOPER AERIAL SURVEYS CO., DATED FEB. 2013. PRELIMINARY SURVEY INFORMATION OF WELLS AND PROBES PROVIDED BY WEAVER BOOS CONSULTANTS.
2. AERIAL IMAGERY PROVIDED BY EAST WEST GATEWAY COORDINATING COUNCIL OF MISSOURI AND ILLINOIS, COLLECTED IN LATE FEBRUARY AND EARLY MARCH OF 2012.



CROSS SECTION A-A'

DRAWN BY: | CHECKED BY: MSP | APPROVED BY: MRB | DRAFT
DATE: NOV. 2013 | DWG SCALE: 1"=150' | PROJECT NO: 131-178.0001 | FIGURE NO.: 2

BRIDGETON LANDFILL - EXISTING CONDITIONS

Attachment D

Vegetative Sampling Results Summary
In Support of Health and Safety Plan
For Vegetation Clearing and Grubbing
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

March 2009

Vegetative Sampling Results Summary

In Support of Health and Safety Plan

For Vegetation Clearing and Grubbing

West Lake Landfill Operable Unit 1, Bridgeton, Missouri

Prepared for: Engineering Management Support, Inc.

7220 West Jefferson Ave., Suite 406

Lakewood, Colorado 80235

Prepared by: TA Woodford and Associates, LLC

5315 Precious Stone Drive

St. Charles, Missouri 63304

March 30, 2009

Table of Contents

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1 Introduction

T. A. Woodford & Associates as a subcontractor to Engineering Management Support, Inc. (EMSI) is part of the Remedial Design team for Operable Unit 1 at the West Lake Landfill. A Remedial Design Work Plan (EMSI et al., 2008) for performance of design investigations and preparation of the remedial design in accordance with Amendment 2 to the Administrative Order on Consent for Operable Unit 1 was previously prepared and submitted to the U.S. Environmental Protection Agency (USEPA) and the Missouri Department of Natural Resources (MDNR).

In support of the Remedial Design activities, a new topographic survey needs to be prepared for Areas 1 and 2 of Operable Unit 1 at the West Lake Landfill. Before the survey can be performed, existing vegetation needs to be cleared from Areas 1 and 2 to allow access for performance of the topographic survey.

It is anticipated that clearing and grubbing of the vegetation will be performed using a skid-steer loader (e.g., Bobcat) with a cutter/grinder attachment. Based on the costs required for mobilization of the equipment and training of the crews, it is more cost effective to clear all of Areas 1 and 2 at one time. Therefore, with the exception of trees with trunk diameters of 6-inches or more, all vegetation will be cleared from Areas 1 and 2 as part of this effort. Topographic surveying can be performed around the larger trees. These trees will be removed at a later date as part of the implementation of the remedial action for the Site.

Cutting and grinding of the vegetation may result in generation of debris that could contain radionuclides. The radiological data contained in this report and its attachments show that no significant radiological uptake has taken place in the vegetation.

2 Purpose and Objectives

The purpose of this effort was to determine the level (if any) of radium 226, isotopic uranium, and isotopic thorium in the vegetation that is slated for removal/grinding. The objective of this effort was to obtain representative samples of the different types of vegetation slated for removal/grinding. These activities are described in greater detail in the Vegetation Sampling Plan dated March 9, 2009. Samples were collected from areas that have previously been identified as having greater than twice gross gamma background (> 25 uR/hr) when possible. Some areas of the site were not accessible due to the overgrowth of vegetation. The balance of the samples were collected from areas with lower gross gamma radiation.

3 Sample Locations

The vegetation sample locations were determined by the presence of vegetation and gross gamma measurements. These locations in Areas 1 and 2 are identified on Figure 1. The gross gamma radiological measurements were performed utilizing a Ludlum Model 12 Micro R Meter. Radiological screening and vegetation sampling focused on areas with greater than twice gross gamma background (> 25 uR/hr), when possible.

A total of seven vegetation samples were collected from the approximately 10 acres to be cleared in Area 1 and 13 vegetation samples were taken from the approximately 30 acres to be cleared in Area 2. A duplicate sample was obtained in each area for quality control purposes. All samples were given a unique sample identification number.

In addition to the collection of samples from areas with low gamma values within Areas 1 and 2, two vegetation background samples were taken from outside of Areas 1 and 2. Figure 2 shows the background sample locations in relation to the West Lake Landfill site. These background samples are numbered 8 and 9 on Table 1 (Vegetative Sampling Results). The background samples were collected along the Missouri River at the end of St. Charles Rock Road.

Samples were collected in the manner described in the Vegetation Sampling Plan (Woodford and Associates, 2009).

4 Data Summary/Conclusion

The data collected as a result of this sampling effort can be found in Table 1. Results reported in picocuries per gram (pCi/g) are provided for each of the various nuclides for each sample. Figures 3 through 9 show the activity concentrations and uncertainties for each of the samples for Radium-226, Thorium-228, Thorium-230, Thorium-232, Uranium-234, Uranium-235, and Uranium-238, respectively.

The highest activity concentration from the vegetation sampling effort is 1.38 pCi/g for Ra-226 from sample location 13 (Figures 1 and 3). All other results for Ra-226 were less than 0.33 pCi/g. This activity concentration of 1.38 pCi/g for Ra-226 found in one vegetation sample is only slightly higher than the background level of 1.3 pCi/g for Ra-226 in soil discussed in the Remedial Investigation (EMSI, 2000) and significantly less than the 5 pCi/g plus background soil cleanup level for Ra-226 contained in the Record of Decision (USEPA, 2008) for the Buffer Zone/Crossroad Property.

While the activity results from the vegetation sampling effort cannot be directly compared to the background and cleanup levels for soil, the vegetative debris generated during the clearing/grubbing effort will be much less of a respiratory hazard than that of soil due to particle size. Also, the vegetation material slated for removal has very high moisture content (as noted during sampling) and therefore will not readily become airborne. Therefore, there will be no increased risk associated with contact with the vegetation debris during the clearing/grubbing effort and no special handling measures need be taken with respect to the vegetation debris that will be left in-place. In addition, although not necessary based on the results of the vegetation sampling effort discussed in this report, the equipment to be utilized for the vegetation clearing/grubbing effort will be one closed-cab skid steer (Bobcat) that is equipped with a filtered air intake for the operator.

Based on the data and the above considerations, we are of the belief that clearing and grubbing can proceed without the need for respiratory protection. All other Health and Safety considerations will apply including but not limited to: Thermoluminescent Dosemeter (TLD) monitoring, Radiological Scanning, and Training.

5 References

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Table 1 - Vegetative Sampling Results

Area	North	West	uR/h	SampleType	Sample Location	Description	ReportUnits	Ra-226	Ra-226unc	Ra-226MDA	Th-228	Th-228unc	Th-228MDA	Th-230	Th-230unc	Th-230MDA
1	38°46.233	90°26.601	50	DUP	1	1LD	pCi/g	0.0228	0.0201	0.0285	0.0372	0.0279	0.0321	0.2385	0.0846	0.0296
1	38°46.233	90°26.601	50	DO	1	1	pCi/g	0.0004	0.0088	0.0384	0.0737	0.0622	0.0276	0.1561	0.1005	0.0667
1	38°46.233	90°26.601	50	TRG	2	1FQA	pCi/g	0.2708	0.0999	0.0642	0.0079	0.0156	0.0326	0.3854	0.1193	0.0267
1	38°46.226	90°26.608	12	TRG	3	3	pCi/g	0.3290	0.0943	0.0547	0.0266	0.0221	0.0251	0.5375	0.1548	0.0195
1	38°46.230	90°26.576	30	TRG	4	4	pCi/g	0.1386	0.0648	0.0501	0.0314	0.0294	0.0376	0.1556	0.0708	0.0275
1	38°46.198	90°26.628	10	TRG	5	5	pCi/g	0.0387	0.0279	0.0369	0.0361	0.0252	0.0318	0.0259	0.0196	0.0229
1	38°46.182	90°26.642	10	TRG	6	6	pCi/g	0.0197	0.0248	0.0386	0.0272	0.0242	0.0335	0.0314	0.0235	0.0223
1	38°46.228	90°26.562	10	TRG	7	7	pCi/g	0.1469	0.0797	0.0489	0.0321	0.0231	0.0218	0.0139	0.0155	0.0234
Background	38°46.905	90°28.163	8	TRG	8	8	pCi/g	0.0647	0.0365	0.0338	0.0095	0.0161	0.0318	0.0369	0.0255	0.0174
Background	38°47.282	90°27.917	7	TRG	9	9	pCi/g	0.0273	0.0202	0.0192	0.0132	0.0171	0.0304	0.0118	0.0151	0.0265
2	38°46.286	90°26.898	25	TRG	10	10	pCi/g	0.2895	0.0831	0.0338	0.0331	0.0181	0.0140	0.4877	0.1125	0.0131
2	38°46.311	90°26.942	10	TRG	11	11	pCi/g	0.0984	0.0410	0.0359	0.0364	0.0232	0.0204	0.0316	0.0206	0.0135
2	38°46.294	90°26.891	1,200	DUP	12	12LD	pCi/g	0.1080	0.0677	0.0710	0.0095	0.0096	0.0143	0.5294	0.1140	0.0102
2	38°46.294	90°26.891	1,200	DO	12	12	pCi/g	0.2621	0.1055	0.0907	0.0236	0.0170	0.0213	0.6819	0.1558	0.0100
2	38°46.398	90°26.889	80	TRG	13	13	pCi/g	1.3780	0.3022	0.1103	0.0132	0.0130	0.0174	0.2698	0.0763	0.0163
2	38°46.424	90°26.903	50	TRG	14	14	pCi/g	0.0695	0.0380	0.0427	0.0108	0.0120	0.0177	0.0414	0.0227	0.0166
2	38°46.424	90°26.903	50	TRG	15	14FQA	pCi/g	0.0670	0.0441	0.0485	0.0080	0.0094	0.0070	0.0164	0.0143	0.0170
2	38°46.436	90°26.721	10	TRG	16	16	pCi/g	0.0305	0.0359	0.0755	0.0045	0.0075	0.0143	0.0300	0.0169	0.0111
2	38°46.420	90°26.744	12	TRG	17	17	pCi/g	0.0390	0.0304	0.0310	0.0041	0.0072	0.0132	0.0040	0.0070	0.0132
2	38°46.380	90°26.966	10	TRG	18	18	pCi/g	0.1744	0.0812	0.0427	0.0232	0.0244	0.0374	0.0420	0.0291	0.0198
2	38°46.400	90°27.024	12	TRG	19	19	pCi/g	0.0436	0.0379	0.0539	0.0252	0.0198	0.0245	0.0111	0.0119	0.0134
2	38°46.454	90°26.985	10	TRG	20	20	pCi/g	0.1122	0.0870	0.0887	0.0092	0.0136	0.0249	0.0346	0.0238	0.0250
2	38°46.474	90°26.957	12	TRG	21	21	pCi/g	0.1177	0.0858	0.0910	0.0116	0.0155	0.0275	0.0141	0.0151	0.0213
2	38°46.503	90°26.902	9	TRG	22	22	pCi/g	0.0383	0.0519	0.1161	0.0168	0.0197	0.0305	0.0371	0.0264	0.0112

Notes:
uR/h = micro Roentgen per hour, the gamma rate at the sample location measured with a Ludlum Model 12 MicroR field meter.
pCi/g = picocuries per gram
DUP = laboratory duplicate sample
DO = duplicate original field sample (i.e., Sample locations 1 and 2 are in the same location, as are Sample locations 14 and 15)
TRG = original field sample
LD = laboratory duplicate
FQA = field quality assurance
unc = uncertainty
MDA = minimum detectable activity

ROSASCO_0000122

Table 1 - Vegetative Sampling Results

Area	North	West	uR/h	SampleType	Sample Location	Description	ReportUnits	Th-232	Th-232unc	Th-232MDA	U-234	U-234unc	U-234MDA	U-235	U-235unc	U-235MDA
1	38°46.233	90°26.601	50	DUP	1	1LD	pCi/g	0.0012	0.0080	0.0248	0.0772	0.0287	0.0194	0.0053	0.0075	0.0071
1	38°46.233	90°26.601	50	DO	1	1	pCi/g	0.0084	0.0209	0.0471	0.0751	0.0264	0.0089	0.0072	0.0083	0.0065
1	38°46.233	90°26.601	50	TRG	2	1FQA	pCi/g	0.0047	0.0105	0.0235	0.2390	0.0569	0.0177	0.0167	0.0139	0.0155
1	38°46.226	90°26.608	12	TRG	3	3	pCi/g	0.0137	0.0148	0.0166	0.0317	0.0178	0.0106	0.0113	0.0114	0.0077
1	38°46.230	90°26.576	30	TRG	4	4	pCi/g	0.0126	0.0181	0.0306	0.0280	0.0161	0.0125	0.0064	0.0090	0.0154
1	38°46.198	90°26.628	10	TRG	5	5	pCi/g	0.0092	0.0121	0.0205	0.0152	0.0123	0.0149	0.0070	0.0092	0.0142
1	38°46.182	90°26.642	10	TRG	6	6	pCi/g	0.0018	0.0077	0.0222	0.0072	0.0093	0.0159	-0.0010	0.0014	0.0152
1	38°46.228	90°26.562	10	TRG	7	7	pCi/g	0.0055	0.0097	0.0181	0.0251	0.0159	0.0107	0.0048	0.0082	0.0155
Background	38°46.905	90°28.163	8	TRG	8	8	pCi/g	-0.0013	0.0018	0.0203	0.0076	0.0099	0.0169	0.0044	0.0086	0.0180
Background	38°47.282	90°27.917	7	TRG	9	9	pCi/g	-0.0001	0.0070	0.0241	0.0113	0.0158	0.0299	-0.0021	0.0025	0.0254
2	38°46.286	90°26.898	25	TRG	10	10	pCi/g	0.0080	0.0081	0.0054	0.0275	0.0164	0.0133	0.0023	0.0055	0.0126
2	38°46.311	90°26.942	10	TRG	11	11	pCi/g	0.0019	0.0060	0.0158	0.2169	0.0536	0.0129	0.0281	0.0180	0.0143
2	38°46.294	90°26.891	1,200	DUP	12	12LD	pCi/g	0.0104	0.0092	0.0118	0.3258	0.0687	0.0090	0.0261	0.0164	0.0112
2	38°46.294	90°26.891	1,200	DO	12	12	pCi/g	0.0169	0.0127	0.0100	0.2937	0.0622	0.0050	0.0132	0.0113	0.0105
2	38°46.398	90°26.889	80	TRG	13	13	pCi/g	0.0091	0.0102	0.0135	0.2211	0.0537	0.0057	0.0103	0.0104	0.0070
2	38°46.424	90°26.903	50	TRG	14	14	pCi/g	0.0021	0.0052	0.0117	0.0288	0.0158	0.0106	0.0024	0.0049	0.0066
2	38°46.424	90°26.903	50	TRG	15	14FQA	pCi/g	0.0000	0.0000	0.0070	0.0120	0.0099	0.0054	0.0025	0.0049	0.0067
2	38°46.436	90°26.721	10	TRG	16	16	pCi/g	0.0017	0.0042	0.0094	0.0161	0.0124	0.0130	0.0017	0.0055	0.0144
2	38°46.420	90°26.744	12	TRG	17	17	pCi/g	0.0024	0.0049	0.0066	0.0010	0.0042	0.0122	-0.0025	0.0021	0.0184
2	38°46.380	90°26.966	10	TRG	18	18	pCi/g	0.0042	0.0126	0.0316	0.0220	0.0168	0.0229	-0.0031	0.0026	0.0224
2	38°46.400	90°27.024	12	TRG	19	19	pCi/g	-0.0015	0.0017	0.0175	0.0234	0.0134	0.0105	-0.0007	0.0010	0.0116
2	38°46.454	90°26.985	10	TRG	20	20	pCi/g	0.0080	0.0114	0.0193	0.0098	0.0089	0.0108	-0.0004	0.0048	0.0171
2	38°46.474	90°26.957	12	TRG	21	21	pCi/g	0.0070	0.0116	0.0228	0.0104	0.0117	0.0196	0.0014	0.0060	0.0173
2	38°46.503	90°26.902	9	TRG	22	22	pCi/g	0.0074	0.0148	0.0320	0.0214	0.0137	0.0109	-0.0004	0.0008	0.0115

