DESIGN INVESTIGATION WORK PLAN

WEST LAKE LANDFILL SUPERFUND SITE OPERABLE UNIT 1

Prepared For:

The United States Environmental Protection Agency Region VII

Prepared on Behalf of:

The West Lake Landfill OU-1 Respondents

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CERTIFICATION STATEMENT

DESIGN INVESTIGATION WORK PLAN
OPERABLE UNIT 1
WEST LAKE LANDFILL SUPERFUND SITE

I, Raymond D'Hollander, certify that I am currently a Missouri State-registered professional engineer and that this Design Investigation Work Plan was prepared under my direction and supervision in accordance with generally accepted practice. This document was prepared to fulfill the requirements of the Third Amendment to Administrative Settlement Agreement and Consent Order for the West Lake Landfill Superfund Site OU-1.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I have no personal knowledge that the information submitted is other than true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

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LIST OF ACRONYMS

ACRONYM	Definition
%	Percent
ABS	acrylonitrile butadiene styrene
AEC	U.S. Atomic Energy Commission
AOC	Administrative Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirements
ASAOC	Administrative Settlement Agreement and Order of Consent
ASTM	American Society for Testing and Materials
Auxier	Auxier & Associates, Inc.
B2005GS	below the 2005 ground surface
BGS	below ground surface
CDF	cumulative distribution function
cpm	counts per minute
DIO	design investigation objective
DIWP	Design Investigation Work Plan
DMP	Data Management Plan
DOE	U.S. Department of Energy
EMSI	Engineering Management Support, Inc.
FS	Feasibility Study
FFS	Final Feasibility Study
FSP	Field Sampling Plan
GSMO	geostatistical modeling objective
HI	hazard index
IC	institutional control
IVM	indicator variability metric
LBSR	leached barium sulfate residues
MDNR	Missouri Department of Natural Resources
MSW	municipal solid waste
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NCC	non-combustible cover
NEP	non-exceedance probability
NRC	Nuclear Regulatory Commission
NRCS	National Resources Conservation Service
OU	Operable Unit
pCi/g	picocurie/gram
PEP	Preliminary Excavation Plan
PSHEP	Project Safety, Health, and Environmental Plan
PSQ	principle study questions
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RA	remedial action
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
Respondents	OU 1 Respondents Bridgeton Landfill, LLC, Cotter Corporation (N.S.L), and the U.S. Department of Energy
RI	Remedial Investigation
RIA	Remedial Investigation Addendum
RIM	radiologically impacted material
ROD	Record of Decision
RODA	Record of Decision Amendment
SD	standard deviation
SDWS	Standard Deviation to Warrant Sampling
Site	West Lake Landfill Superfund Site
SOP	standard operating procedure
SOW	Statement of Work
SSHEP	Subcontractors Safety, Health, and Environmental Plan
SSP&A	S.S. Papadopulos & Associates, Inc.
STL	St. Louis International Airport
UMTRCA	Uranium Mill Tailings Radiation Control Act
USEPA	United States Environmental Protection Agency
UU/UE	unlimited use/unrestricted exposure

1.0 INTRODUCTION

This Design Investigation Work Plan (DIWP) has been prepared on behalf of West Lake Landfill Operable Unit (OU)-1 Respondents Bridgeton Landfill, LLC, Cotter Corporation (N.S.L), and the U.S. Department of Energy (DOE) (collectively, Respondents). This work plan presents the proposed scope of the investigation to assist in the design of the selected Amended Remedy for OU-1 of the West Lake Landfill Superfund Site (site) in Bridgeton, Missouri. The site is a United States Environmental Protection Agency (USEPA) Superfund Site (ID #MOD079900932). A Record of Decision Amendment (RODA) for OU-1 of the site was issued on 27 September 2018 (USEPA 2018). The Respondents entered into a Third Amendment to the Administrative Settlement Agreement and Order of Consent (ASAOC) with USEPA (Docket No. VII-93-F-0005) to perform the design of the Amended Remedy selected in the RODA for OU-1 on 6 May 2019 (USEPA 2019). USEPA is the lead agency for the site and the Missouri Department of Natural Resources (MDNR) is the supporting agency.

The site is located east of the Missouri River in the western portion of the St. Louis metropolitan area in northwestern St. Louis County, with a physical address of 13570 St. Charles Rock Road, Bridgeton, Missouri (**Figures 1 and 2**). The site consists of approximately 200 acres of land and includes six inactive waste disposal areas, or units, as indicated on **Figure 3**. The six units include Radiological Area 1, Radiological Area 2, a closed demolition landfill, an inactive sanitary landfill, the North Quarry, and the South Quarry. The North Quarry and the South Quarry are part of the permitted Bridgeton Landfill, a former sanitary landfill. These six identified units were used for solid and industrial waste disposal at the site from approximately the 1950s through 2004.

The site is composed of three OUs. OU-1 contains the radiologically contaminated areas and is comprised of Radiological Areas 1 and 2, the Buffer Zone (a 1.78-acre parcel of land adjacent to Area 2), and Lot 2A2 of the Crossroads Industrial Park. OU-2 contains areas not identified as containing radiological contamination and is comprised of the closed demolition landfill, the inactive sanitary landfill, the North Quarry, and the South Quarry. OU-3 covers the sitewide groundwater. This DIWP addresses OU-1 only.

The primary objective of this DIWP is to lay out the process for the remedial design investigation activities for OU-1 at the site in accordance with the RODA (USEPA 2018) and the Remedial Design (RD) Statement of Work (SOW) attached to the ASAOC (USEPA 2019). This DIWP has been developed consistent with applicable federal and state RD guidance documents for hazardous waste sites (USEPA 1995a, USEPA 1995b, USEPA 2005).

1.1 Site History

The site received radiologically contaminated materials from the processing of uranium ore for the Manhattan Engineering District and the U.S. Atomic Energy Commission (AEC), in addition to receiving municipal, demolition, and other waste. The U.S. Nuclear Regulatory Commission (NRC), as successor to the AEC, reported that parts of the site were radiologically contaminated when soil mixed with leached barium sulfate residues (LBSR) was brought to the landfill and reportedly used as cover for landfilling operations at the site in 1973. The NRC commissioned a radiological study that ultimately confirmed the presence of two distinct radiological areas at the site. The USEPA added the site to the National Priorities List in 1990.

On 3 March 1993, the USEPA and the Respondents (at that time Laidlaw Waste Systems [Bridgeton], Inc.; Rock Road Industries, Inc.; Cotter Corporation [N.S.L.]; and the DOE) entered into an Administrative Order on Consent (AOC) for performance of a Remedial Investigation/Feasibility Study (RI/FS) for OU-1. Between 1994 and 2006, the OU-1 Respondents performed multiple investigations at the site, including the collection and analysis of waste and soil samples and the monitoring of surface water, sediments, groundwater, and air quality. The results of these evaluations were summarized in the Remedial Investigation Report (Engineering Management Support, Inc. [EMSI] 2000), Baseline Risk Assessment (Auxier & Associates, Inc. [Auxier] 2000), and Feasibility Study Report (EMSI 2006) reports. Based on these reports, the USEPA issued a proposed plan for OU-1 (and OU-2) in June 2006 (USEPA 2006) and, in May 2008, selected a remedial action (RA) for OU-1 in a Record of Decision (ROD) (USEPA 2008).

In the 2008 ROD, the USEPA selected a capping remedy for OU-1. As a result of stakeholder and community concerns following the 2008 ROD, the USEPA determined that further evaluation of remedial alternatives was warranted. Other actions that have been taken at the site since 2008 include the following:

- Preparation of a Supplemental Feasibility Study (EMSI et al. 2011)
- Installation of a non-combustible cover (NCC) over portions of Area 1 and Area 2
- Development and implementation of an Incident Management Plan
- Installation of engineering controls and other active measures in the North Quarry of the Bridgeton Landfill (OU-2) in response to a subsurface reaction in the South Quarry portion of Bridgeton Landfill
- Air monitoring on and around the perimeter of the site
- An investigation of the extent of radiologically impacted material (RIM) in Area 1 (Feezor Engineering 2014 and EMSI et al. 2016)
- An Isolation Barrier Alternatives Analysis (EMSI et al. 2014)
- Additional characterization of Area 1 and Area 2
- Preparation of a Remedial Investigation Addendum (EMSI 2018a), an updated Baseline Risk Assessment (Auxier 2018), and a Final Feasibility Study (FFS) (EMSI 2018b) for OU-1

In September 2018, the USEPA amended the remedy for OU-1 in the RODA (USEPA 2018).

1.2 Remedy of Record – 2018 Selected Remedy

The Amended Remedy selected in the RODA (USEPA 2018) addresses the portions of the West Lake Landfill that are contaminated with radiologically impacted soils and landfilled waste, through a combination of excavation and placement of an engineered cover. The selected Amended Remedy is summarized below.

- The overburden, consisting of waste materials with a combined radium and/or combined thorium activity less than 52.9 picocuries/gram (pCi/g), in OU-1 Radiological Areas 1 and 2 is to be excavated and stockpiled to access the RIM containing combined radium and/or combined thorium activity greater than (>) 52.9 pCi/g.
- RIM from the Areas 1 and 2 of OU-1 that contains combined radium or combined thorium activities >52.9 pCi/g and is located generally within 12 feet of the 2005 topographic surface is to be excavated. Optimization of RIM removal above and below the 12-foot target depth (excavation as deep as 20 feet or as shallow as 8 feet) will be completed during the RD based on criteria set forth in Section 12.0 of the RODA (USEPA 2018).
- Radiologically impacted soil is to be excavated from the Buffer Zone and/or Lot 2A2 sufficient to reduce concentrations of radionuclides to background levels to allow for unlimited use and unrestricted exposure (UU/UE) of these areas. Any radiologically impacted soil is to be brought back to Areas 1 or 2 and incorporated into these areas as part of implementation of the remedy, unless it exceeds the 52.9 pCi/g criteria, in which case it is to be disposed of offsite.
- The excavated RIM and radiologically impacted soil containing combined radium or combined thorium >52.9 pCi/g is to be loaded and transported for disposal at an off-site permitted disposal facility. RIM greater than 7.9 pCi/g but less than 52.9 pCi/g may be used to backfill the excavation at depth.
- The remaining solid waste materials within Areas 1 and 2 will be regraded to meet the minimum and maximum slope criteria as described in the Draft 30 Percent (%) Design (Parsons et al. 2020a).