Notes:
uR/h = micro Roentgen per hour, the gamma rate at the sample location measured with a Ludlum Model 12 MicroR field meter.
pCi/g = picocuries per gram
DUP = laboratory duplicate sample
DO = duplicate original field sample (i.e., Sample locations 1 and 2 are in the same location, as are Sample locations 14 and 15)
TRG = original field sample
LD = laboratory duplicate
FQA = field quality assurance
unc = uncertainty
MDA = minimum detectable activity

ROSASCO_0000123

Table 1 - Vegetative Sampling Results

Area	North	West	uR/h	SampleType	Sample Location	Description	ReportUnits	U-238	U-238unc	U-238MDA
1	38°46.233	90°26.601	50	DUP	1	1LD	pCi/g	0.0829	0.0296	0.0158
1	38°46.233	90°26.601	50	DO	1	1	pCi/g	0.0892	0.0293	0.0126
1	38°46.233	90°26.601	50	TRG	2	1FQA	pCi/g	0.2331	0.0558	0.0146
1	38°46.226	90°26.608	12	TRG	3	3	pCi/g	0.0433	0.0209	0.0062
1	38°46.230	90°26.576	30	TRG	4	4	pCi/g	0.0192	0.0134	0.0135
1	38°46.198	90°26.628	10	TRG	5	5	pCi/g	0.0180	0.0130	0.0128
1	38°46.182	90°26.642	10	TRG	6	6	pCi/g	0.0011	0.0047	0.0136
1	38°46.228	90°26.562	10	TRG	7	7	pCi/g	0.0339	0.0186	0.0125
Background	38°46.905	90°28.163	8	TRG	8	8	pCi/g	0.0084	0.0098	0.0145
Background	38°47.282	90°27.917	7	TRG	9	9	pCi/g	0.0198	0.0170	0.0157
2	38°46.286	90°26.898	25	TRG	10	10	pCi/g	0.0278	0.0164	0.0119
2	38°46.311	90°26.942	10	TRG	11	11	pCi/g	0.2053	0.0516	0.0128
2	38°46.294	90°26.891	1,200	DUP	12	12LD	pCi/g	0.3092	0.0660	0.0053
2	38°46.294	90°26.891	1,200	DO	12	12	pCi/g	0.2376	0.0535	0.0050
2	38°46.398	90°26.889	80	TRG	13	13	pCi/g	0.2264	0.0545	0.0056
2	38°46.424	90°26.903	50	TRG	14	14	pCi/g	0.0176	0.0120	0.0053
2	38°46.424	90°26.903	50	TRG	15	14FQA	pCi/g	0.0089	0.0090	0.0120
2	38°46.436	90°26.721	10	TRG	16	16	pCi/g	0.0057	0.0075	0.0116
2	38°46.420	90°26.744	12	TRG	17	17	pCi/g	0.0094	0.0091	0.0109
2	38°46.380	90°26.966	10	TRG	18	18	pCi/g	0.0052	0.0102	0.0221
2	38°46.400	90°27.024	12	TRG	19	19	pCi/g	0.0101	0.0086	0.0080
2	38°46.454	90°26.985	10	TRG	20	20	pCi/g	0.0083	0.0081	0.0096
2	38°46.474	90°26.957	12	TRG	21	21	pCi/g	0.0211	0.0150	0.0162
2	38°46.503	90°26.902	9	TRG	22	22	pCi/g	0.0073	0.0081	0.0109

Notes:
uR/h = micro Roentgen per hour, the gamma rate at the sample location measured with a Ludlum Model 12 MicroR field meter.
pCi/g = picocuries per gram
DUP = laboratory duplicate sample
DO = duplicate original field sample (i.e., Sample locations 1 and 2 are in the same location, as are Sample locations 14 and 15)
TRG = original field sample
LD = laboratory duplicate
FQA = field quality assurance
unc = uncertainty
MDA = minimum detectable activity

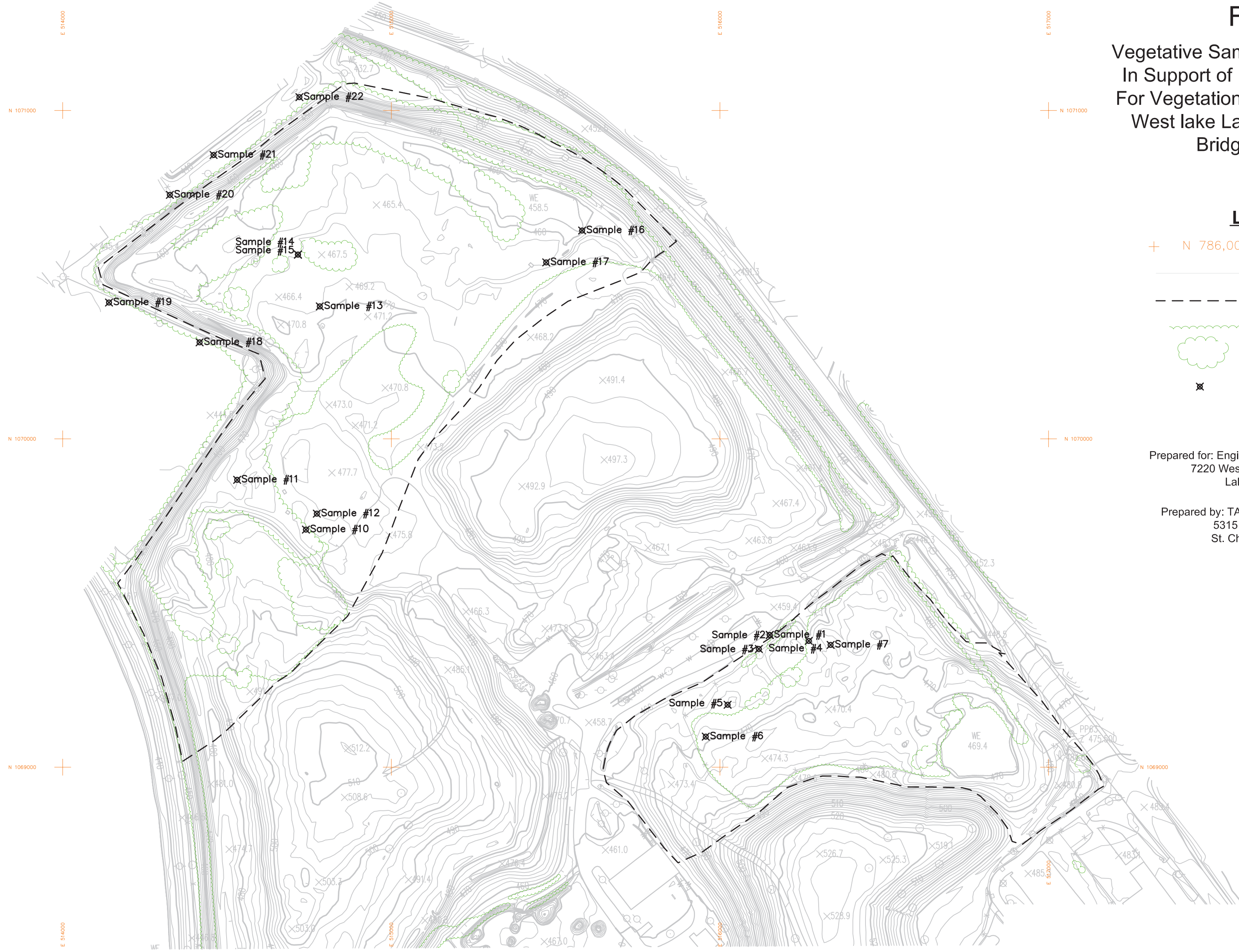


Figure 1

Vegetative Sampling Results Summary In Support of Health and Safety Plan For Vegetation Clearing and Grubbing West lake Landfill Operable Unit 1, Bridgeton, Missouri

LEGEND

- N 786,000 GRID COORDINATES
- EXISTING TOPO
- LIMITS OF REGRADING AREA
- EXISTING SHRUB
- EXISTING TREE LINE
- VEGETATION SAMPLE LOCATION

Prepared for: Engineering Management Support, Inc.
7220 West Jefferson Ave. Suite 406
Lakewood, Co. 80235

Prepared by: TA Woodford and Associates, LLC
5315 Precious Stone Drive
St. Charles, Missouri 63304

March 30, 2009

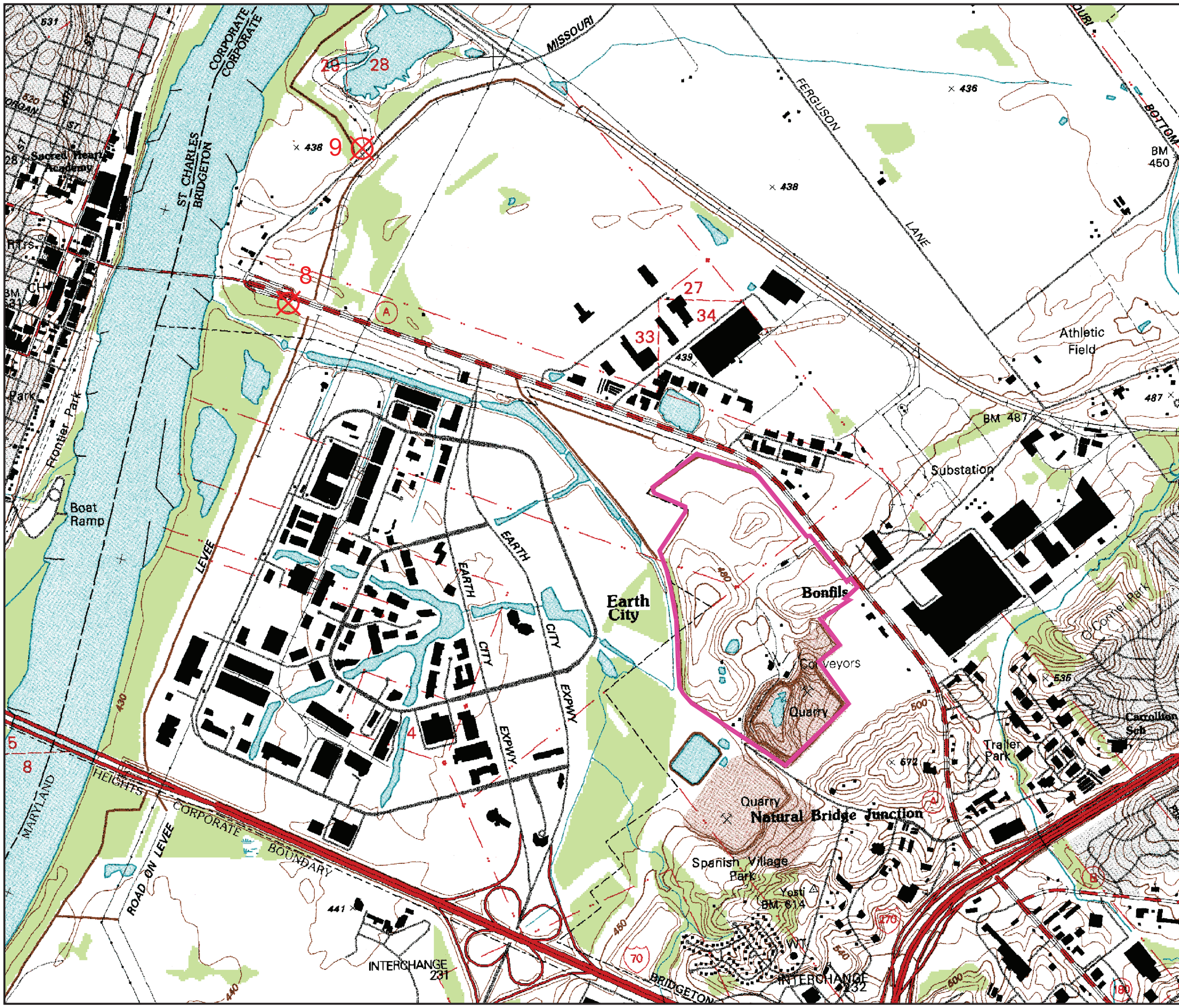


Figure 2

Vegetative Sampling Results Summary
In Support of Health and Safety Plan
For Vegetation Clearing and Grubbing
West lake Landfill Operable Unit 1,
Bridgeton, Missouri

LEGEND

Approximate Landfill Boundary

Vegetation Sample Location

Prepared for: Engineering Management Support, Inc.
7220 West Jefferson Ave. Suite 406
Lakewood, Co. 80235

Prepared by: TA Woodford and Associates, LLC
5315 Precious Stone Drive
St. Charles, Missouri 63304