- A landfill cover is to be installed over Areas 1 and 2. The cover must be designed to meet the Resource Conservation and Recovery Act (RCRA) hazardous waste design criteria, municipal waste landfill regulations, and Uranium Mill Tailings Radiation Control Act (UMTRCA) performance and longevity standards.
- Surface water runoff controls are to be designed, installed, and maintained.
- Groundwater will be monitored.
- Landfill gas and radon will be monitored and controlled, in accordance with Applicable or Relevant and Appropriate Requirements (ARARs).
- Institutional controls (ICs) will be put in place to prevent land uses that are inconsistent with a closed landfill containing radiological materials.
- There will be long-term surveillance and maintenance of the landfill cover in Areas 1 and 2 and other remedial components.

1.3 Remediation Objectives

Remedial action objectives (RAOs) are specific goals selected for the Amended Remedy in the RODA (USEPA 2018) that must be accomplished to protect human health and the environment from risks posed by the site. The RAOs also serve as the design basis for the Amended Remedy selected for OU-1.

1.3.1 Updated RAOs for Areas 1 and 2 of OU-1

In the RODA, USEPA modified the RAOs for Areas 1 and 2 as follows:

- Prevent direct contact to contaminated media (including waste material, fill, stormwater, sediments, leachate, and groundwater) located on or emanating from OU-1.
- Limit inhalation and external radiation exposure from contaminated media (including waste material, fill, leachate, and gas emissions) located on or emanating from OU-1 to within the acceptable risk range (10^{-4} to 10^{-6} cancer risk or a hazard index [HI] of less than 1 for non-carcinogenic risk).
- Minimize water infiltration to prevent contaminants from leaching to groundwater above levels protective for the reasonably anticipated use of the groundwater and surface water.
- Control and manage leachate that emanates from OU-1 in accordance with standards identified in the ARARs.
- Control and treat landfill gas from OU-1, including radon, in accordance with standards identified in the ARARs.
- Control surface water runoff and minimize erosion associated with OU-1 in accordance with standards identified in the ARARs.

Based on USEPA's site-specific evaluation of risk, the Amended Remedy selected in the RODA (USEPA 2018) requires partial excavation of most RIM >52.9 pCi/g down to 12 feet below the 2005 ground surface (B2005GS). This partial excavation of most RIM, in combination with the installation of the engineered cover, will meet the above RAOs.

The proposed delineation of RIM >52.9 pCi/g is outlined in Section 3.2 of this work plan.

Components of the Amended Remedy pertaining to leachate and landfill gas management are discussed in the design documents, including the Draft 30% Design and the relevant appendices (Parsons et al. 2020a) and subsequent design documents. Leachate will be sampled and tested for analytical and hydrologic parameters during the design investigation to evaluate anticipated volumes and treatability as discussed in Section 3.3.3 and in the Draft Field Sampling Plan (Parsons et al. 2020b).

1.3.2 Updated RAOs for Buffer Zone and Lot 2A2 of OU-1

Presumed historical erosion of the landfill berm along the north side of Area 2 resulted in deposition of radiologically impacted soil on the surface of the Buffer Zone and Lot 2A2 of the Crossroads Industrial Park (also known as the former Ford Property). In the RODA, the updated RAO for this property is to remediate soils to the extent necessary to allow for unrestricted land use. The USEPA determined the radiologically impacted soils on Lot 2A2 and parts of the Buffer Zone should be remediated to background levels. Additional background characterization will be performed during the design investigation to select statistically valid background concentrations for the Buffer Zone and Lot 2A2. Additional delineation of impacted soils on Lot 2A2 and parts of the Buffer Zone and the proposed background concentration evaluation are described in Section 3.2.4.

1.4 Overview of DIWP

1.4.1 Objective

The primary objective of the design investigation is to collect information necessary for the design of the Amended Remedy in the RODA (USEPA 2018). Per the requirements listed in Section 3.6 of the SOW, this DIWP includes the following information to meet this objective:

- An evaluation and summary of existing data and description of additional data needs including:
  - Extent of RIM on the Buffer Zone and Lot 2A2 of the Crossroads Industrial Park.
  - Additional background characterization to select statistically valid background concentrations for the Buffer Zone and Lot 2A2.
  - Boundary confirmation of OU-1/OU-2.
  - The extent of historical impacts, if any, in drainage areas and northwest surface water body.
  - Additional characterization to support the proposed preliminary excavation, including the proposed optimized excavation locations, presented in the Preliminary Excavation Plan (PEP) described in Section 3.4 of the SOW.
- A Field Sampling Plan (FSP) (**Appendix A**) as described in Section 5.7(d) of the SOW and submitted in accordance with the schedule in Section 6.2 of the SOW, including media to be sampled, contaminants or parameters for which sampling will be conducted, sample locations (including boring locations and sample depths), and number of samples.
- Cross references to quality assurance/quality control (QA/QC) requirements set forth in the Quality Assurance Project Plan (QAPP) (**Appendix B**) as described in Section 5.7e of the SOW and submitted in accordance with the schedule in Section 6.2 of the SOW.
- A Data Management Plan (DMP) (**Appendix C**) as described in Section 5.7(g) of the SOW and in accordance with the schedule in Section 6.2 of the SOW.
- A Project Safety, Health, and Environmental Plan (PSHEP) (**Appendix D**) as described in Section 5.7(a) of the SOW and in accordance with the schedule in Section 6.2 of the SOW. Air monitoring, impact control, and mitigation procedures, including related contingencies, are discussed in the PSHEP. The PSHEP also contains the site-specific Radiation Safety Plan.

1.4.2 DIWP Organization

Following this introduction, the DIWP is organized as follows:

- Section 2: Evaluation and Summary of Existing Data – summarizes historical data sets and evaluates the usability of these sets. This section also discusses the geostatistical model and activity calculations.

- Section 3: Design Investigation Rationale and Strategy – describes various investigational phases for the project, each designed to supplement existing data or provide new information. Additional data will be obtained during a proposed RIM Investigation, Geotechnical Investigation, Groundwater Investigation, Utility Investigation, and site Survey.
- Section 4: Supporting Plans – lists the FSP, QAPP, PSHEP, and DMP developed for the investigational phases of the project.
- Section 5: References – provides references for documents cited in this DIWP.

2.0 EVALUATION AND SUMMARY OF EXISTING DATA

2.1 Geostatistical Model Background

The results of the previous investigations completed in OU-1, which are shown in Table 1, and the geostatistical model previously developed to support the FFS (EMSI 2018b), were evaluated to identify any data gaps that could affect the RD or remedy implementation. Evaluations performed for the DIWP also identified areas of the geostatistical model that would benefit from additional analyses. An initial summary of the model was provided in the PEP. Subsequent to the PEP, the USEPA and MDNR requested that Respondents further evaluate the model basis, fundamentals, potential improvements, and data needs. This review and elaboration of the model limitations since the PEP are provided in Appendix E, with an overview provided here. The additional data needed to improve the model, as well as agency comments, are the basis for the geostatistical modeling objectives (GSMOs), which are presented and discussed in Section 3.1.

The geostatistical component of the West Lake project involves the development of a three-dimensional distribution of non-exceedance probabilities and activities throughout Area 1 and Area 2 based on various geostatistical analyses. The purpose of these geostatistical analyses and the geostatistical model is to provide a basis for design of the optimized remedial excavation, including calculation of activities of RIM >52.9 pCi/g from 0-16 feet and from 0-12 feet B2005GS in accordance with the RODA. The optimized excavation requires the estimation of RIM activity at specific depth intervals (0-12, 12-16, and 16-20 feet B2005GS) as described in the RODA.

This DIWP identifies data needs that will support modeling improvements (provided in Appendix E) with the goal of converging on a representation that meets the expected precision for decision-making during RD. The current model is tested and improved throughout this process with the objective of recognizing and minimizing uncertainty/limitations and addressing stakeholder concerns. These improvements include an in-depth review of the data pre-processing steps and the interpolation algorithms. Additional data collection for geostatistical model improvement is described in Section 3.0.

Appendix E provides an in-depth review of the current model status and expected updates once new data are collected. Furthermore, there are additional details on the logic and progression of model development that has occurred since submittal of the PEP, and which address USEPA and MDNR comments. The components of the geostatistical process in Appendix E are:

- Expanded details on model development and model improvements since submittal of the PEP, such as sensitivity testing, variogram adjustments and other components
- Opportunities for improvement of the FS model developed by S.S. Papadopulos & Associates, Inc. (SSP&A 2017), which was the basis for the PEP modeling
- Analysis of historical boring locations (Figure 4) and kriging standard deviation (SD) as related to RIM extent to support the location of additional borings
- Improvements of the optimization process as related to total activity calculations
- Identified model-specific design investigation model-specific data collection needs

Additional sensitivity testing and general model refinement will be included in the Revised Excavation Plan and 90% Design documents, and will incorporate data collected during the design investigation.