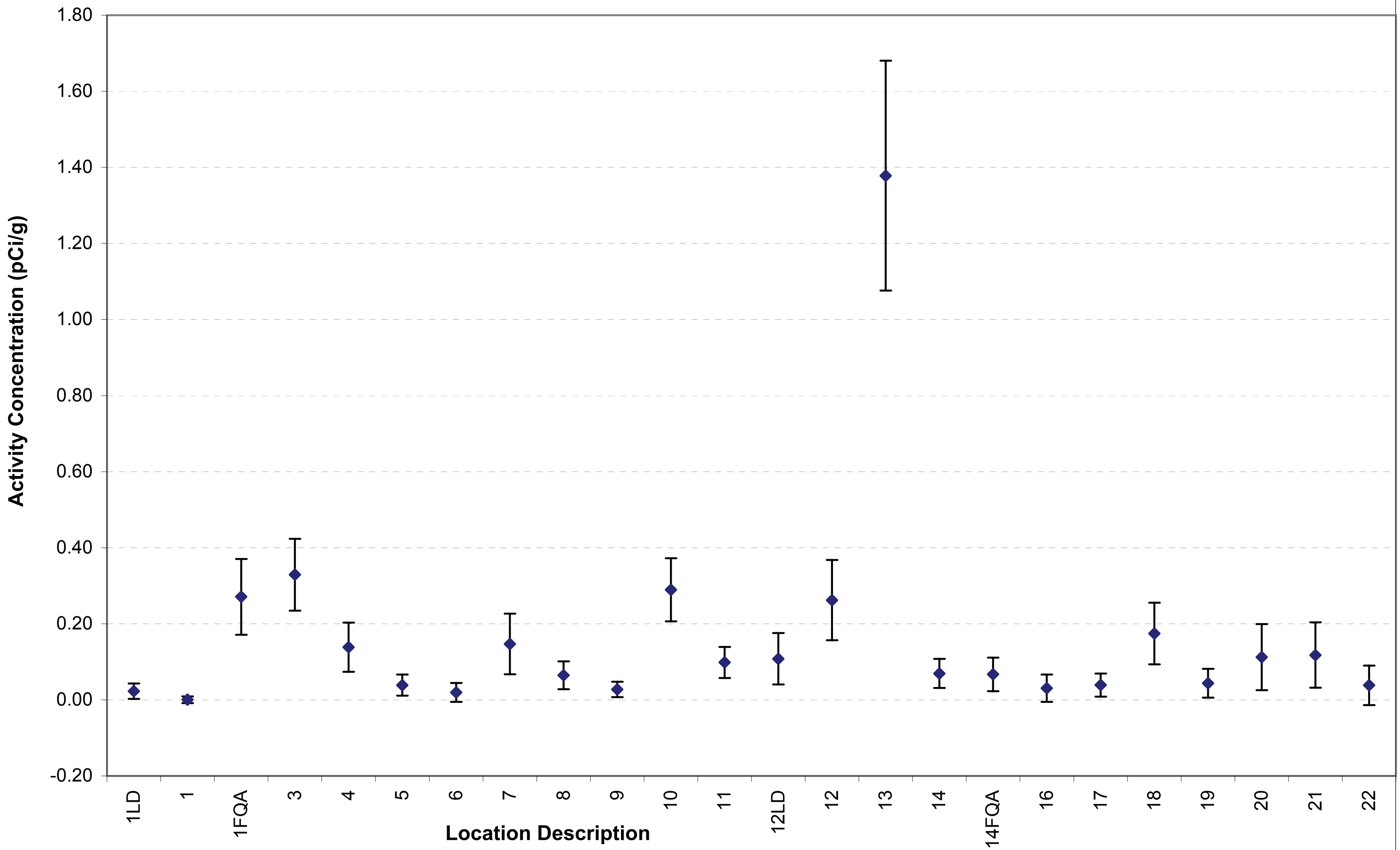
March 30, 2009

1500 0 1500
SCALE IN FEET
Source: St. Charles, MO USGS 7.5' Quadrangle, 1994

M:\CLIENTS\EMSI\WESTLAKE\2009\WL-VEG-OFFSITE-SAMPLES.DWG-LAYOUT1 04/03/2009 5:27PM

ROSASCO_0000126

Figure 3 - Ra-226 in Vegetation



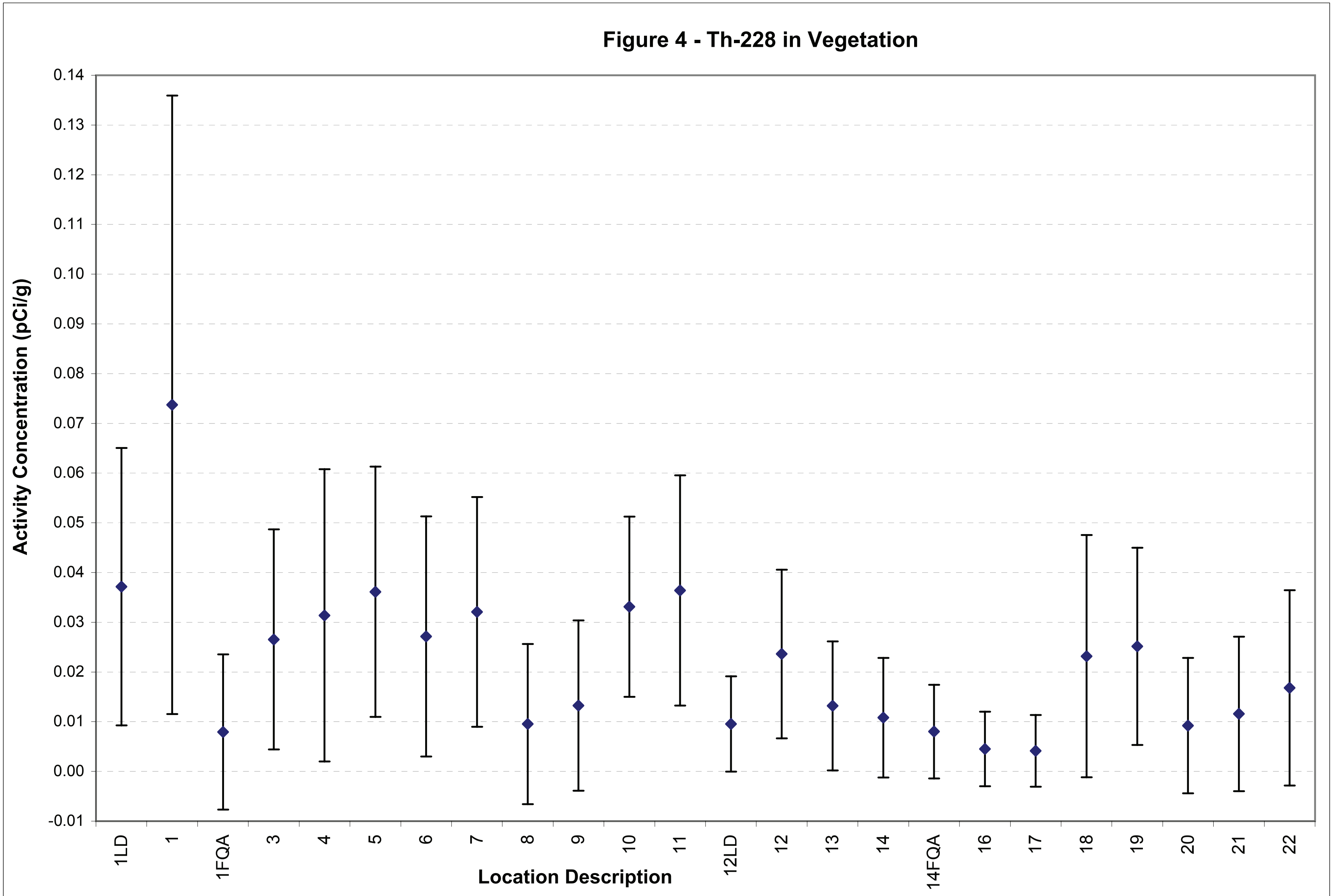


Figure 4 - Th-228 in Vegetation
Activity Concentration (pCi/g)
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
1LD
1
1FQA
3
4
5
6
7
8
9
10
11
12LD
12
13
14
14FQA
16
17
18
19
20
21
22
Location Description

Figure 5 - Th-230 in Vegetation

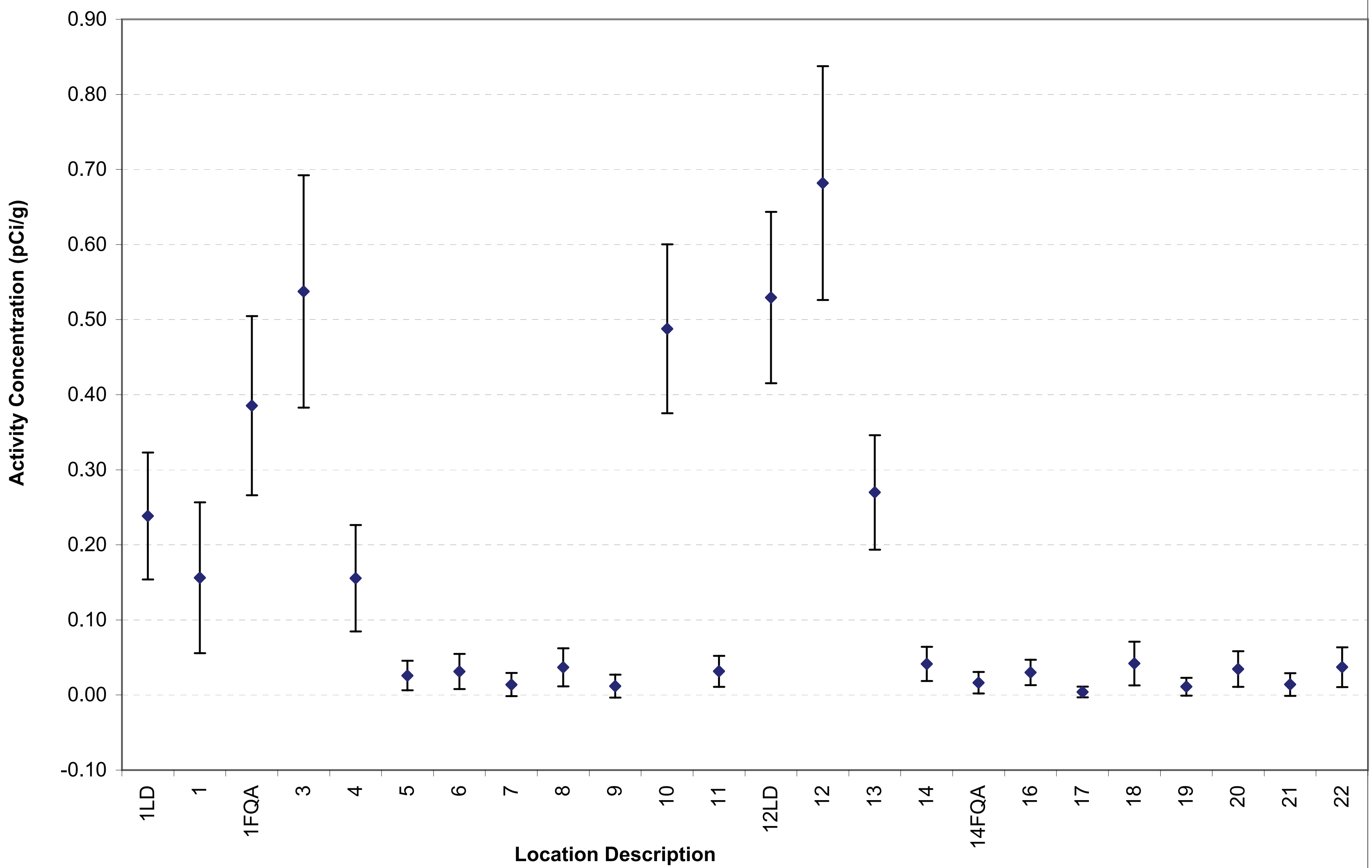
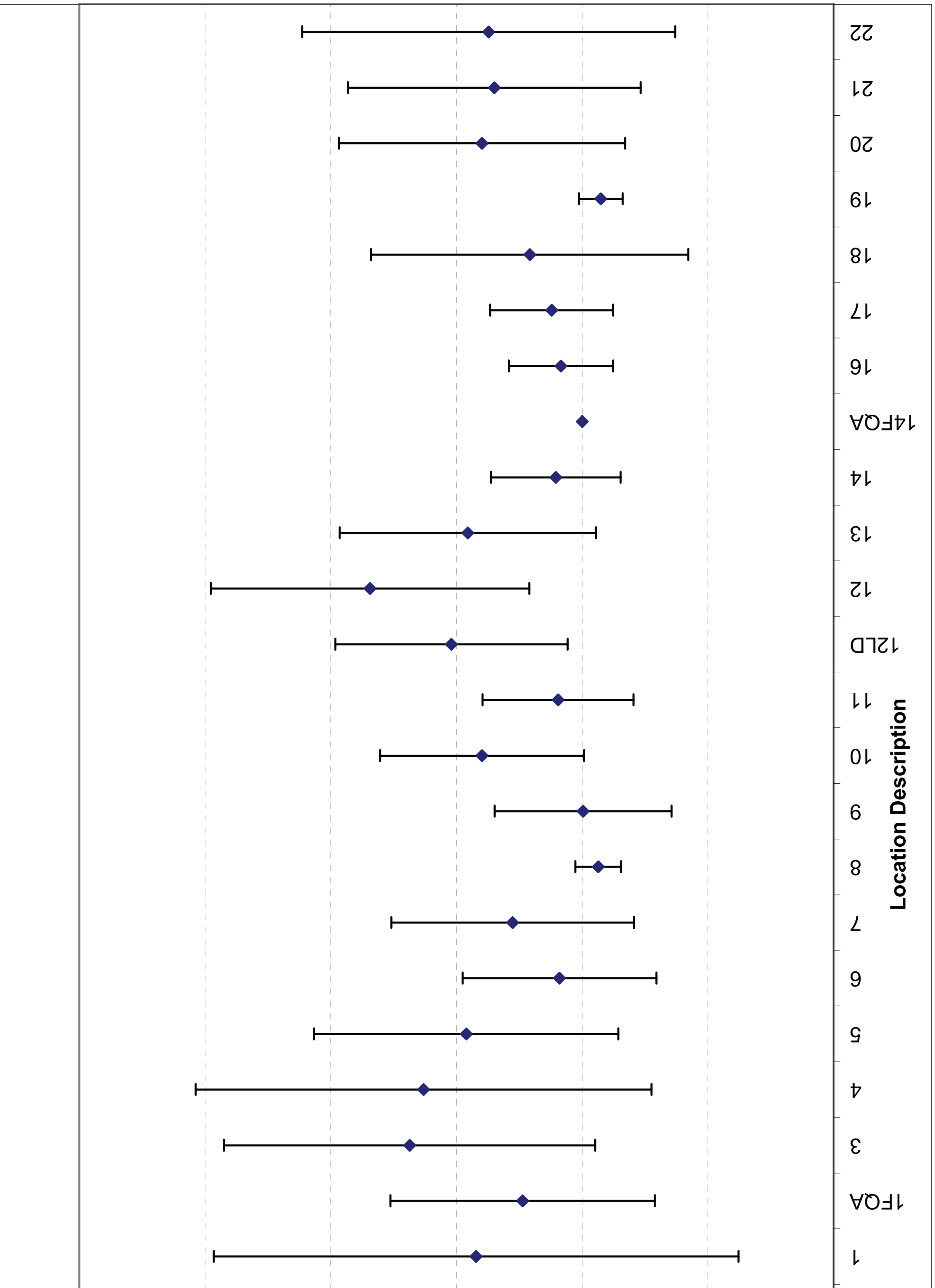