Appendix E includes a discussion of specific geostatistical requests from the USEPA in its comment letter dated February 13, 2020, as well as discussion points conveyed during meetings with USEPA and MDNR on February 19 and 20, 2020. **Appendix E** was developed to align with the DIWP GSMOs, which were developed based on limitations of the geostatistical model and comments from USEPA and MDNR. Details are organized to address the USEPA and MDNR comment related to limitations and justification of the geostatistical modeling and include:

1. Geostatistical Pre-Processing and Regression Analyses
2. Indicator Kriging – RIM Boundary Model Enhancements
3. Ordinary Kriging – Activity Model Enhancements
4. General RIM Uncertainty
5. Excavation Optimization
6. Spatial and Depth Limitations of Current Data

2.2 Elevation Standardization for Design Investigation Data Collection

2.2.1 Elevation Data In the Geostatistical Model

The existing geostatistical model has been developed using the 2005 ground surface to align with the depth datum. In other words, currently all depth measurements of RIM (i.e., 12 feet below ground surface) are referenced from the 2005 ground surface. There have been changes to the ground surface since the time that past samples were collected, which creates uncertainty in the accuracy of the previously measured sample depths. In addition, no ground surface survey was performed on OU-1 in the 2005 timeframe. The absence of a ground survey further adds uncertainty to the accuracy of the currently assigned hard and soft sample depths in the existing geostatistical model. This DIWP describes procedures that reduce this uncertainty (to the extent practical) through standardizing the depth (and elevations) of all hard and soft data (both existing and new). In order to understand how the standardization will be conducted, it is important to detail what changes have occurred.

- Since 2005 an NCC consisting of clean gravel and inert debris was placed over portions of Areas 1 and 2 where surface RIM was present, as shown in Figures 6-12 and 6-13 of the Remedial Investigation Addendum (RIA) (EMSI 2018a). NCC material and geotextile fabric were applied to a minimum depth of 8 inches, as described in the RIA.
- Placement of inert fill material occurred from 2006 – 2008 (see additional discussion in **Section 2.2.2.3**).
- Because Areas 1 and 2 are landfills, subsidence may have occurred due to differential settlement as part of the natural breakdown of wastes and/or resulting from the placement of either the inert fill or the NCC described in the bullets above. However, due to the age of the waste in Areas 1 and 2 at the time of the installation of the borings, natural subsidence since the borings were installed is not expected to be significant.

The addition of fill material, combined with differential settlement, introduces a level of uncertainty to historical sample depths and elevations. The spatial accuracy of estimated elevations associated with collected laboratory analytical data and field measurements of radiological parameters will be improved during the design investigation through a sitewide topographic survey.

Due to the reasons provided above, the 2005 surface is subject to unknowns that may be difficult to estimate. Therefore, while the 2005 surface is outlined in the RODA, it is expected that once new data (including surveys) are collected, the elevations will be reevaluated and retranslated without consideration of the previous 2005 vertical translations.

Another potential source of variability that was considered when reviewing historical data sets is the uncertainty associated with areas exhibiting poor soil core recovery. Soil recovery from municipal solid waste (MSW) landfill materials can range from complete (100%) to almost nothing (0%) depending upon the nature of the materials encountered (e.g., tires, wood, concrete, loose soil), potentially preventing representative collection of all the subsurface materials. Coring at the site was previously performed with runs of varying lengths and were often 10 feet or greater. Waste materials preventing representative recovery of soils were sometimes encountered in certain borings that could affect the entire run. As a result, elevation uncertainty was introduced through the entire run for the core collected from these borings. Short core runs, as discussed below, are proposed to constrain the effects of poor core recovery to a smaller depth interval. During data evaluations, the uncertainty related to the core recovery will be assessed in order to evaluate how the depths, and associated activities will be integrated into the gamma/activity regressions, the indicator model, and activity model/calculations. Such analyses may include concepts such as vertical alignment of core data with downhole gamma (as appropriate), development of alternative regressions, and/or other processes for both new borings, as well as previous borings (to the extent practical).

Uncertainty is inherent when interpreting borehole sample depths versus lengths of recovered core. Translation errors can occur due to core expansion or sample loss during extraction. Variability associated with uncertainty in observed depths versus actual depths below ground surface manifests in areas where laboratory and field data collected from soil cores are directly compared to *in situ* measurements such as downhole gamma logging. Sample collection methods proposed during the design investigation aim to decrease variability related to depth-based uncertainty.

The following multipronged approach will be undertaken to improve the elevation data for use in the geostatistical model.

- A sitewide ground surface survey will be performed in Areas 1 and 2 prior to data collection associated with the design investigation to document the current (2020) ground surface topography. Vegetation will be cleared in select regions of Areas 1 and 2 to improve the accuracy of the survey, and new survey benchmarks/monuments will be installed. The 2020 ground surface topographic survey will be developed in the North American Datum of 1983 (NAD83) coordinates as required by 5.4(b) of the SOW with elevations referenced to the North American Vertical Datum of 1988 (NAVD88). Following the survey, historical site data will be converted to these geodetic standards.
- The historical laboratory and field data from the historical local coordinate system will be updated to NAD83 and NAVD88 based on the new survey and observations of waste surfaces that will be made during the design investigation. This will also allow for the correction of elevations associated with historical data to account for differential settlement between historic sample collection and present-day surface elevation. Differential settlement is discussed further in Section 2.2.4.
- Core sample recoveries will be maximized by using sonic drilling methods and performing short core runs within the waste extent. Sonic drilling methods are more effective than conventional drilling methods, such as hollow-stem auger and split-spoon sampling, for recovering representative soil samples within waste material. The use of 4-foot core runs will limit expansion or loss during extraction, reducing the possibility for translation error between interpreted core depths as compared to typical 10-foot core runs. Short core runs will also provide a more accurate elevation relationship between downhole and core scan data since poor soil recovery (and the resulting elevation uncertainty) will be minimized within each core run, instead of being accumulated throughout the total depth of the soil

boring. Additionally, the field program has been designed in an attempt to match core run intervals with the RIM excavation decision zones specified in the RODA. Specifically, the RIM excavation decision zones are defined in multiples of 4-foot depths (e.g., 0-8 feet, 8-12 feet, 12-16 feet, and 16-20 feet B2005GS).

- Correlations will be developed on a boring-by-boring basis comparing downhole responses to laboratory and core scan responses to improve the elevation resolution between data collection tools.

Following the design investigation, the geostatistical model will be updated to include the 2020 surveyed ground surface elevation, as well as corrected historical laboratory and field data. The updated survey will be used to estimate localized settlement rates across the site and can be used to correct the elevations of laboratory analytical samples that may since have undergone settlement. As discussed in Appendix E, the 2005 ground surface is used in the model as a datum for RODA depth discretization (i.e., 0-8 feet, 8-12 feet, 12-16 feet, and 16-20 feet B2005GS) as well as an upper surface for model limits.

Based on observations of the model as compared with sample data, in some cases there is a potential for the 2005 model surface to be falsely located below the current ground surface, potentially resulting in failure to identify RIM >52.9 pCi/g due to 3D truncation at the 2005 ground surface. Future modeling will establish an upper bounding limit based on details provided in the following section. Details of the sitewide topographic survey are discussed in Section 3.6.

2.2.2 Defining the 2005 Ground Surface For Use in the Design Investigation

Since the 2005 surface elevation was used to define zones of interest in the RODA, it is proposed that the 2005 ground surface and the specific depth intervals of interest (0-8, 8-12, 12–16, and 16–20 feet B2005GS) be incorporated into the development and implementation of the design investigation. Further evaluation of the modeling methodology will occur during and after the completion of the design investigation, including the selection of datum and model limits. The approach for defining the 2005 ground surface for use during the design investigation is outlined in the sections below.

2.2.2.1 Areas of NCC Placement

Elevation data were collected during the construction of the NCC, measured from the geotextile fabric, and then again following placement of fill material, effectively providing a thickness of the NCC. These areas will also be resurveyed during the 2020 sitewide topographic survey. The pre-NCC placement elevation (top of geotextile fabric) will be considered the same as the 2005 ground surface, and the difference in elevation between 2020 surface elevation and the pre-NCC placement elevation will be used to determine the depth at which the 2005 ground surface is expected during boring installation and at which point the 4-foot core runs will begin.

In addition to the approach above, a field geologist/engineer will inspect recovered soils for a change in soil-type and presence of the geotextile fabric demarcation layer, which will indicate penetration of the NCC and the top of the 2005 ground surface.

2.2.2.2 Undisturbed Vegetated Areas

Vegetated areas that have been undisturbed since 2005 will require clearing for the implementation of the sitewide topographic survey and installation of the soil borings proposed in Section 3.2. The ground surface below the vegetation will be considered equivalent to the 2005 surface elevation.

Vegetation will be cut down to an appropriate height to allow for traversal during the 2020 sitewide topographic survey, while still allowing the root system to be protective of erosion. Gravel drilling pads and access paths will be installed prior to boring installation as necessary. The surface elevation of these drilling pads will be surveyed in order to ascertain the starting depth for 4-foot core runs during drilling operations.

2.2.2.3 Inert Fill Areas

Areas where inert fill material has historically been placed have been identified through analysis of historical aerial photographs and are shown on Figure 5B. The 2005 ground surface elevation in these areas was determined through aerial photogrammetry, and these areas are largely free of vegetation. Elevations of inert fill areas will be measured during the 2020 sitewide topographic survey and then compared to elevations measured via photogrammetric analysis to calculate a correction factor for use during drilling. Since these areas of inert fill constitute a relatively small percentage of the total area being investigated, it is anticipated that the lower resolution of this comparison (when compared to direct elevation difference measured in the NCC and undisturbed vegetation areas) will be adequate for satisfying the design investigation objectives described in Section 3.1.

2.2.2.4 Evaluating Differential Settlement

As discussed in Section 2.2.1, differential settlement has been identified as a component contributing to inherent uncertainty associated with the use of historical data to predict three-dimensional occurrences of RIM. During the design investigation, the following actions will be taken to evaluate the extent to which differential settlement has occurred since the prior RIA data were collected:

1. Identify historical NRC polyvinyl chloride (PVC) borings with intact casings. It is assumed that most historical PVC locations remain intact; however, the current status will be evaluated in the field.
2. Perform a downhole gamma survey in the identified NRC PVC borings consistent with both the methods proposed in this DIWP and those used during the previous gamma survey.
3. Compare radiological responses at depth and potential displacement of gamma "peaks" to evaluate total settlement through the total depth of the NRC PVC borehole, as well as potentially identify specific depth intervals where settlement may have been more prevalent.
4. Re-collect surface elevation at the re-logged NRC PVC borings for comparison to elevation data currently used in the geostatistical model and the elevation data collected at the time of sample collection.
5. Re-collect top-of-NCC elevation data from a subset of as-built NCC thickness confirmation shots. The NCC as-built survey includes both top-of-NCC and top-of-geotextile elevation data that was historically used to calculate cover thickness. These data will be used to identify the location of the 2005GS (base of NCC), as well as evaluate potential settlement (difference between as-built surface elevation and 2020 surface elevation).

The historical dataset (SSP&A) was queried to identify NRC PVC borings with a gamma response. The following locations in Area 1 will be assessed in the field to determine viability of downhole gamma data re-collection:

- PVC-24
- PVC-26
- PVC-28
- PVC-36
- PVC-37
- PVC-38
- PVC-41

The following locations in Area 2 will be assessed in the field to determine viability of downhole gamma data re-collection:

- PVC-04
- PVC-05
- PVC-06
- PVC-07
- PVC-08
- PVC-09
- PVC-10
- PVC-11A
- PVC-11B
- PVC-12
- PVC-13
- PVC-18
- PVC-19
- PVC-20
- PVC-33
- PVC-34
- PVC-35
- PVC-39
- PVC-40

The final locations for downhole gamma and surface elevation data re-collection will depend on the results of the field assessment. Boreholes with compromised casings will not be included in the data re-collection process.

3.0 DESIGN INVESTIGATION RATIONALE AND STRATEGY

The objective of this DIWP is to collect data needed to support design and implementation of the selected remedy as defined in the RODA. The RODA states that the excavation plan will identify the locations where RIM >52.9 pCi/g is to be removed from Area 1 and Area 2 down to 12 feet. It will also identify: a) deeper areas where RIM may be removed to achieve the long-term effectiveness and permanence objectives; and b) isolated pockets of RIM >52.9 pCi/g to remain between 8 and 12 feet in certain instances to achieve the same or better short-term effectiveness. The USEPA expects the areas between 12 and 16 feet will be excavated if they are greater than 1,000 pCi/g. Additionally, the USEPA expects to focus the excavation in the areas between 16 to 20 feet on the higher activity occurrences of RIM (greater than 1,000 pCi/g) if it does not add significant excavation of non-RIM waste.

These specific data needs identified in the RODA were used to develop the design investigation objectives below.

3.1 Design Investigation Objectives

Per Section 3.6 of the SOW, the following design investigation objectives (DIOs) were developed to support the design and implementation of the selected remedy:

1. The extent of waste and RIM associated with OU-1 Areas 1 and 2 will be sufficiently delineated to confirm the OU-1/OU-2 boundaries. This DIO will be addressed through installation of perimeter borings based on the conceptual site model. A combination of field and analytical methods will be required to achieve this objective (**Section 3.2.1**).
2. Locations with RIM >52.9 pCi/g will be further characterized to design an optimized excavation that meets the RODA requirements (**Section 3.2.2**). This will be achieved through the installation of proposed borings (**Figure 5A**) and the collection of both field and laboratory analytical data at boring locations. Further details on how this DIO is being addressed are provided in the geostatistical modeling objectives listed below.
3. Further characterize RIM between 7.9 pCi/g and 52.9 pCi/g to identify the extent of RIM greater than 7.9 pCi/g for the purposes of confirming the OU-1 boundary and designing and specifying the extent of the UMTRCA cap (**Section 3.2.3**).
4. Compare analytical results for soil samples from four off-site reference units to support calculation of a statistically valid background concentration for the Buffer Zone and Lot 2A2 (**Section 3.2.4.2**).
5. Determine whether or not the concentrations of radionuclides in the Buffer Zone and Lot 2A2 decision units are statistically greater than background (**Section 3.2.4.1**).
6. Estimate radionuclide concentrations in drainage areas, including the Northern Surface Water Body and Earth City Flood Control Channel via sediment sampling and bathymetric survey (**Section 3.2.5**).
7. Collect geotechnical data needed to further design objectives, such as waste density, moisture content, and soil properties in areas projected to be beneath starter berms and future drainage structures (**Section 3.3.1**).
8. Collect data to assess site infrastructure requiring removal during the RA. This DIO will be addressed by performing utility locating and mark out, as well as ground penetrating radar (GPR) survey (**Section 3.5**).
9. Collect data to characterize materials related to waste acceptance criteria of potential waste disposal facilities (**Section 3.3.2**).

10. Evaluate liquid levels within the potential excavation footprint and previously identified seeps through the installation of soil borings and standpipe wells (Section 3.3.3).
11. Estimate baseline concentrations of constituents that are important to leachate treatment system design (Section 3.3.3 and QAPP).
12. Assess the impact of the RA on wildlife attractiveness (Section 3.7).
13. Perform a detailed topographic survey of Areas 1 and 2 (Section 3.6).

Table 2-1 lists the DIOs and identifies the key components of each objective, as well as the proposed solution for addressing the specific objectives.

This DIWP also includes data collection for improvement of the geostatistical model. DIO #2 outlines the goal of further characterizing RIM >52.9 pCi/g to design an optimized excavation that meets the RODA requirements. A key component of this DIO is improvement of the geostatistical model, which is used to estimate thorium and radium activities within Area 1 and Area 2. GSMOs were developed specifically to address the data collection needs of DIO #2, which are associated with improving the model and are discussed below. GSMOs are listed in Table 2-2.

Principle study questions (PSQs) and data quality objectives associated with the geostatistical model are discussed in the QAPP.

3.1.1 GSMO #1 – Increase Data Density Between Radium, Thorium, and Gamma

Data needs for the geostatistical model are based largely on radium and thorium, as the geostatistical model uses these constituents directly, either as measured in laboratory samples or as estimated from gamma radiation measurements. There is uncertainty regarding the relationship between combined thorium and gamma due to anthropogenic processing of the RIM, which disrupts the secular equilibrium between thorium-230 and radium-226. The isotopes are expected to have some correlation with the gamma signature by way of the thorium association with radium, a known gamma emitter (Figure E-12). A limitation of using gamma responses for lower range thorium activity concentrations is discussed in Appendix E (Section 4.3), where correlation between gamma response and thorium concentrations are weak at or below 52.9 pCi/g, but become more reliable above 52.9 pCi/g (when correlated with radium results).

Existing data is limited between 40,000 to 500,000 counts per minute (cpm) gamma. Insufficient data density is attributable to previous investigations biasing laboratory analytical samples towards areas of highest and lowest core gamma response intervals. Sample collection during the design investigation has been developed to increase data density within target areas (generally “mid-range”) of the regression. Specific areas targeted for increased data collection include thorium-specific data collection in the gamma count target range of 40,000 to 500,000 cpm (approximately 250 to 10,000 pCi/g combined thorium), and radium-specific data collection in the gamma count target range of 40,000 to 500,000 cpm (approximately 100 – 1000 pCi/g combined radium). These targeted ranges have insufficient data to support the estimated relationship between combined thorium, combined radium, and gamma. Additionally, it is recognized that additional data generally above 40,000 cpm will potentially decrease the standard error of the slope estimate of the regression. Given the large number of samples for comparison (greater than 2,000), the population density in many areas of greater than 40,000 cpm will be available for further development of these regressions. For lower range radium activity concentrations (7.9 to 52.9 pCi/g) where the relationship to gamma is not particularly strong, boring locations were selected based on proximity to areas of low RIM predictions. Furthermore, these areas often coincide with areas where thorium is predicted but radium is not. A random sampling program was established to provide unbiased data density in cores exhibiting a low gamma response, as well as cores where a target gamma range is not present during core scanning. The random sampling procedure is described in Section 2.4.3.1 of the FSP.

This DIWP proposes data additional data collection techniques with the intent of improving the understanding of the relationships between radium, thorium, and gamma through the following techniques:

- Sampling every interior boring once every four feet to allow for greater data density and distribution throughout the site.
- Using a sodium iodide (NaI) detector with a 2-inch crystal for both core and downhole data collection to provide the basis for comparison of field scanning results to further correlate sample depth.
  - If core has limited recovery, an elevated gamma response in the core scan can be related to observations in downhole scans to provide depth corrections, if needed.
- Performing four-foot core runs (within interior borings) while sonic drilling to maximize recovery and reduce elevation uncertainty associated with laboratory sample collection depths relative to the results of the downhole logging.
- Evaluation of historical and new data for usability of downhole gamma, core scan gamma, and analytical results via regression comparison. Should new data indicate clear trends in regression analyses, historical data outliers will be identified and may be excluded from the model.
- Targeting areas of the regression where data density is low.