Figure 6 - Th-232 in Vegetation



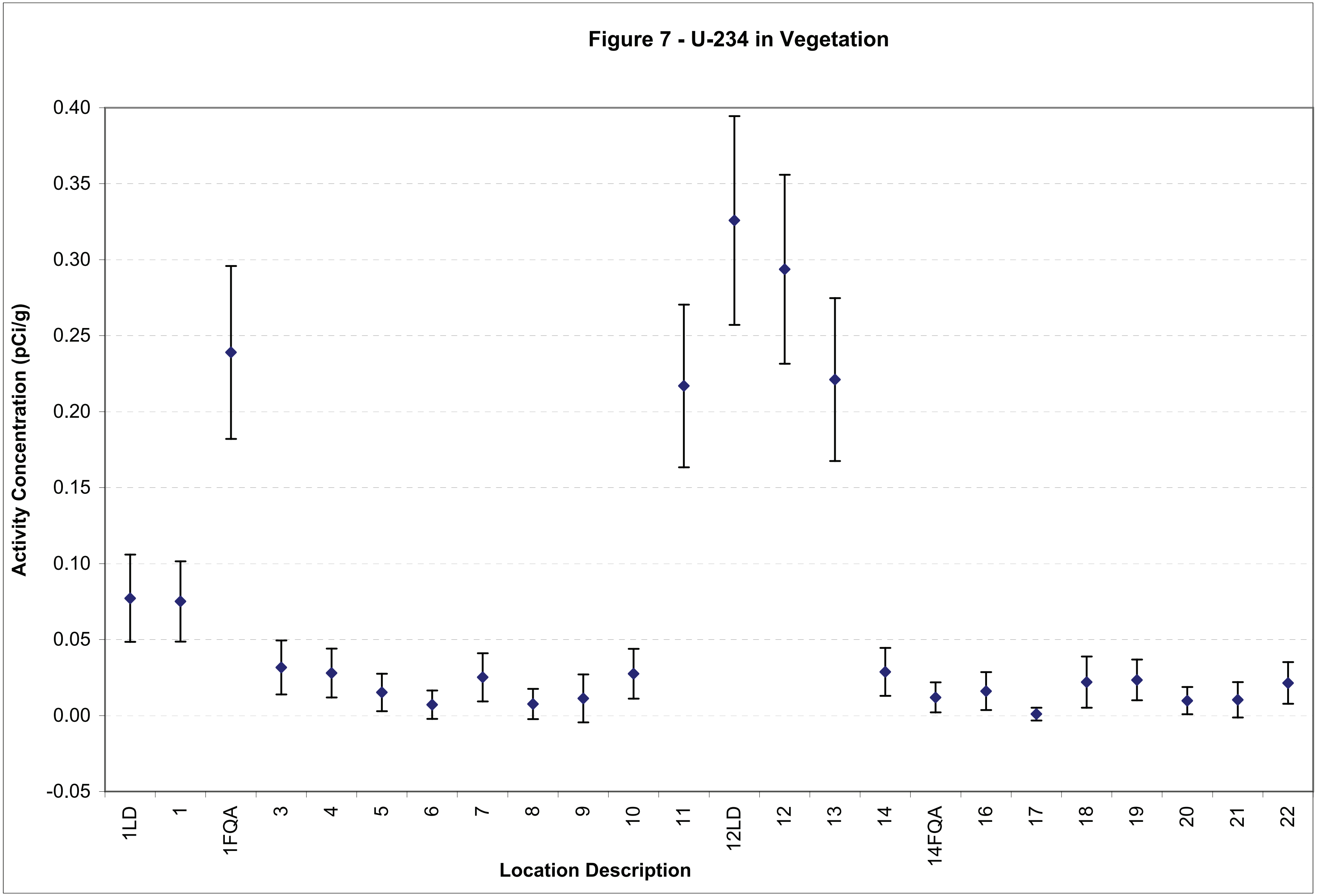


Figure 7 - U-234 in Vegetation
Activity Concentration (pCi/g)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
1LD
1
1FQA
3
4
5
6
7
8
9
10
11
12LD
12
13
14
14FQA
16
17
18
19
20
21
22
Location Description

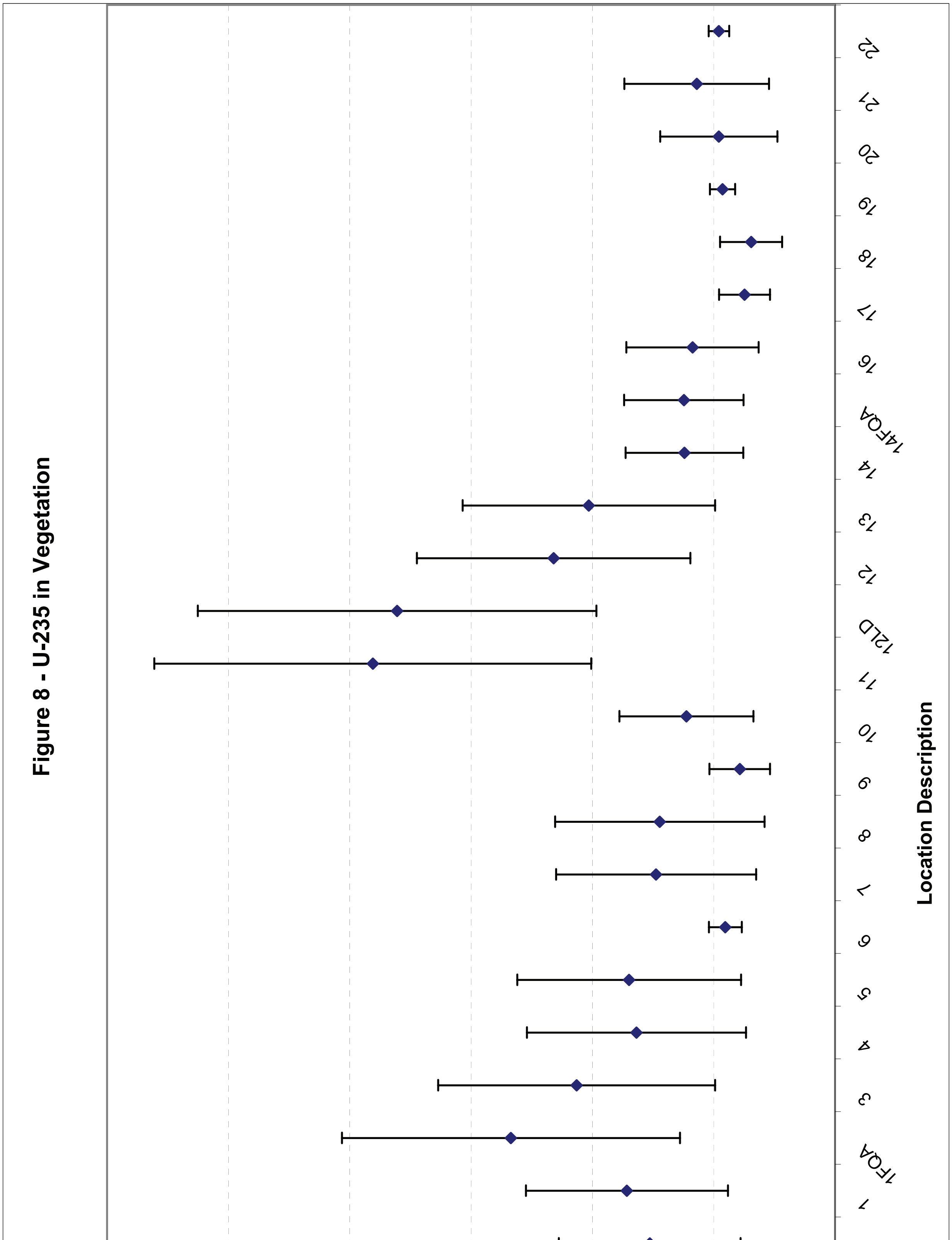


Figure 8 - U-235 in Vegetation
Activity Concentration (pCi/g)
Location Description
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
1LD
1
1FOA
3
4
5
6
7
8
9
10
11
12LD
12
13
14
14FOA
16
17
18
19
20
21
22

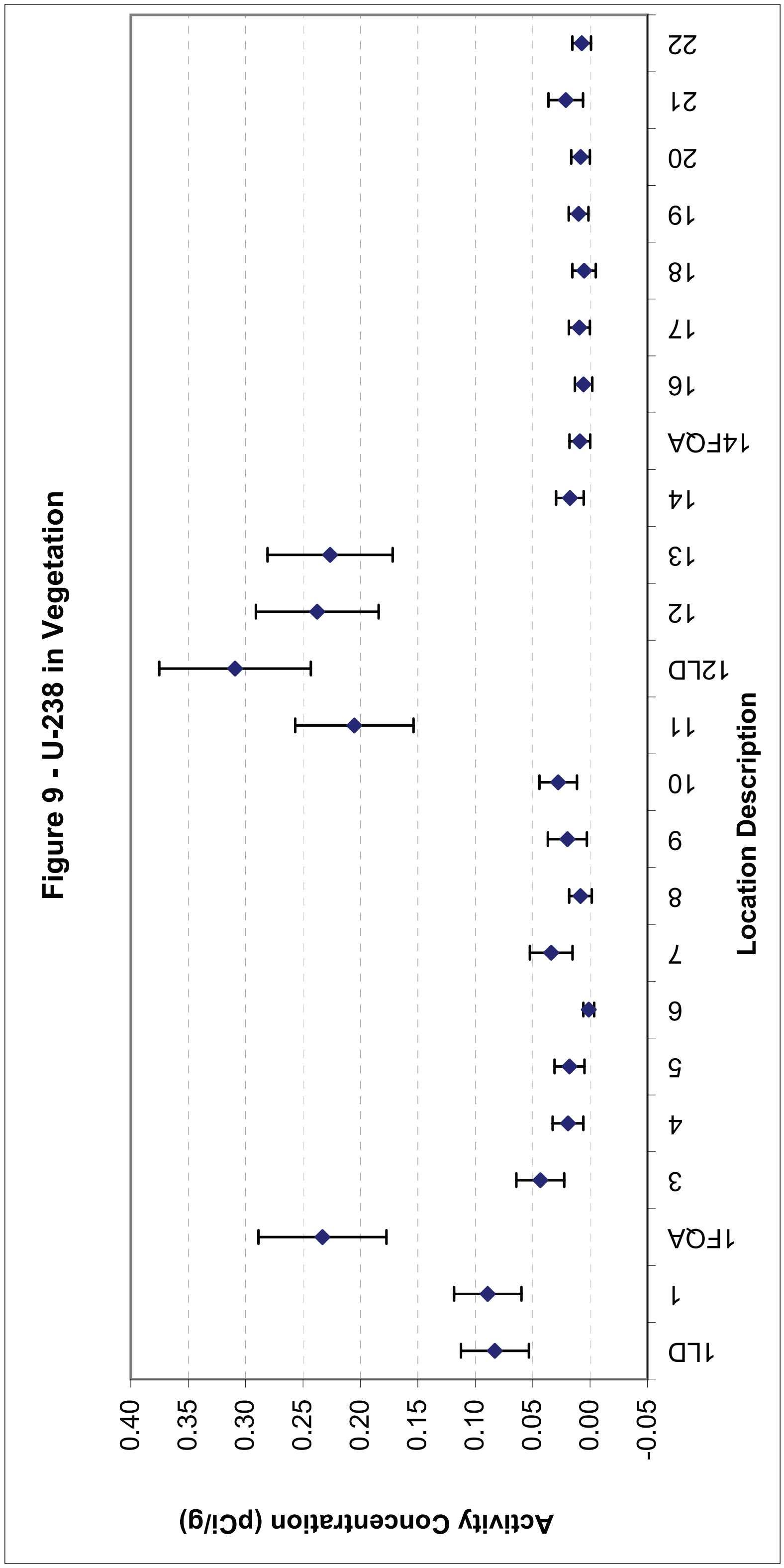


Figure 9 - U-238 in Vegetation
Activity Concentration (pCi/g)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
Location Description
1LD
1
1FQA
3
4
5
6
7
8
9
10
11
12LD
12
13
14
14FQA
16
17
18
19
20
21
22

Attachment E

Summary Exhibits

List of Tables

List of Figures

Table 1: Comparison of Risks from a Variety of Radiation Sources

Activity/Exposure	Risk (___ x 10^{-6})
Long-term risk to West Lake RME (Grounds Keeper), "Complete Rad Removal" with Off-site Disposal	**< 0.1** [a]
Point of departure for EPA's generally acceptable risk range at CERCLA Sites	**1**
Long-term risk to West Lake RME (Grounds Keeper), ROD-Selected Remedy	**1.3** [a]
Long-term risk to West Lake RME (Grounds Keeper), "Complete Rad Removal" with On-site Disposal	**1.5** [a]
Radiation from a transcontinental plane flight, one-way	2 [b]
Cooking or heating with natural gas (radon in the gas)	5 [b]
Radiation from one routine chest X-ray	6 [b]
Annual radiation exposure to cosmic rays at sea-level	18 [b]
Watching a cathode-ray TV or computer screen	18 [b]
Annual radiation exposure from internal exposure to naturally-occurring radionuclides in the human body (such as potassium-40)	23 [b]
Annual radiation exposure from cosmic rays in Denver	30 [b]
Living in a brick house	45 [b]
Short-term risk to West Lake RME (RadCon Tech) during construction of ROD Remedy	**72** [a]
Top of EPA's generally acceptable risk range at CERCLA Sites	**100**
Annual exposure to naturally occurring radon in air	120 [b]
Nuclear medicine bone scan (Tc-99)	258 [b]
EPA published value for acceptable risk from 20 pCi/m^2/s radon emitted by tailings piles (preamble to NESHAPS)	300 [c]
Short-term risk to West Lake RME (RadCon Tech) during "Complete Rad Removal" with On-site Disposal of Soil	**740** [a]
Short-term risk to West Lake RME (RadCon Tech) during "Complete Rad Removal" with Off-site Disposal of Soil	**760** [a]
Annual radiation exposure from smoking a pack and a half of cigarettes a day	780 [b]

[a] Calculated in this report and values greater than 10^{-7} rounded to two (2) significant figures.

[b] Calculated using the dose to risk conversion factor of 6 x 10^{-04} per rem Total Effective Dose Equivalent (TEDE) recommended by EPA (ISCORS, 2003) (http://homer.ornl.gov/oepa/guidance/risk/iscors.pdf).
Dose information supplied by the University of Iowa, http://www.uihealthcare.com/topics/medicaldepartments/cancercenter/prevention/preventionradiation.html.

[c] Preamble to 40 CFR 61, "National Emission Standards of Hazardous Air Pollutants; Radionuclides; Final Rule and Notice of Reconsideration Federal Register" Vol. 54, No.240, pg 51682. (Subsection VI.L.3 Disposal of Uranium Mill Tailings Piles).