The collection of data to fulfill GSMO #1 will focus on apparent weaker areas (discussed in the second paragraph of Section 3.1.1) of the correlation between radium, thorium, and gamma. The collection of these data will provide more information as to whether the correlation can be improved through targeted laboratory sample collection resulting in increased data density within the specific gamma range (measured during core scanning) where co-located gamma and laboratory data are sparse. Soil cores will be archived and held on site to allow for additional laboratory analytical testing and flexibility in refining the regressions, as necessary.

3.1.2 GSMO #2 – Improve Boring/Sample Spacing and Geometry to Reduce Model Uncertainty

The current geostatistical model uses historical data sets to determine areas that have a greater than 50% probability of being >52.9 pCi/g. However, the current model relies heavily on gamma data for thorium prediction, and this prediction occurs for values below a reliable detection level and correlation range, as discussed in Section 3.1.1 and expanded upon in Appendix E. The potential underprediction of thorium when utilizing gamma data could result in a modeled extent of RIM >52.9 pCi/g that is smaller in extent than is present at the site. The goal of GSMO #2 is to strategically increase data density and reduce the SD of the kriging estimate of the extent of RIM >52.9 pCi/g throughout Areas 1 and 2. The linear distance between borings has been reduced to 140 feet, which is approximately the variogram range length within the geostatistical model. An analysis of SD reduction, including methods for using SD reduction to target areas for sample collection, is discussed in greater depth in Appendix E.

A total of 223 borings are proposed for installation during the design investigation, and over 2,000 analytical samples (proposed borings only) will be collected. The resulting data set will be significantly larger than the historical data set, which will undoubtedly improve the SD of the overall model. Additionally, samples for laboratory analyses will be collected from each 4-foot core run, even if RIM is not indicated by core scan, to provide lower activity data and characterize depth intervals above and below the currently predicted RIM extent. Figure 6A shows the historical and proposed boring program overlain by 2,000-square-meter grids that serve to provide a visual aid for assessing overall boring density. While a grid area of 2,000 square meters was not specifically considered when placing borings, it provides a comparison to the confirmation sampling reference unit area specified in the RODA (see Section 3.2.4 for further detail).

Beyond generally improving the model, borings were proposed strategically with the goal of reducing kriging SD throughout Areas 1 and 2. Proposed borings addressing this GSMO are presented in **Section 3.2**. The SD analytical method performed to identify appropriate sampling areas has been discussed with the USEPA, and is presented in **Appendix E**. Standard Deviation to Warrant Sampling (SDWS) was developed utilizing geostatistical error rates, modeled RIM non-exceedance probability, and kriging SD, to select sampling locations (method detailed in **Appendix E**).

GSMO #2 is addressed through judgement-based placement of borings in areas of kriging SD and uncertainty methods, as discussed in the PEP, and then updated to include areas of inconsistency between the intermediate and final cumulative distribution function (CDF) (**Figure 6B**), and areas of high variability using the indicator variability metric (IVM) method. IVM was used as an exploratory analysis to back-check the boring placement, with preference given to SDWS areas. A summary of comparative and statistical evaluations for identifying boring locations is provided in **Appendix F** (with tables of borings and placement metrics), including but not limited to the following additional and updated analyses (detailed in **Appendix E**):

Qualitative review of SD and RIM > 52.9 pCi/g
First, the current model predictions of SDWS and probability of exceeding 52.9 pCi/g were mapped and reviewed for areas of relatively higher SD. Regions of the highest SD were targeted for additional borings. Next, the model was rerun with inclusion of proposed borings as artificial data. Results of the current model alongside the proposed model with artificial data were graphically compared (see **Appendix E**) to discern if the areas of highest SD were being targeted.

SDWS
The SDWS metric was employed in Area 2 as discussed with USEPA.

IVM

IVM was developed to mathematically combine the estimated indicator values (i.e., non-exceedance probability) with the SD. This process "weights," (places more emphasis on) areas where both non-exceedance probability (NEP) approaches 0.5 and where SD is relatively higher. Therefore, this metric highlights the intersection of areas both near the threshold of interest (0.5 NEP) and where the uncertainty is highest. Results of this exploratory analysis were used to ensure that both the qualitative review and the SDWS correctly identified areas of model uncertainty for boring placement. IVM was not used as a primary driver of boring placement.

In addition to increasing overall sample density and reducing SD (including SDWS and random sampling), analyses are proposed to evaluate the nugget effect and short-range variance on the model through vertical variograms and paired sample analyses (discussed in FSP Section 2.4.3.4). Since analytical data will be collected at several depths within each boring, there will be a high data density for estimation of variance at small lag distances, as detailed in Appendix E (Section 2.2.1). Additionally, 5% of the samples will include two paired samples collected one foot on either side of the primary sample. This will support the short-range variance analysis.

3.1.3 GSMO #3 – Further Define Activities and Extent of RIM

The goal of GSMO #3 is to further define activities and RIM extent throughout Areas 1 and 2 through the collection of additional laboratory analytical and field data in the following areas:

- Areas where current estimates suggest that thorium is >52.9 pCi/g and radium is less than 52.9 pCi/g (**Figures 7A-F**).
- Along the currently estimated 52.9 pCi/g boundary (**Figure 8A**).

- Isolated pockets where RIM >52.9 pCi/g is shallower than 12 feet B2005GS (**Figure 8B**), as identified in the PEP Figures 13 and 14.
- Areas where elevated RIM activities (significantly above 52.9 pCi/g) are expected to occur between 16 and 20 feet B2005GS (**Figure 8B**).

This GSMO will be addressed through the installation of targeted soil borings, as presented in **Section 3.2,** based on current model estimations. Generally, the model uses a 50% probability of non-exceedance for RIM >52.9 pCi/g; however, for the purposes of the design investigation, the 25% and 75% non-exceedance probabilities were also considered in the boring placement process.

Further details regarding the geostatistical model and DIWP data needs are provided in the QAPP, including the seven-step process used to develop and explain each principal study question. **Table 2-2** shows a summary of GSMOs and proposed solutions presented in this DIWP.

Appendix E provides updated analyses to evaluate a site-specific quantification limit for thorium based on the:

- Known relationship between radium and gamma
- Relationship between thorium and radium
- Relationship between thorium and gamma

Upon collection of new data, the regressions will be updated, and the analyses revisited. Furthermore, data processing, such as indicator assignment (as related to the CDF), can be explored such that thorium values (approximately 52.9 pCi/g) can be used in the model while minimizing underestimation or overestimation of material volumes.

3.2 RIM Investigation

The objectives of the RIM investigation include defining the extent of waste and verifying that the RIM occurrences and extent are limited to the Area 1 and Area 2 boundaries, further characterizing RIM >52.9 pCi/g, determining a statistically valid background concentration for the Buffer Zone and Lot 2A2, and evaluating the extent of RIM above statistically valid background concentrations in the Buffer Zone and Lot 2A2.

A total of 223 borings (65 in Area 1 and 158 in Area 2) are proposed to fulfill the data needs of the design investigation. The proposed borings are shown on **Figure 5A.** The proposed boring count, as well as expected total sample count, is summarized in **Table 3**.

A conceptualized cross-section of RIM areas >52.9 pCi/g is included on **Figure 9**. While this figure is not representative of site conditions, it was designed to demonstrate the processes used to optimize boring placement for the fulfillment of multiple data collection needs and objectives. These processes are discussed as they relate to specific objectives in **Section 3.2.2** below. The current model estimations of RIM >52.9 pCi/g are shown on **Figure 9A** (Area 1) and **Figure 9B** (Area 2).

As discussed previously and expanded upon in **Appendix E**, the current model utilizes gamma data for thorium prediction below a reliable detection level and correlation range. This process began with qualitative comparisons and became more quantitative in nature with the development and use of SDWS as a statically based determination of when the number of borings and locations is sufficient. The following sequence describes the detailed step-by-step approach used to identify boring locations. This process began with qualitative comparisons and became more quantitative with the development and use of SDWS as a statistically based determination of the number of borings and locations necessary satisfy the data collection needs of the design investigation.

1. Spatial areas were identified where the model estimated RIM >52.9 pCi/g, yet there were no borings already located in these areas. In other words, regions of predicted RIM >52.9 pCi/g that were not substantiated by hard or soft data were identified. Proposed borings were added to these areas.
2. Areas where thorium was estimated above 52.9 pCi/g, and radium was below 52.9 pCi/g were identified. Additional borings were added in these areas, if not coincident with proposed borings already added.
3. Additional borings were added in which:
   a. The RIM shell geometry was complex, with irregular and/or lenticular shapes that were sometimes vertically separated by estimated material <52.9 pCi/g
   b. Areas that were predicted to contain high activities
   c. Areas of RIM that were based on model estimates without previous borings
4. The SD field was mapped to graphically determine areas of highest error, while considering RIM activities. Additional borings were added in these areas, if not coincident with other proposed borings.
5. Areas of estimated activity between 7.9 and 52.9 pCi/g were identified, and proposed borings were located where no borings had been previously drilled.
6. Overland gamma survey results from the original Remedial Investigation (EMSI 2000) were compared to previous and proposed borings to ensure these areas were accounted for. Because these overland gamma data could not be incorporated into the geostatistical model, there were some discrepancies between the modelled extent of RIM and areas of elevated overland gamma results from this survey. As such, borings were added to areas that did not overlap with other proposed additional borings. In other words, the overland gamma results from the original RI were compared with the proposed borings defined above, and if there were areas (of reasonable size) of overland gamma with no borings, additional proposed borings were added.
7. Existing and proposed borings (above) were compared with a 2,000-square-meter grid. If there were any grid cells without a boring, an additional proposed boring was added to that grid cell center. The use of the 2,000-square-meter grid was chosen both as a qualitative reference point and as a mechanism for "infilling" areas without borings.
8. The SDWS tool was used for highlighting regions to target for sampling based on SD and RIM NEP, as developed by the USEPA in response to Comment #17 of the USEPA's *Comments on 3/30/2020 Design Investigation Work Plan*.
9. The IVM, which combines SD and indicators with a weighted function that identifies areas of highest SD and RIM near 52.9 pCi/g, was used as a graphical comparison to other evaluation methods as discussed above.
10. Recommendations from USEPA, including Figures 17 and 18 from the RODA (USEPA 2018).