Table 2: Comparison of Estimated Days of Life Expectancy Lost from Various Activities

Health Risk	Estimated Days of Life Expectancy Lost
Being an unmarried male	3500
Smoking (1 pk/day)	2250
Being an unmarried female	1600
Being a coal miner	1100
15% overweight	777
Alcohol (US average)	365
Being a construction worker	227
Driving a motor vehicle	205
All industry	60
Radiation 100 mrem/yr (70 yrs)	10

Table 3: Summary of Potential Risks, Implementation Schedules and Costs for the ROD-Selected Remedy and the "Complete Rad Removal" Alternatives

	ROD-Selected Remedy	"Complete Rad Removal" with Off-site Disposal	"Complete Rad Removal" with On-Site Disposal
Long term residual cancer risk 1,000 years after cleanup	1.3×10^{-6} (1.3 extra incidences in 1,000,000 people)	<1×10^{-7} (less than 0.1 extra incidence in 1,000,000 people)	1.5×10^{-6} (1.5 extra incidences in 1,000,000 people)
Short term risks during cleanup	On-Site Workers Industrial accidents: 4.7 Cancer risk: 7.2×10^{-5} (0.72 extra incidences in 10,000 people) Worker dose: 50 mrem/yr	On-Site Workers Industrial accidents: 7.6 Cancer risks: 7.6×10^{-4} (7.6 extra incidences in 10,000 people) Worker dose: 260 mrem/yr	On-Site Workers Industrial accidents: 9.0 Cancer risks: 7.4×10^{-4} (7.4 extra incidences in 10,000 people) Worker dose: 260 mrem/yr
	Community Transportation accidents: 0.61 Cancer risk: 3.3×10^{-6} (0.33 extra incidences in 100,000 people) Carbon dioxide emissions: 8,350 tons	Community Transportation accidents: 1.4 Cancer risks: 2.1×10^{-5} (2.1 extra incidences in 100,000 people) Carbon dioxide emissions: 35,400 tons	Community Transportation accidents: 0.79 Cancer risks: 2.0×10^{-5} (2.0 extra incidences in 100,000 people) Carbon dioxide emissions: 17,900 tons
Schedule to reach cleanup goals	3 years (or 5 years at spend rate of $10M per year)	4 years (or 29 years at spend rate of $10M per year)	6 years (or 13 years at spend rate of $10M per year)
Costs	Capital construction: $41,400,000 OM&M per year: $42,000 to $414,000	Capital construction: $259,000,000 to $415,000,000 OM&M per year: $40,000 to $412,000	Capital construction: $117,000,000 OM&M per year: $52,000 to $604,000

Table 4: Summary of Tree Core Sample Vials Included in Each of Dr. Usman's Sample Batches

Batch	1	2	2 - re	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	A	B	C
Vials	239	226	226	250	200	54	44	34	24	19	4	1	63	81	72	190	129	121	180	169	221	162	146	152	209	200	232
	247	227	227	249	201	55	45	35	25	20	5	2	64	82	73	191	130	122	181	170	222	163	147	164	210	201	233
	241	229	229	238	202	56	46	36	26	21	6	3	65	83	74	192	131	123	182	172	223	165	148	217	225	202	234
	248	230	230	237	203	57	47	37	27	22	7	141	70	84	75	193	132	124	183	173	224	167	150	219	226	203	235
	246	231	231	225	204	58	48	38	28	23	8	142	71	85	76	194	133	125	184	174	220	166	151	218	227	204	236
	242	232	232	255	205	59	49	39	29	14	9	188	90	86	77	195	134	126	185	175	211	168	155	216	228	205	237
	243	233	233	254	206	60	50	40	30	15	10	189	91	87	78	196	135	127	186	176	212	158	154		231	206	238
	245	234	234	253	207	61	51	41	31	16	11	135	92	88	79	197	136	128	187	177	213	159	153		249	207	
	244	235	235	252	208	62	52	42	32	17	12	143	93	89	80	144	137	145	198	178	214	160	156		250	208	
	240	236	236	251	209	210	53	43	33	18	13	140	94	95	66	228	138	149	199	179	215	171	157		251		
																									252		
																									255		

242	Duplicate sample
231	Field blank sample
208	Trip blank sample
155	No such sample vial exists. Notes Field 2.pdf indicates that there is no such sample. No Vial no. 155 is included in Summary.pdf file.

10/23/15

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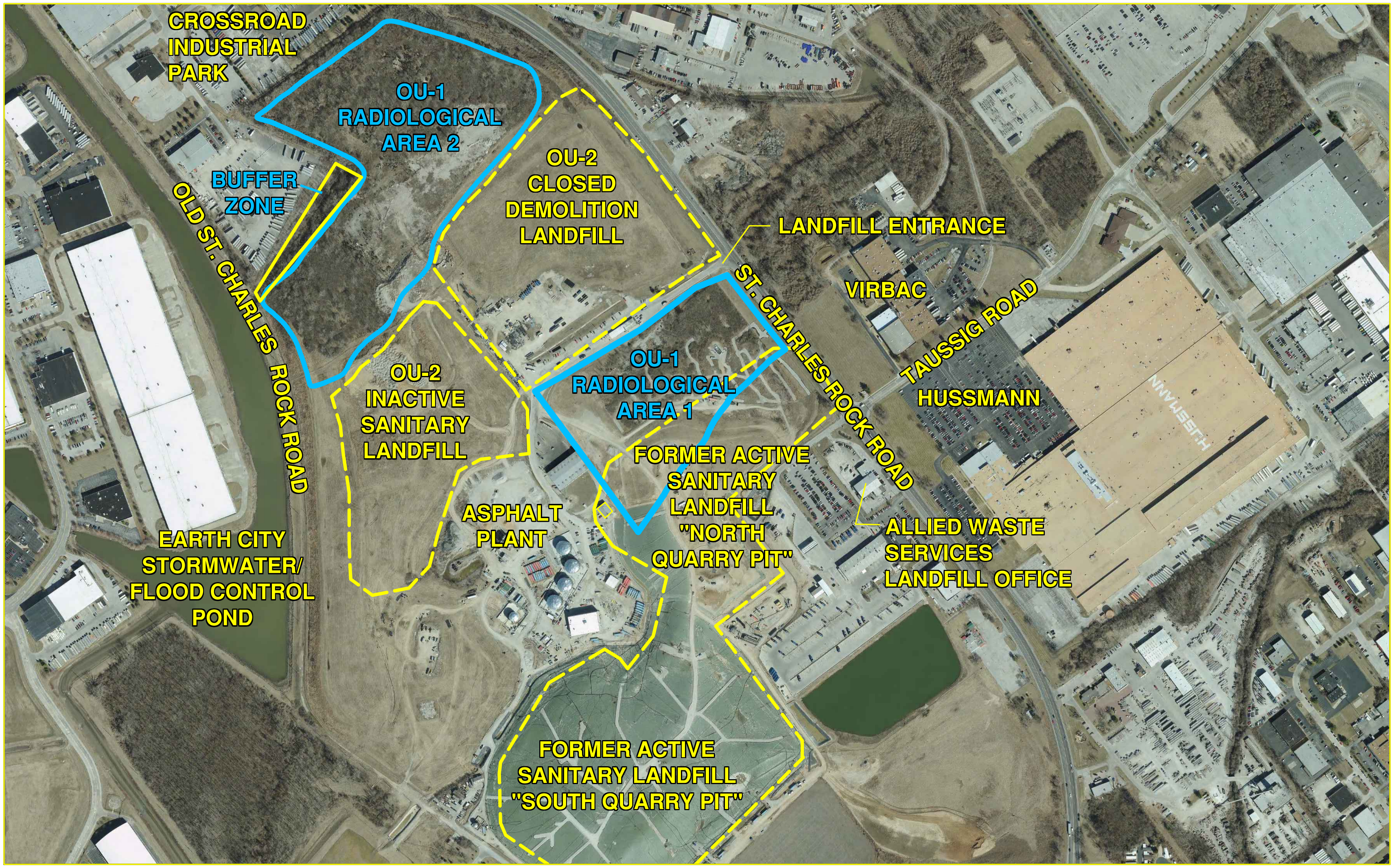
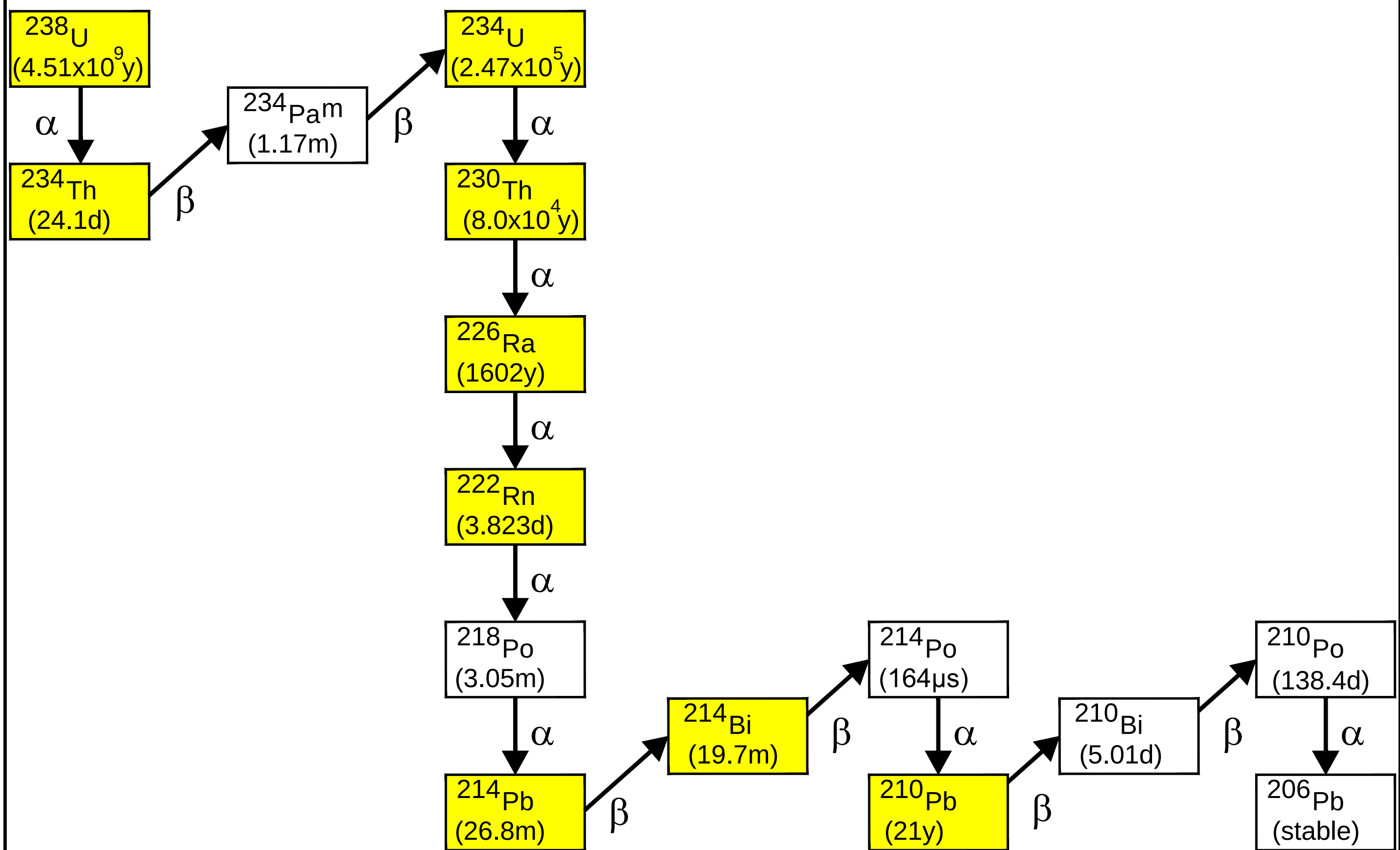


Figure 1

Facility Layout

West Lake Landfill

EMSI Engineering Management Support, Inc.



Legend

^{238}U ($4.51x10^9$ y) = Radionuclide / Half-Life

Note:
Analytical Results Obtained for Highlighted Radionuclides

Note:
Radionuclides produced in less than one percent of the transformations of the parent are not shown.

Figure 2

Uranium-238
Radioactive Decay Series

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\Fig2-Uranium-238.dwg

Legend

- From 1st Batch Vials
- From KMZ T
- From KMZ J

200 0 200
SCALE IN FEET

Image Courtesy of USGS © 2015 Micorsoft Corporation

Figure 3

Locations of Tree Core Samples

West Lake Landfill

EMSI Engineering Management Support, Inc.

Legend

BATCH 1	BATCH 7	BATCH 13	BATCH 19	A BATCH A
BATCH 2	BATCH 8	BATCH 14	BATCH 20	B BATCH B
BATCH 3	BATCH 9	BATCH 15	BATCH 21	C BATCH C
BATCH 4	BATCH 10	BATCH 16	BATCH 22	
BATCH 5	BATCH 11	BATCH 17	BATCH 23	
BATCH 6	BATCH 12	BATCH 18		

200 0 200
SCALE IN FEET

Image Courtesy of USGS © 2015 Micorsoft Corporation

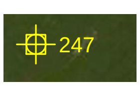
Figure 4

Location of Tree Core Samples Included in Each of Dr. Usman's Batches of Samples

West Lake Landfill

EMSI Engineering Management Support, Inc.

Legend



Tree Core Sample Vial Number

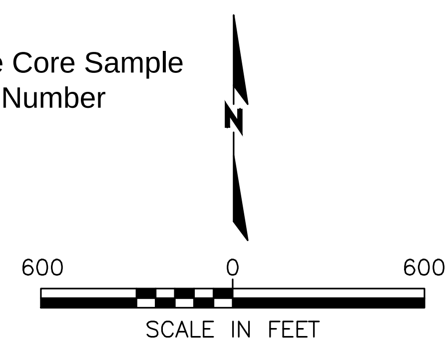


Figure 5

Location of Tree Core Sample Vials Included in Batch 1

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

226 Tree Core Sample Vial Number

400 0 400
SCALE IN FEET

Figure 6

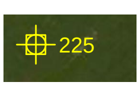
Location of Tree Core Sample Vials Included in Batch 2

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend



Tree Core Sample Vial Number

600 0 600

SCALE IN FEET

Figure 7

Location of Tree Core Sample Vials Included in Batch 3

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

Tree Core Sample Vial Number

400 0 400
SCALE IN FEET

Figure 8

Location of Tree Core Sample Vials
Included in Batch 4

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

Tree Core Sample Vial Number

500 0 500

SCALE IN FEET

Figure 9

Location of Tree Core Sample Vials Included in Batch 5

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

53 Tree Core Sample Vial Number

N

200 0 200

SCALE IN FEET

Figure 10

Location of Tree Core Sample Vials Included in Batch 6

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

35 Tree Core Sample Vial Number

200 0 200

SCALE IN FEET

Figure 11

Location of Tree Core Sample Vials Included in Batch 7

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

33 Tree Core Sample Vial Number

250 0 250
SCALE IN FEET

Figure 12

Location of Tree Core Sample Vials Included in Batch 8

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

23 Tree Core Sample Vial Number

N

400 0 400
SCALE IN FEET

Figure 13

Location of Tree Core Sample Vials Included in Batch 9

West Lake Landfill

EMSI Engineering Management Support, Inc.

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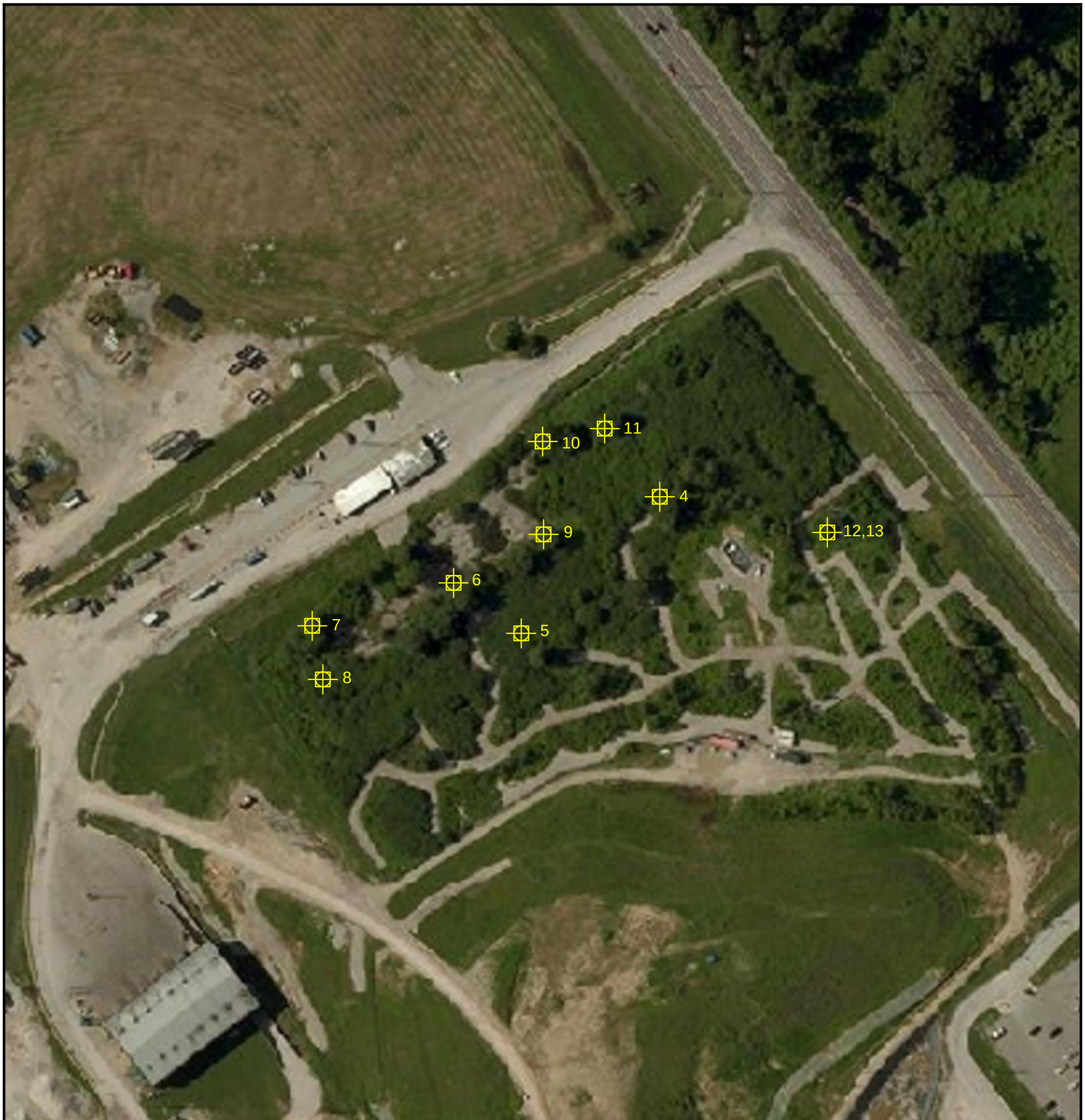

Legend

13 Tree Core Sample Vial Number

N

200 0 200
SCALE IN FEET

Figure 14

Location of Tree Core Sample Vials Included in Batch 10

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

143 Tree Core Sample Vial Number

N

200 0 200
SCALE IN FEET

Figure 15

Location of Tree Core Sample Vials
Included in Batch 11

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

Tree Core Sample Vial Number

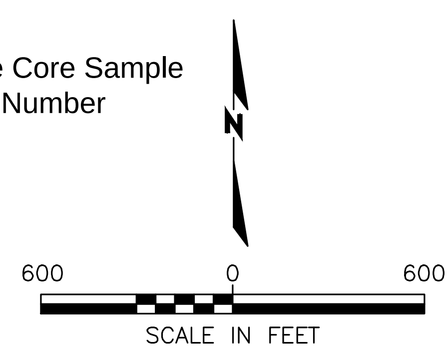

Figure 16

Location of Tree Core Sample Vials Included in Batch 12

West Lake Landfill

EMSI Engineering Management Support, Inc.

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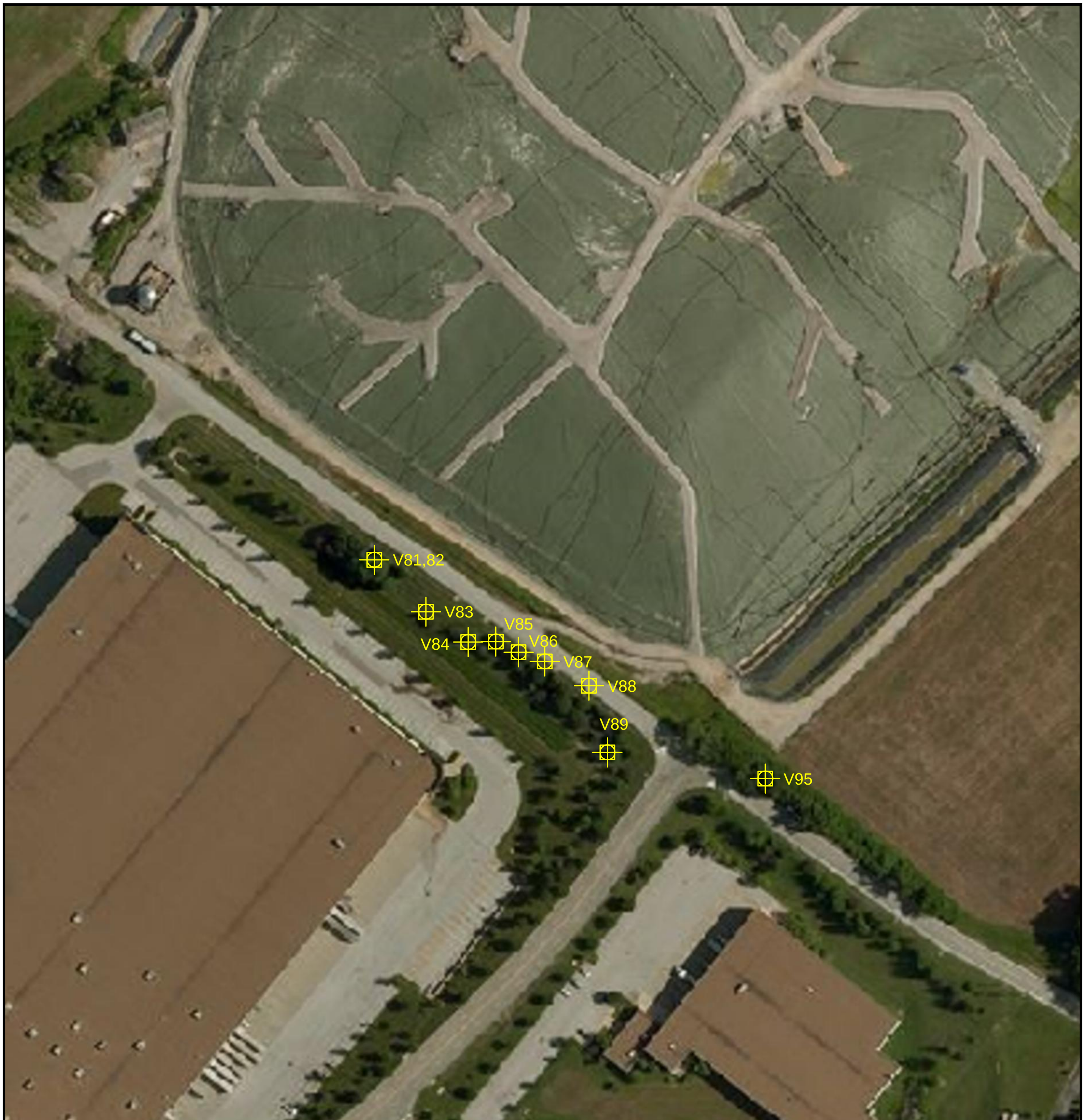

Legend

81 Tree Core Sample Vial Number

N

200 0 200
SCALE IN FEET

Figure 17

Location of Tree Core Sample Vials
Included in Batch 13

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

80 Tree Core Sample Vial Number

N

500 0 500

SCALE IN FEET

Figure 18

Location of Tree Core Sample Vials Included in Batch 14

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

193 Tree Core Sample Vial Number

800 0 800
SCALE IN FEET

Figure 19

Location of Tree Core Sample Vials Included in Batch 15

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

Tree Core Sample Vial Number

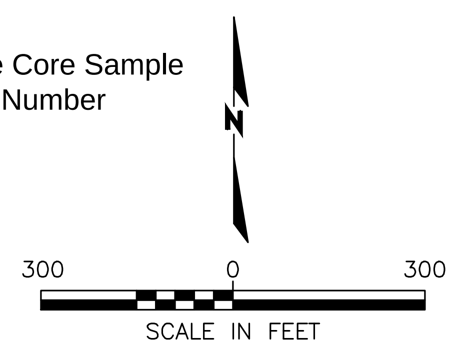

Figure 20

Location of Tree Core Sample Vials Included in Batch 16

West Lake Landfill

EMSI Engineering Management Support, Inc.

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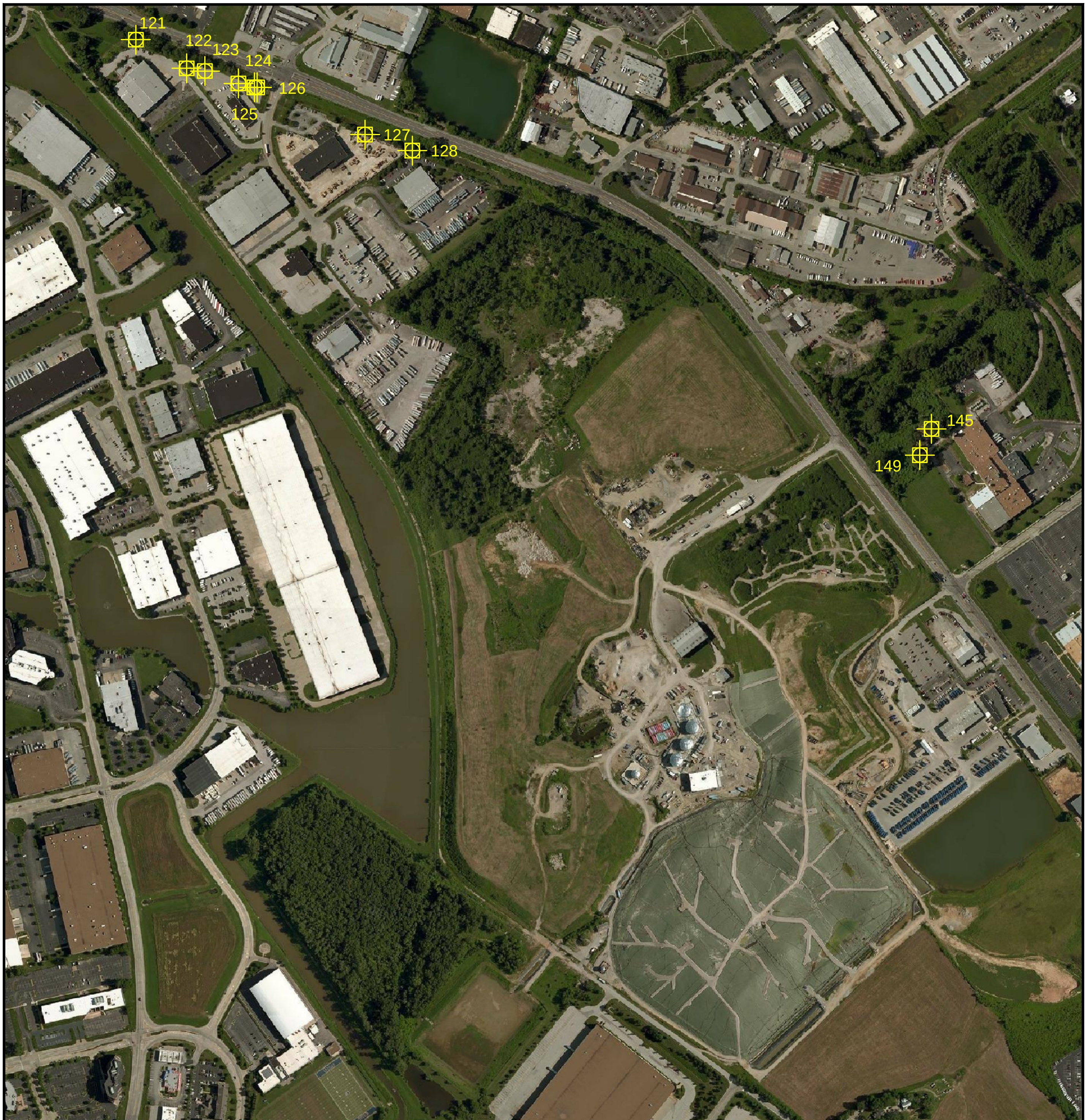