Further discussion and summary of boring placement rationale is provided in Appendix F.

It is anticipated that some of the current boring placement may need to shift based upon physical accessibility as determined in the field. In order to provide flexibility and adaptability regarding boring locations, as well as promote expedited USEPA and MDNR approval of this DIWP, it is proposed that borings may be relocated up to 25 feet within Areas 1 and 2. Relocation beyond 25-feet with be performed in consultation with USEPA. Global positioning system coordinates for proposed borings in the geographical information system database will be updated, and a log will be kept maintaining a record of changes.

The following tasks (described in Sections 3.2.1 through 3.2.5) define the scope of data gap investigation activities to be performed at the site.

Work completed during the design investigation will be performed in accordance with the field methodologies and techniques outlined in this DIWP, the FSP (Appendix A), and the QAPP (Appendix B).

3.2.1 Waste/RIM Extent Delineation Along Area 1 and Area 2 Perimeters, and OU-1 Boundary Confirmation (DIO #1)

Additional data will be collected along the perimeters of Area 1 and Area 2 to further delineate the extent of waste and/or RIM, as well as evaluate the potential for radiologically impacted soil migration down the landfill toe to have occurred historically during rain events. The proposed perimeter borings will be sampled for radiological parameters to evaluate the presence and magnitude of RIM impacts, and results from these locations will be integrated in the geostatistical model. Such information will support future design activities.

3.2.1.1 Perimeter Borings

Nineteen borings are proposed along the perimeter of Area 1, and 41 borings are proposed along the perimeter of Area 2, to evaluate (a) whether RIM is present and (b) the extent of waste as it pertains to cap design. Perimeter boring locations are proposed at a maximum of every 200 feet along area perimeters, except where historical borings and data were present (e.g., RIM/waste observed in historical borings) and design objectives dictated specific data needs (e.g., geotechnical data needs in specific areas). This spacing was judgmentally determined through professional judgment to be adequate for fulfilling the goal of characterizing the perimeters of Areas 1 and 2, and includes a significant increase in RIM boring density when considering that, in areas where historical data indicates the presence of RIM, boring density was increased significantly.

Similarly, perimeter borings are proposed along the boundary of Area 2 to confirm the area boundary along the margins of the Inactive Sanitary Landfill with a higher density to ensure that the outer boundary of RIM occurrences are sufficiently defined to determine the extent of the landfill cover. The spacing was deemed adequate for investigating the boundaries of Area 2.

While perimeter borings primarily serve the purpose of waste extent delineation and geotechnical evaluation of site soils, data from laboratory analyses, core scans, and downhole gamma measurements will be collected from each proposed perimeter boring to be input into the geostatistical model. In addition to radiological samples collected at depth, radiological samples will also be collected from the top 2 feet of select proposed perimeter borings (i.e., perimeter borings outside the expected extent of the waste mass), as described in worksheet #11 of the QAPP and Tables 1 and 2 of the FSP.

A small subset of borings proposed along the southwestern and northeastern edge of Area 2 are adjacent to a potential thorium-driven excavation boundary. As addressed in Section 3.2.2.1, these areas will be evaluated through the placement of gridded borings, but will be drilled and sampled through the base of waste as per the procedures outlined for perimeter borings (see “Hybrid Borings” in Section 2.4.3.1 of the FSP).

The proposed boring locations are shown on Figure 5A and are shown with the 1973 aerial and topography on Figure 10.

Perimeter borings will be installed via hollow-stem auger drilling methods to a depth of 25 feet below ground surface (BGS) at locations that are expected to be outside the waste boundary extent. Borings installed within the expected waste boundary, including those proposed along the North Quarry boundary and along the southeastern edge of Area 2, will be installed through the total thickness of waste and five feet into the alluvial substrate using sonic drilling methods.

Boring installation and sample collection will be performed in accordance with the methods and boring specific data collection needs detailed in the FSP, DMP, and QAPP.

For geotechnical perimeter borings installed outside the waste mass in *in situ* soils, split-spoon soil samples will be collected continuously. Blow counts will be recorded, soils will be visually described and logged, and each spoon will be scanned with hand-held alpha, beta, and gamma detectors in the field to fulfill the data collection needs detailed in the FSP.

For perimeter borings installed within the waste mass, soil samples will be collected using sonic cores extruded into sample bags. Soils will be visually described and logged, and each core will be scanned with hand-help alpha, beta, and gamma detectors in the field to fulfill the data collection needs detailed in the FSP. Soils will be visually described and logged, and each core will be scanned with hand-held alpha, beta, and gamma detectors in the field to fulfill the data collection needs detailed in the FSP.

Duplicate composite samples will be collected from each perimeter boring installed within waste at a frequency of one duplicate per boring. If the duplicate fails the acceptance criteria (described in Worksheet #12 of the QAPP), the boring will be re-logged and sampled in 1-foot intervals. The procedures and methods for duplicate composite sample collection are discussed in Section 2.4.3.5 of the FSP.

If analytical results from primary composite and/or biased sample exceed 7.9 pCi/g for RIM, step-out borings may be installed perpendicular to the previously defined OU-1 boundary.

3.2.1.2 Stepping Out from Perimeter Borings Outside of Waste

Perimeter borings proposed outside the expected waste extent may be subject to step-out if the following conditions are met:

1. A significant layer (thicker than 2 feet) of predominantly MSW is identified during split spoon logging; or
2. Analytical sample results exceed 7.9 pCi/g for RIM in a specific boring.

Offset borings outside the expected waste extent will be installed with a 10-foot offset from the parent boring (measured perpendicular to the OU-1 boundary), except along St. Charles Rock Road, where the offset distance will be approximately 25 feet. The increased offset distance along St. Charles Rock Road is due to the difficulty associated with access path and drilling pad construction.

If MSW is observed during split-spoon sampling to be thicker than 2 feet (Condition 1) within the top 4 feet of a perimeter boring outside waste, but there is no evidence of waste or RIM from 5 to 25 feet BGS, then step-out borings will consist of shallow direct-push borings advanced to 5 feet BGS.

The step-out protocol for borings outside the expected waste mass is detailed further in Section 2.2.2.1 of the FSP. Sampling protocol and procedure for each perimeter boring type is described in Section 2.4.3 of the FSP.

3.2.1.3 Stepping Out from Perimeter Borings Within Waste

Step-out borings may also be installed at an offset from perimeter borings proposed within the waste mass if the following conditions are met:

1. If laboratory analytical results from biased grab samples collected from an interval within a specific five-foot core run exceed 7.9 pCi/g for RIM; or
2. If laboratory analytical samples from composite samples from a given core run exceed 7.9 pCi/g for RIM.

Step-out borings will be installed with a 50-foot offset, measured perpendicular to the OU-1 boundary. Each step-out boring will have the same sample collection and step-out protocol as the parent location. This protocol is described further in Section 2.2.2.2 of the FSP. Sampling procedures for each perimeter boring is described in Section 2.4.3 of the FSP.

Boring installation and sample collection will be performed in accordance with the methods and boring specific data collection needs detailed in the FSP, DMP, and QAPP.

3.2.1.4 Enclosure A Borings Proposed within the Inactive Sanitary and Closed Demolition Landfills

In addition to, and separate from, the perimeter boring programs described above, Enclosure A borings are proposed beyond the currently estimated boundary of Area 2 within the Closed Demolition Landfill and Inactive Sanitary Landfill to ensure that the outer boundary of RIM occurrences is sufficiently defined to determine the extent of the landfill cover. Enclosure A borings were placed in areas where historical filling operations were observed to supplement historical data collected and better define RIM distribution in these areas. These borings include ISL-EA-154, ISL-EA-159, ISL-EA-160, ISL-EA-161, CD-EA-163, and CD-EA-164.

The Enclosure A boring locations were selected by the USEPA and are shown on Figure 5A, and shown with 2005 topography on Figure 5B. Enclosure A borings are denoted by the “ISL-EA” prefix for those within the Inactive Sanitary Landfill, and “CD-EA” for those within the Closed Demolition Landfill. Similar to the perimeter borings proposed within the waste mass, these borings will be installed using sonic drilling methods, through the extent of waste and five feet into the underlying alluvium.

The sampling approach and method for the Enclosure A borings are discussed in Section 2.4.3 of the FSP. The sampling approach is generally consistent with the approach outlined for perimeter borings within the waste mass. These borings are not subject to the offset/delineation protocols described above.

3.2.2 Further Define Activities and Extent of RIM >52.9 pCi/g (DIO #2)

The Amended Selected Remedy specifies the removal of RIM from Areas 1 and 2 containing combined radium or combined thorium activities >52.9 pCi/g located generally within the top 12 feet B2005GS. To optimize RIM removal by maximizing removal of RIM volume and minimizing removal of non-RIM waste, additional data is needed to define margins of the areas containing RIM >52.9 pCi/g for both thorium and radium. This will be achieved by increasing data density along the 52.9 pCi/g combined thorium and combined radium RIM edges, as well as in areas of deeper activity removal (from 12 to 20 feet B2005GS) and areas where RIM is expected to exist in isolated pockets shallower than 12 feet B2005GS.

The current lateral extent of margins of RIM >52.9 pCi/g are shown on Figure 8A. The extent of RIM >52.9 pCi/g was developed using the kriging parameters presented in the PEP and discussed in Appendix E and is consistent with the extent of RIM >52.9 pCi/g shown in previous submittals. Statistical SD analysis of the model indicates areas of low confidence and high SD, both of which will be improved through the installation of additional soil borings. These borings will serve to increase the density of both field and laboratory data within and along the 52.9 pCi/g RIM edge. The vertical extent of RIM is largely driven by modeling the distribution of RIM through the correlation of field and laboratory data sets. The proposed soil borings will be installed using short (4-foot) core run lengths to maximize recovery, thereby reducing inherent elevation uncertainty associated with interpolating depth intervals in low-recovery soil cores. These methods will allow for better correlation between downhole gamma, gamma core scanning, and laboratory analytical data.

Borings were proposed based on visual comparison of 25% and 75% probabilities of non-exceedance of RIM >52.9 pCi/g as compared to the current RIM margins (50% probability), as shown on Figure 8A. The margins of the areas where a probability of 25% non-exceedance indicates a 75% likelihood that RIM is present >52.9 pCi/g have been used to identify where additional borings may be required to define the extent of RIM >52.9 pCi/g. The use of probability of non-exceedance, or a null hypothesis, is carried over from the FFS as presented by

SSP&A (2017). Borings were placed near the boundary of the 25% non-exceedance to increase data density of field and laboratory analytical data and reduce the minimum linear distance to less than 140 feet between borings (including historical borings). Additional borings are also located outside the 50% probability of non-exceedance, in some cases between the 50% and the 75% non-exceedance probability to investigate these areas. It should be recognized that since the model is an estimation tool and all additional data within the variogram range length of the estimation point will improve the estimation. Therefore, the sampling program does not include staggered borings directly inside and outside the 25% and 75% non-exceedance probability. These limits were considered as one of the multiple comparative tools for location of additional borings. Furthermore, the overall distribution of borings between the 25% and 75% non-exceedance probability provide a collective distribution between 25% and 75% for future comparisons to the model (similar to a transect approach).

Additionally, overland gamma survey data collected by McLaren-Hart (1994) was included on Figure 8A, and borings were placed to provide coverage in locations where elevated counts were observed outside the currently modeled extent of RIM >52.9 pCi/g. The overland gamma survey data is not incorporated into the geostatistical model for the following reasons:

- Correlation between overland gamma and activity concentrations was only confirmed for a small number of samples at very high concentrations (several hundreds to thousands of pCi/g);
- Correlated surface samples were not co-located with overland gamma;
- Surface soil samples were not collected at the same time as the overland gamma; and
- There is no discrete depth interval associated with the overland gamma (SSP&A 2017).

As shown in Figure 8A, there are discrepancies between the overland gamma survey elevated gamma response areas and the modeled extent of RIM >52.9 pCi/g. This may be due to truncation of data by the prior model at the 2005 surface, resulting in the false elimination of surface soil samples This will be addressed in future models, as discussed in Section 2.2.1.

To optimize boring placement while minimizing total boring count, borings proposed with the purpose of improving understanding of RIM distribution also fulfill other design investigation objectives and GSMOs; therefore, additional analytical samples may be collected from these borings and submitted for laboratory analysis. A summary of placement rationale related to interior RIM borings is provided in Appendix F. The FSP details the specific data collection needs of each borings.

The sampling strategy and methodology as related to both the design investigation objectives and GSMOs are detailed in the FSP. All analytical samples will be collected and submitted to the laboratory in accordance with the QAPP and DMP.

3.2.2.1 Thorium-Driven Excavation Areas (GSMO #3)

Several RIM areas are predominantly defined by activities >52.9 pCi/g of combined thorium. This is based on the indicator kriging workflow where the lower non-exceedance probability between radium or thorium was chosen. For these RIM areas, 47 borings (nine borings in Area 1 and 38 borings in Area 2) are proposed using systematic spacing. These borings serve to delineate areas where the geostatistical model estimates RIM >52.9 pCi/g at depth and historical data sets consist primarily or exclusively of thorium activities derived from only surface samples and/or downhole gamma readings.

There are specific locations where RIM is expected to be composed predominantly of thorium >52.9 pCi/g, as shown on Figures 7B, 7D, and 7F, as opposed to the areas expected to consist of predominantly radium >52.9 pCi/g shown on Figures 7A, 7C, and 7E. In these areas, thorium was often modeled based on laboratory samples collected from the surface and interpolated to depth. Therefore, the occurrence of RIM >52.9 pCi/g should be confirmed. Typically, a phased design investigation approach would be considered to better define those areas where thorium-driven RIM is interpolated to occur at depth (0-16 feet B2005GS) through successive installation of soil borings in each phase until the characterization is complete. For this design investigation, the timeframe and schedule as outlined in the SOW makes this level of phased approach impractical; therefore, borings were proposed with systematic spacing with samples collected from 0 to 20 feet B2005GS to better define these thorium-driven areas. Additionally, installation of proposed borings located in areas where thorium concentrations exceed the definition of RIM are likely to extend beyond concentrations of radium at the RIM boundary, including along the 52.9 pCi/g boundary, will be prioritized during the field investigation. Specific boring installation sequencing will be dependent upon conditions encountered in the field.

At proposed borings addressing thorium-driven excavation areas, laboratory thorium and radium data will be collected. Each soil core will be scanned in the field using alpha, beta, and gamma detectors.

Figure 9 shows a conceptualized cross-section through Area 2. As shown, proposed borings in areas where RIM >52.9 pCi/g is defined by combined thorium were placed in select locations to better define the extent of the proposed excavation and improve understanding of thorium concentrations at depth.

In the interest of optimizing boring placement and minimizing the total boring count, a small subset of systematically spaced borings will also fulfill other DIOs, such as general RIM delineation and identifying the extent of waste. Therefore, select borings may be advanced to greater depth (25 feet B2005GS) to fulfill the data needs of perimeter borings described above, in addition to the data needs associated with thorium-driven RIM delineation. The sampling strategy and methodology as related to both the DIOs and GSMOs is detailed in the FSP. Analytical samples will be collected and submitted to the laboratory in accordance with the QAPP and DMP.

Following boring installation, the borehole will be cased with 3-inch PVC or acrylonitrile butadiene styrene (ABS) solid casing and logged in 6-inch intervals with a NaI gamma detection assembly using the methods specified in the FSP.

Once the downhole gamma scan has been conducted and all data collection activities specified in this DIWP and related documents (FSP and QAPP) have been completed, the borehole will be decommissioned by removing the casing and grouting the borehole from total depth to surface grade, in accordance with applicable state regulations as discussed in the FSP.

3.2.2.2 Combined Radium and Thorium Excavation Areas (GSMO #3)

In areas where RIM is predominantly defined by activities >52.9 pCi/g of combined radium and thorium, proposed sample locations were selected to increase data density, decrease linear distance between data points, and fulfill the needs of the geostatistical model as outlined in the GSMOs.

Figure 9A and Figure 9B, respectively, show cross-sections along transects in Area 1 and Area 2 where RIM has a greater than 50% probability of exceeding 52.9 pCi/g. RIM in these areas is generally present from 0 to 12 feet B2005GS in Area 1 and from 0 to 16 feet B2005GS in Area 2. Proposed boring locations and sampling intervals described below were selected to better understand RIM distribution and to assist in determining and supporting total activity calculations throughout these depth intervals. Proposed borings to address areas where RIM may be present deeper than 16 feet B2005GS are discussed in Section 3.2.2.3.

Borings in areas where RIM >52.9 pCi/g is expected to consist of radium and thorium will generally be installed and downhole logged to a depth of 20 feet B2005GS to evaluate and delineate RIM generally within 12 feet B2005GS and to collect additional data from 12 to 20 feet B2005GS for the optimization of total activity calculations and removal, as discussed in Appendix E.

At these locations, laboratory thorium/radium soil samples will be collected from 0 to 20 feet B2005GS based on field results of gamma readings during core scanning, as well as from randomly selected depth intervals. The data needs and sampling strategy for these borings is detailed in the FSP.

Following boring installation, the borehole will be cased with three-inch PVC or ABS solid casing and logged in 6-inch intervals with a NaI gamma detection assembly using the methods specified in the FSP.

Once the downhole gamma scan has been conducted and all data collection needs specified in this DIWP and related planning documents (i.e., FSP and QAPP) have been completed, the borehole will be decommissioned by removing the casing and grouting the downhole borehole to grade in accordance with applicable state regulations as discussed in the FSP.

3.2.2.3 Isolated RIM Pockets (GSMO #3)

Borings have been proposed in areas where RIM is expected to exist in isolated pockets with Areas 1 and 2 (PEP Figures 13 and 14), generally shallower than 12 feet B2005GS. As shown on Figure 8B, borings have been proposed around and within isolated RIM pockets to better determine both lateral and vertical extent of RIM >52.9 pCi/g for use in activity calculations and consideration during generation of an optimized excavation extent.

Borings installed to better define isolated pockets will generally be installed to 20 feet B2005GS to evaluate and delineate RIM >52.9 pCi/g from 0 to 12 feet B2005GS, as well as collect additional data from 12 to 20 feet B2005GS for the optimization of total activity calculations and removal, as discussed in Appendix E.

3.2.2.4 Areas of Deeper RIM Excavation (GSMO #3)

In the areas of potential deeper RIM removal shown on Figures 8B where RIM is generally greater than 1,000 pCi/g is expected to consist of radium and thorium, laboratory and field data will be collected to better define excavation limits and support total activity calculations, as discussed in Appendix E.