Legend

123 Tree Core Sample Vial Number

800 0 800

SCALE IN FEET

Figure 21

Location of Tree Core Sample Vials Included in Batch 17

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

183 Tree Core Sample Vial Number

400 0 400
SCALE IN FEET

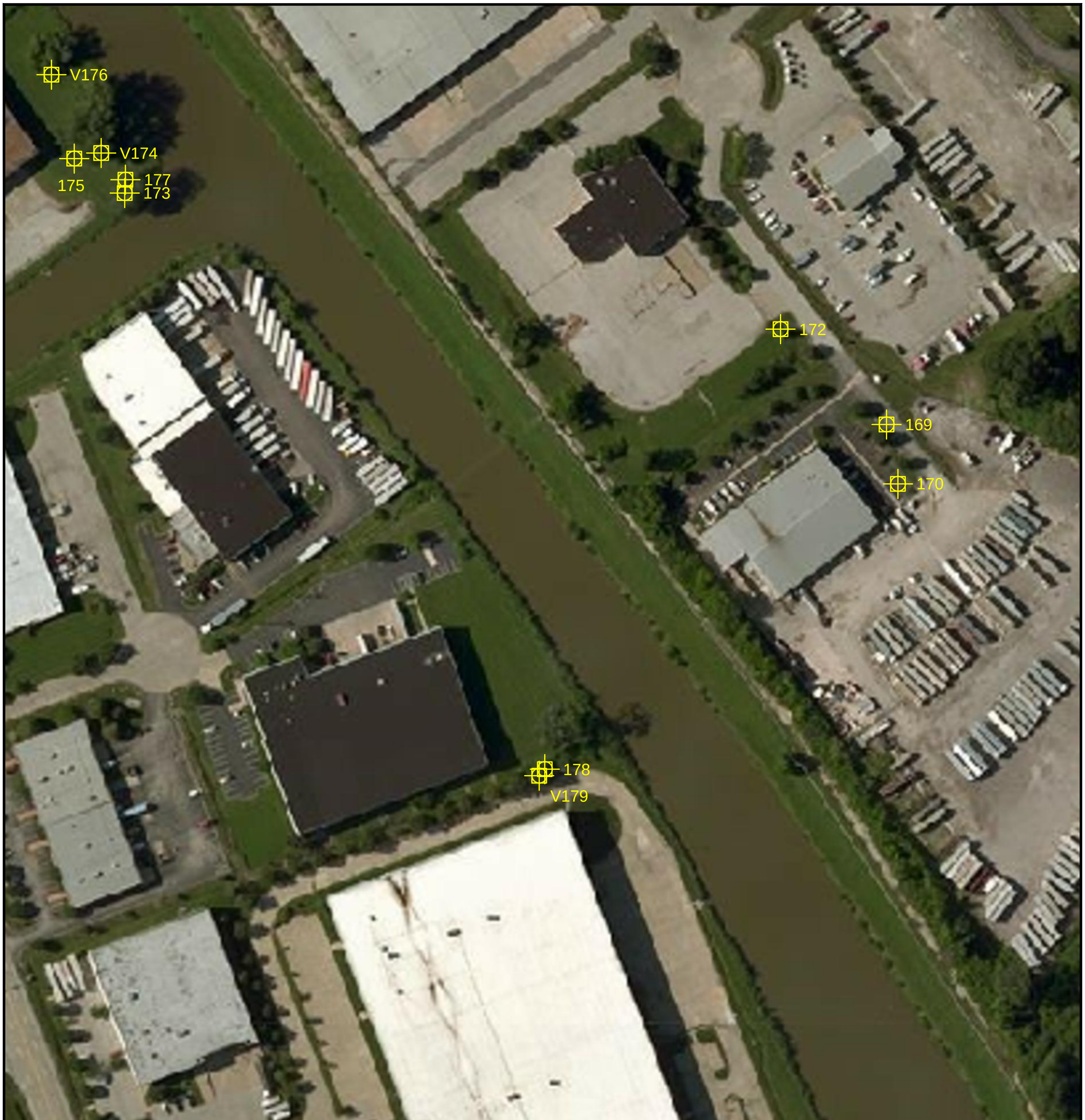
Figure 22

Location of Tree Core Sample Vials
Included in Batch 18

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015



Legend

173 Tree Core Sample Vial Number

200 0 200
SCALE IN FEET

Figure 23

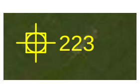
Location of Tree Core Sample Vials Included in Batch 19

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend



Tree Core Sample
Vial Number

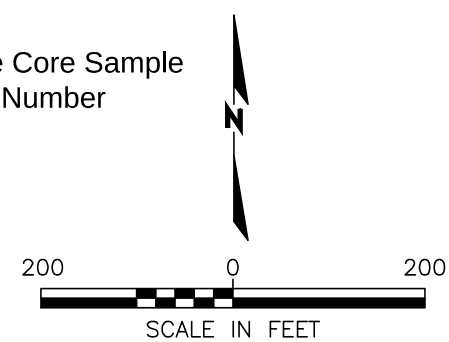


Figure 24

Location of Tree Core Sample Vials
Included in Batch 20

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

163 Tree Core Sample Vial Number

N

200 0 200
SCALE IN FEET

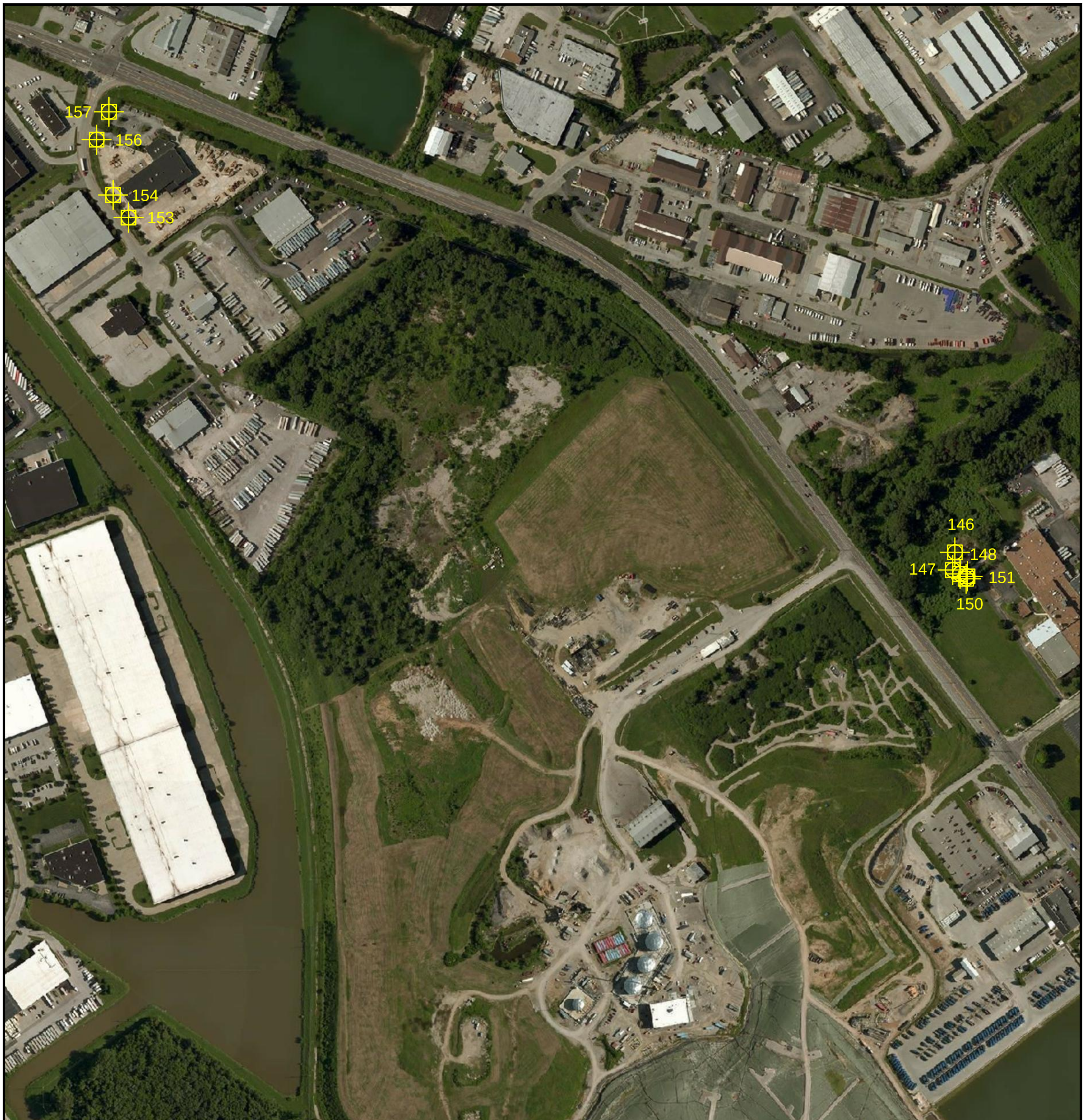
Figure 25

Location of Tree Core Sample Vials Included in Batch 21

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015



Legend

153 Tree Core Sample Vial Number

600 0 600
SCALE IN FEET

Figure 26

Location of Tree Core Sample Vials Included in Batch 22

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

Tree Core Sample Vial Number

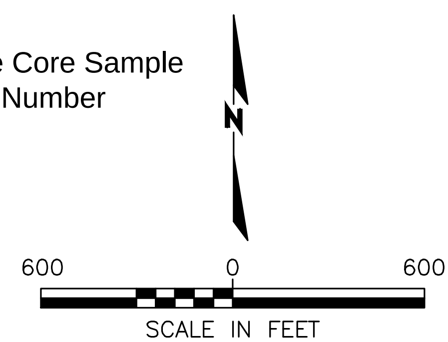


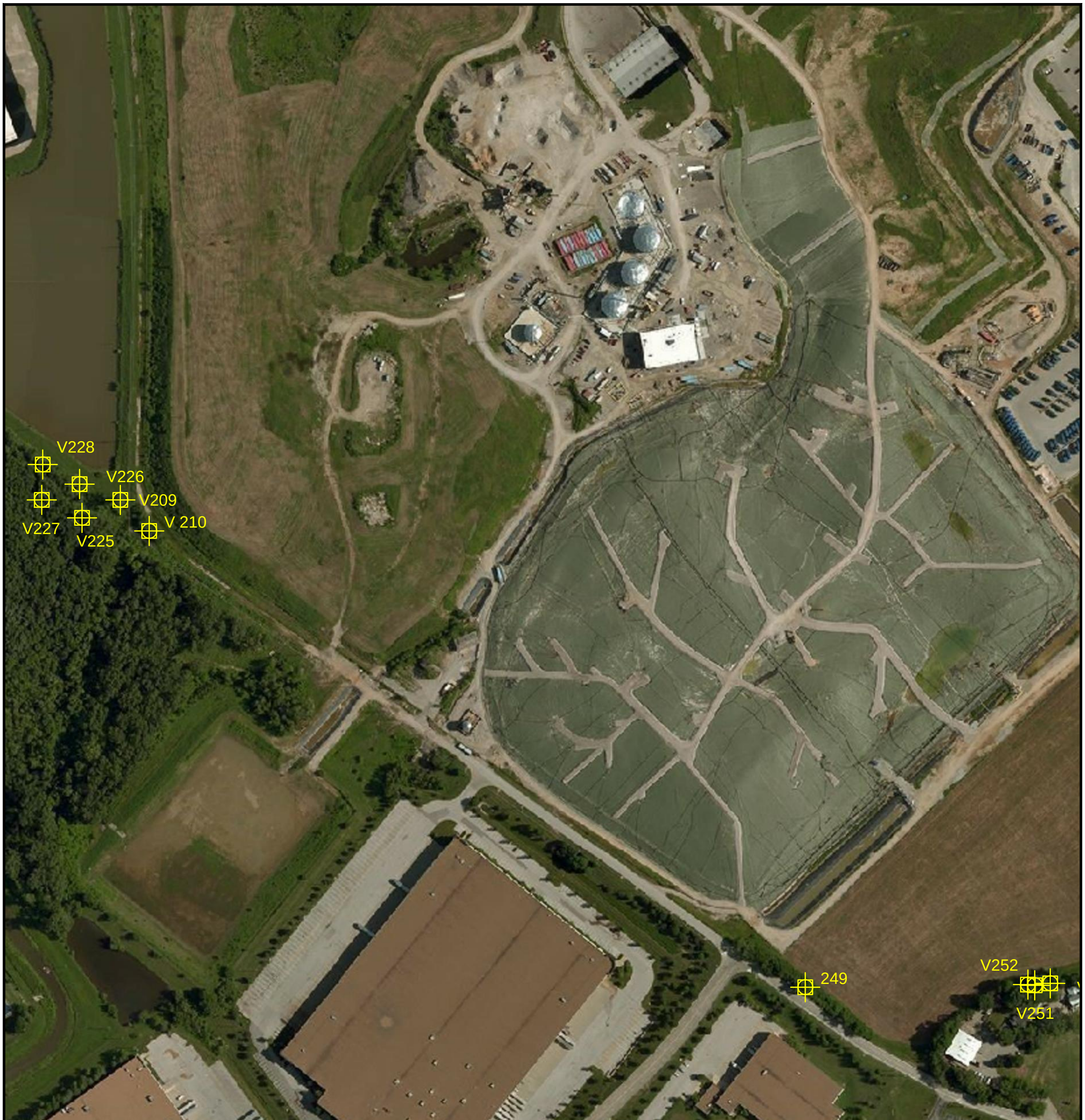
Figure 27

Location of Tree Core Sample Vials Included in Batch 23

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015



Legend

249 Tree Core Sample Vial Number

400 0 400
SCALE IN FEET

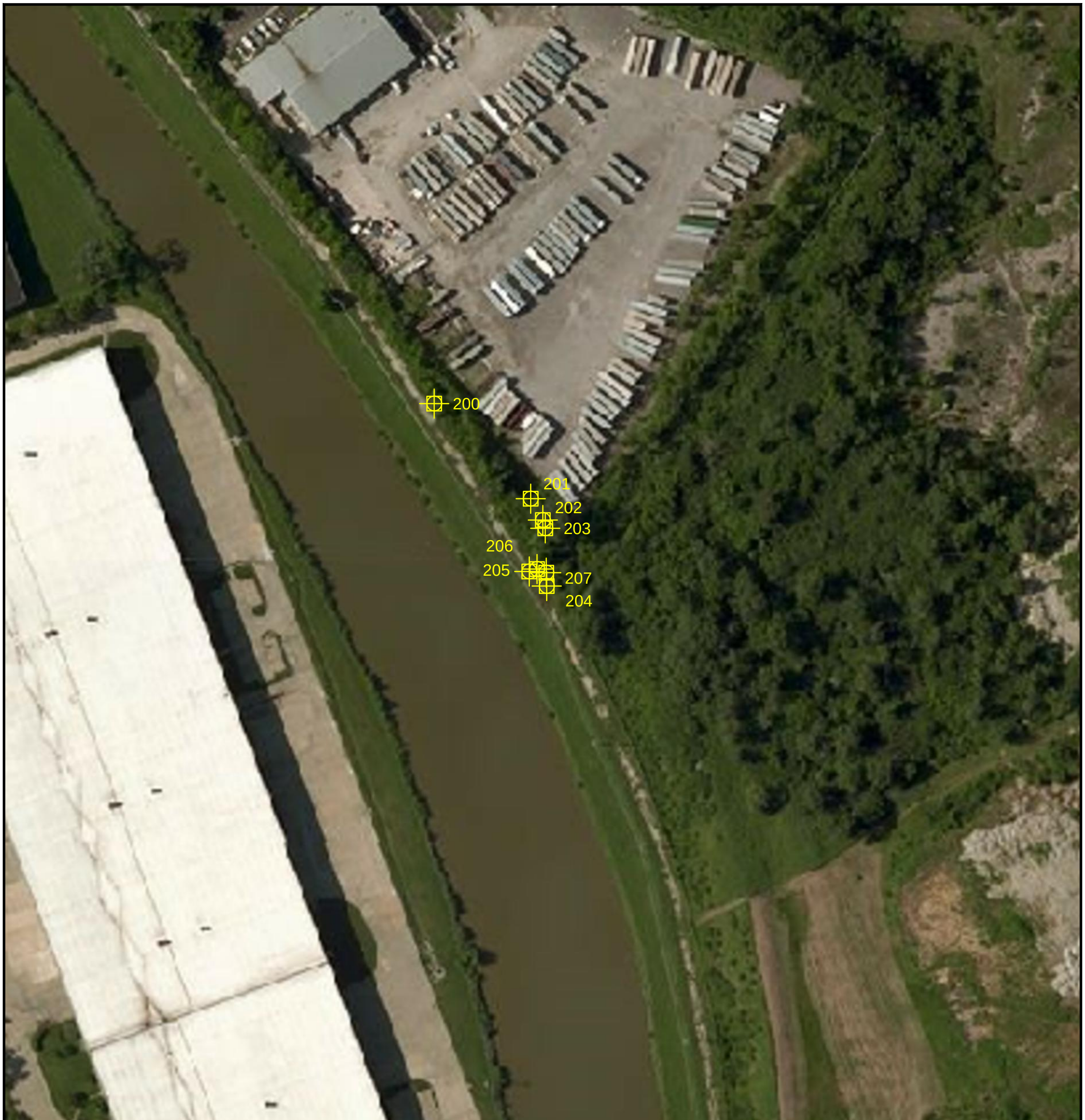
Figure 28

Location of Tree Core Sample Vials Included in Batch A

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015



Legend

203 Tree Core Sample Vial Number

400 0 400
SCALE IN FEET

Figure 29

Location of Tree Core Sample Vials
Included in Batch B

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Legend

232 Tree Core Sample Vial Number

N

200 0 200
SCALE IN FEET

Figure 30

Location of Tree Core Sample Vials Included in Batch C

West Lake Landfill

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2015\Tree-Coring\WL-Tree-Core-Samp-locs-Sept-batches-separate.dwg 4/14/2015

Figure 31

UM S&T Reported Tetrachloroethylene Results in Tree Core Samples

West Lake Landfill

EMSI Engineering Management Support, Inc.

Image Courtesy of USGS © 2015 Micorsoft Corporation

TRICHLOROETHYLENE CONCENTRATIONS

- ND
- <10 PPT
- 10-100 PPT
- 100 PPT to 1 PPB
- 1-10 PPB
- 10-100 PPB

200 0 200
SCALE IN FEET

Image Courtesy of USGS © 2015 Micorsoft Corporation

Figure 32

UM S&T Reported
Trichloroethylene Results in
Tree Core Samples
West Lake Landfill

EMSI Engineering Management Support, Inc.

cis-1,2-DCE CONCENTRATIONS

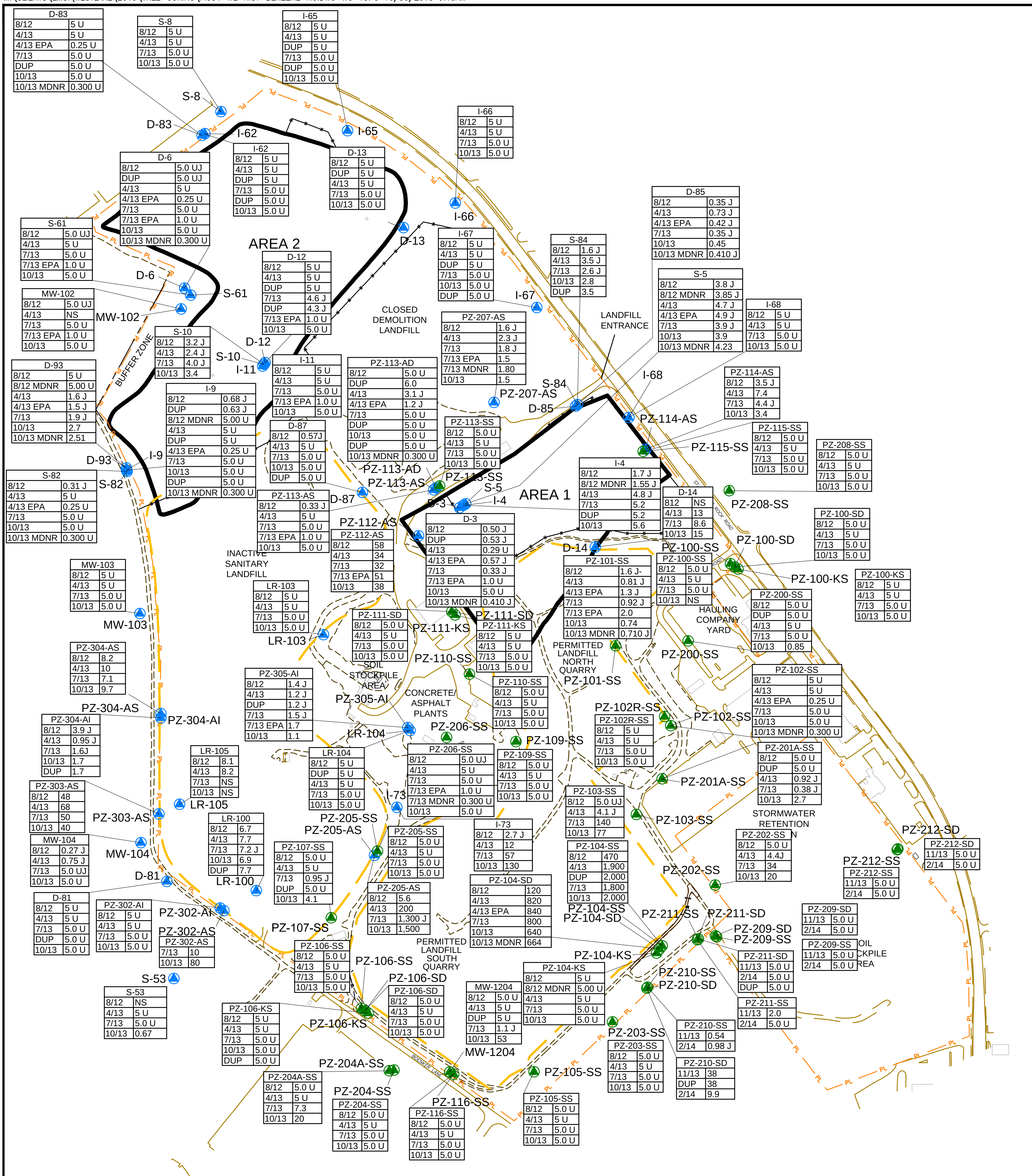
- ND
- <10 PPT
- 10-100 PPT
- 100 PPT to 1 PPB
- 1-10 PPB
- 10-100 PPB

200 0 200
SCALE IN FEET

Image Courtesy of USGS © 2015 Micorsoft Corporation

Figure 33
UM S&T Reported
cis-1,2-DCE Results in
Tree Core Samples
West Lake Landfill

EMSI Engineering Management Support, Inc.



LEGEND

- Alluvium Groundwater Well
- Bedrock Groundwater Well
- Operable Unit-1 Area as Defined By ROD
- Paved Road
- Unpaved Road

BENZENE EXPLANATION

1.10 Benzene (μg/L)

Data Validation Qualifiers:

U = Non-detect at the reported value
UJ = Non-Detect at the estimated reported value
UJ+ = Non-Detect at the estimated reported value which may be biased high
J = Estimated result
J+ = Estimated result which may be biased high

WELL FORMATION DESIGNATIONS

LR or MW: Undifferentiated
S or AS: Alluvial Shallow Well
I or AI: Alluvial Intermediate Well
D or AD: Alluvial Deep Well
SS: St. Louis Formation Well
SD: Salem Formation Well
KS: Keokuk Formation Well

NOTES:

1. Horizontal Coordinates Based on State Plane Missouri East Zone NAD 27
2. Elevations Based on U.S.G.S. Datum.
3. Existing Grade Contours are from the Aerial Survey Completed by the Sanborn Mapping Company on July 20, 2011.
4. Base Map Prepared by Aquaterra Environmental Solutions, Inc.

NORTH

0 250 500
SCALE IN FEET

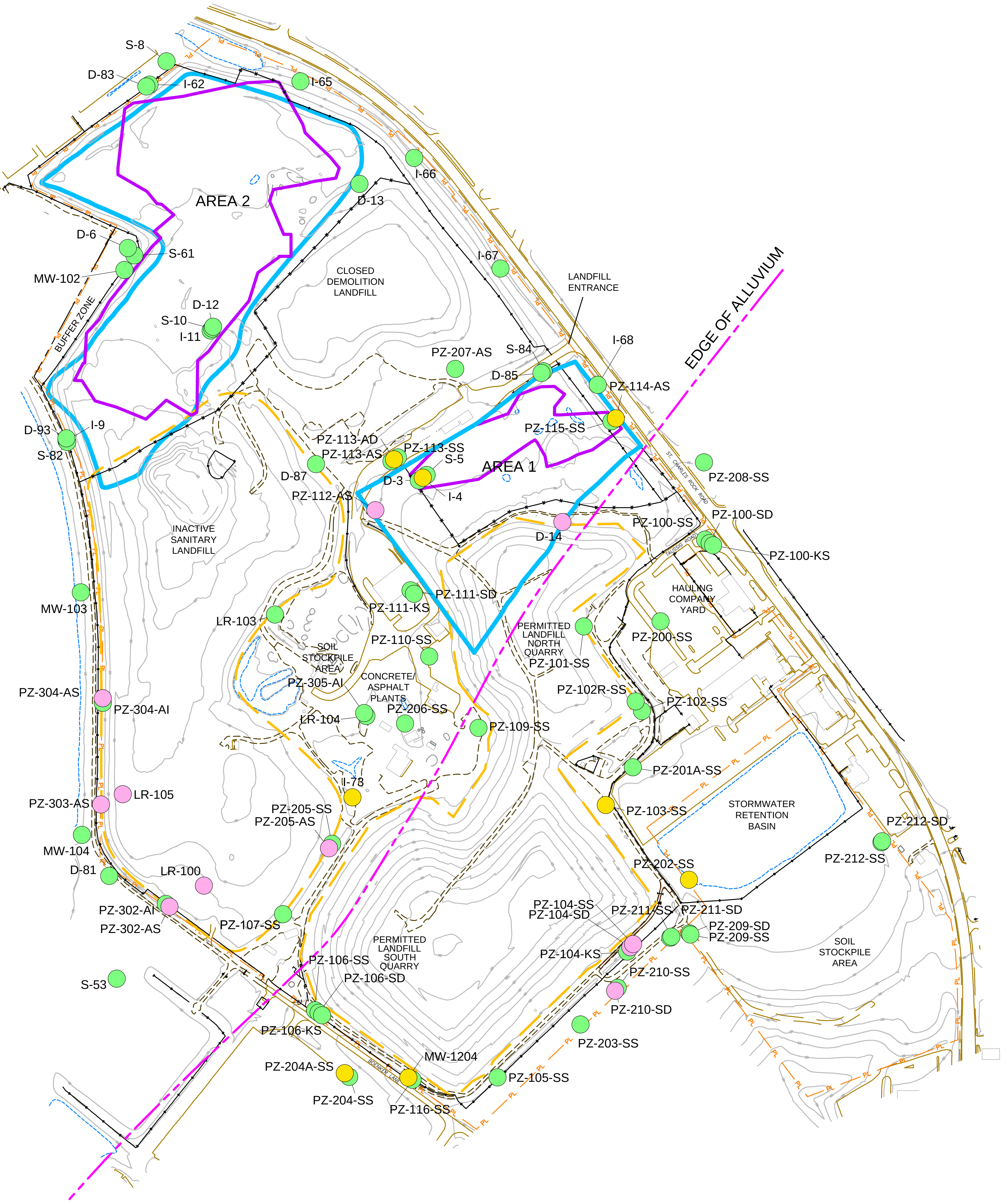
Figure 34

Benzene in Groundwater, August 2012 Through February 2014

West Lake Landfill

EMSI Engineering Management Support, Inc.

C:\USERS\FRED.CADD\APPDATA\LOCAL\TEMP\ACPUBLISH_9044\FIG35-WL-HIST-BENZENE_PYG.DWG-WO-TOPO 10/30/2015 9:17AM



LEGEND

- Operable Unit-1 Area as Defined By ROD
- Estimated Extent of Radiologically Impacted Material
- Paved Road
- Unpaved Road

BENZENE EXPLANATION

- Benzene greater than the Maximum Contaminant Level of 5 μg/L for Benzene (all sampling dates)
- Benzene greater than the Maximum Contaminant Level of 5 μg/L for Benzene (at least one sampling data but not all sampling dates)
- Benzene less than the Maximum Contaminant Level of 5 μg/L for Benzene (all sampling dates)

WELL FORMATION DESIGNATIONS

LR or MW: Undifferentiated
S or AS: Alluvial Shallow Well
I or AI: Alluvial Intermediate Well
D or AD: Alluvial Deep Well
SS: St. Louis Formation Well
SD: Salem Formation Well
KS: Keokuk Formation Well

NOTES:

1. Horizontal Coordinates Based on State Plane Missouri East Zone NAD 27
2. Elevations Based on U.S.G.S. Datum.
3. Existing Grade Contours are from the Aerial Survey Completed by the Sanborn Mapping Company on July 20, 2011.
4. Base Map Prepared by Aquaterra Environmental Solutions, Inc.

NORTH

0 250 500
SCALE IN FEET

Figure 35
Comparison of Benzene Levels in Groundwater, August 2012 Through November 2014 to the Benzene MCL
West Lake Landfill

EMSI Engineering Management Support, Inc.

BENZENE CONCENTRATIONS

- ND
- <10 PPT
- 10-100 PPT
- 100 PPT to 1 PPB
- 1-10 PPB
- 10-100 PPB

200 0 200
SCALE IN FEET

Image Courtesy of USGS © 2015 Micorsoft Corporation

Figure 36

UM S&T Reported
Benzene Results in
Tree Core Samples
West Lake Landfill

EMSI Engineering Management Support, Inc.

TOLUENE CONCENTRATIONS

- ○ ND
- <10 PPT
- 10-100 PPT
- 100 PPT to 1 PPB
- 1-10 PPB
- 10-100 PPB

200 0 200
SCALE IN FEET

Figure 37

UM S&T Reported
Toluene Results in
Tree Core Samples
West Lake Landfill

EMSI Engineering Management Support, Inc.

ETHYLBENZENE CONCENTRATIONS
- ND
- <10 PPT
- 10-100 PPT
- 100 PPT to 1 PPB
- 1-10 PPB
- 10-100 PPB

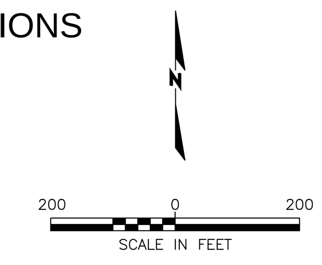


Image Courtesy of USGS © 2015 Micorsoft Corporation

Figure 38

UM S&T Reported Ethylbenzene Results in Tree Core Samples

West Lake Landfill

EMSI Engineering Management Support, Inc.

XYLENE CONCENTRATIONS
- ND
- <10 PPT
- 10-100 PPT
- 100 PPT to 1 PPB
- 1-10 PPB
- 10-100 PPB

200 0 200
SCALE IN FEET

Image Courtesy of USGS © 2015 Micorsoft Corporation

Figure 39

UM S&T Reported
Xylene Results in
Tree Core Samples
West Lake Landfill

EMSI Engineering Management Support, Inc.

ROSASCO_0000179