Proposed borings in areas where RIM may be present greater than 16 feet B2005GS will be installed to a depth of 20 feet B2005GS. Laboratory analytical samples will be collected for both thorium and radium from each four-foot core run. Results of core scanning and downhole gamma logging will be used to increase the resolution of the data set to better support the needs of the geostatistical model at depth and in determining the total activity calculations. In addition, samples will be collected and submitted from randomly-selected depth intervals where field scanning does not identify gamma within the target range.

The sampling strategy and methodology for areas of potential deeper RIM removal as related to both the DIOs and GSMOs are detailed in the FSP. Analytical samples will be collected and submitted to the laboratory in accordance with the QAPP and DMP.

Following boring installation, the borehole will be cased with 3-inch PVC or ABS casing and logged in 6-inch intervals using a NaI gamma detection assembly as specified in the FSP.

Once the downhole gamma scan has been conducted and all data collection needs have been satisfied, as determined in coordination with the USEPA, the borehole will be decommissioned by removing the casing and grouting the borehole to grade, in accordance with applicable state regulations as discussed in the FSP.

3.2.3 Delineate Extent of UMTRCA Cap (extent of RIM greater than 7.9 pCi/g) (DIO #3)

Areas of RIM defined by the total activities of combined thorium and radium greater than 7.9 pCi/g require further characterization to interpolate (via kriging methods) the boundary of the RIM that will be left in place. In addition, samples of relatively low activity (7.9 to 52.9 pCi/g) will provide data to bolster the regressions used by the model to calculate total activities and define the required limits of the UMTRCA cap. These proposed borings will be located outside of the currently expected extent of RIM >52.9 pCi/g, and will also aid in the characterization of overburden/sidewall material consisting of RIM with activities between 7.9 and 52.9 pCi/g that may be placed in the bottom of the excavation during the implementation of the RA.

Borings to better define RIM margins between 7.9 and 52.9 pCi/g are shown on **Figure 5A** as locations proposed outside the 52.9 pCi/g boundary and listed in **Appendix F**. These borings will be advanced to a depth of 20 feet B2005GS, and soil samples will be collected and submitted to the laboratory for combined thorium and combined radium analysis. Samples will be collected based on field results of gamma readings during core scanning, as well as through random sampling as discussed in the FSP. The FSP summarizes the data needs related to both the design investigation objectives and GSMOs, as well as sampling strategy for each boring.

Analytical samples will be collected and submitted to the laboratory in accordance with the QAPP and DMP.

Following boring installation, the borehole will be cased with 3-inch PVC or ABS casing and logged in 6-inch intervals using a NaI gamma detection assembly as specified in the FSP.

Once the downhole gamma scan has been conducted and all data collection specified in this DIWP and related planning documents (i.e., FSP and QAPP) have been completed, the borehole will be decommissioned by removing the casing and grouting the borehole to grade, in accordance with applicable state regulations as discussed in the FSP.

3.2.4 RIM Extent on Buffer Zone and Lot 2A2 and Background Investigation

The Buffer Zone and Lot 2A2 are distinct parcels adjacent to the site where it is suspected that historical rainfall and surficial runoff may have transported radionuclides from Area 2 of the West Lake Landfill and deposited it in the surface soils of these parcels. The Buffer Zone and Lot 2A2 of the Crossroads Industrial Park are components of OU-1 that are located to the west of Area 2. Previous investigations of the site and surrounding parcels have demonstrated radionuclide impacts to surface soils of the Buffer Zone and Lot 2A2, likely as a result of historical erosion of Area 2 slopes.

3.2.4.1 Buffer Zone and Lot 2A2 of the Crossroads Industrial Park (DIO #5)

Surface soil samples will be collected to further define and delineate the extent of RIM in both the Buffer Zone and Lot 2A2 areas.

These areas are known to have been covered by gravel and other gravel-like material after it was discovered that RIM material had migrated from Area 2 (EMSI 2018a). However, following application of a gravel cover, surface soils were disturbed due to anthropogenic activities (grading and regrading); therefore, it is not certain that radionuclide impacts will be constrained to the 6 inches of soil directly underlying gravel/asphalt cover.

For evaluation purposes, the Buffer Zone and Lot 2A2 parcels were divided into contiguous decision units, each approximately 2,000 square meters in area. The division into decision units reflected a balance between proximity to potential contamination and minimizing spatial extremities within each decision unit. There are eight decision units proposed for Lot 2A2 and three decision units proposed for the Buffer Zone. Within each decision unit, 14 sample locations were selected based on random-start systematic sampling on a square grid, as shown on **Figure 11**. A discussion of sampling design and rationale is included in the QAPP.

Since the nature of deposition and subsequent anthropogenic disturbance of soils on the Buffer Zone and Lot 2A2 are not fully understood, soil samples will be collected from 0 – 6 inches and 6 – 12 inches (as measured below the reworked gravel and/or asphalt interface), and soils will be screened with a radiological detector. In the event that radionuclide impacts are observed from 6 – 12 inches, additional soils will be collected and analyzed until a clean interval is observed.

Access to the properties, specifically Lot 2A2, will be carefully coordinated with all applicable property owners. Lot 2A2 is currently used as a staging area for covered semi-trailers. As such, the ability to access sample locations will be highly dependent on site conditions and the ability to relocate these trailers. Surface soils will be sampled in accordance with the data needs defined in the FSP, and laboratory analytical samples will be prepared and submitted in accordance with the QAPP and DMP.

3.2.4.2 Background Concentration Investigation (DIO #4)

The scope of RIM investigations for the Buffer Zone and Lot 2A2 includes the determination of statistically valid background radioactivity concentrations for comparison to the results obtained from the surface samples collected at Buffer Zone and Lot 2A2. Background sampling is deemed necessary based on review of the "Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites" (USEPA 2002). Background samples will be evaluated to characterize the distribution of background concentrations and determine the extent to which site RIM concentrations exceed background for the soil remediation objectives associated with soil cleanup in the Buffer Zone and Lot 2A2. This determination will be made based on statistical comparisons which are described in the QAPP.

Background measurements generally comprise a range of values, particularly for mineral elements that are naturally occurring as well as a result of anthropogenic activities. In order to select a statistically valid background concentration range, four proposed reference units with characteristics similar to those in the Buffer Zone and Lot 2A2 (Figure 12) have been chosen. These reference units will be compared based on analytical results and statistical analysis described below and in the QAPP, and will be used to develop a background concentration for the Buffer Zone and Lot 2A2.

Backup reference units have been provided in the event that a reference unit is deemed unsuitable, or access cannot be obtained.

Reference units were chosen from undisturbed/undeveloped reference units (to the extent practicable given the generally urban area) consistent with the requirements outlined Section 2.3 of the "Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites" (USEPA 2002).

An analysis of regional National Resources Conservation Service (NRCS) soil data (Figure 13) indicates that surface soils at each of the proposed background study reference units are:

- Reference Unit #1: Menfro silt loam
- Reference Unit #2: Urban land, bottomland complex
- Reference Unit #3: Menfro silt loam
- Reference Unit #4: Urban land, harvester complex
- Backup Reference Unit #1: Urban land, bottom land complex
- Backup Reference Unit #2: Sans Dessein silty clay
- Backup Reference Unit #3: Urban land, fishpot complex
- Backup Reference Unit #4: Urban land, harvester complex

The surface soil complexes surrounding the site generally consist of silty loam and silty clay, which includes Reference Units #1 and #3, as well as backup Reference Unit #2. Menfro series soils are characteristic of loess deposits, or windblown river sediment which was later deposited on benches, backslopes, and ridgetops adjacent to the Missouri River (NRCS). Sans Dessein soils, on the other hand, are formed from alluvial deposits and can be found along the flood plains of the Missouri River (NRCS).

Reference Units #2 and #4, as well as Backup Reference Units #1, #3 and #4, are composed of urban land (developed/fill). The Fishpot series is an anthropogenic soil type where fill has been placed above alluvial soils in river valleys. These soils often contain anthropogenic materials such as asphalt, brick, cinders, and glass (NRCS). The Harvester series is similar, but describes the redevelopment of loess deposits for urban and suburban purposes (NRCS). The bottom land complex is more general and describes the anthropogenic modification of flood plain soils.

While depositional processes forming Menfro and Sans Dessein soil series differ, their composition is expected to be quite similar such that both are suitable for inclusion in the background study.

Reference Units #2 and #4 are listed as "urban land" complexes; nonetheless, the soils themselves share a provenance with the Menfro and Sans Deissen series and are viable for consideration in the background study.

Each reference unit is approximately 2,000 square meters in areal extent. Fourteen sample locations were randomly selected within each reference unit. Surficial soil samples will be collected at two depth intervals at each location. One laboratory analytical sample will be collected from 0 to 6 inches, and a second laboratory analytical sample will be collected from 6 to 12 inches. Proposed sample locations are shown on Figure 12.

Simple random sampling calculations were used to determine sample locations within each reference unit. Corner coordinates determined in geographic information system (GIS) for each reference unit and random numbers generated in MS Excel were used to calculate random coordinate (X,Y) pairs until 15 sample locations were generated within the bounds of each approximately 2,000 square meter unit. In addition to the 15 random sample locations, 3 alternates were generated per reference unit, in case one of the 15 primary locations is inaccessible during the design investigation. In the event that a reference unit is deemed unsuitable for sampling, a backup reference unit will be selected, and sample locations will be chosen using the same process.

The results of laboratory analytical sampling from background areas will be evaluated using the one-way analysis of variance (ANOVA) method to compare group means for each of the background study reference units. The F values, or the ratio of mean squares between groups and the mean squared within groups, will be compared to a critical value (calculated with an $\alpha = 0.05$) to determine whether or not the difference in means is likely to be due to chance. If the F value is less than the critical value, the data sets will be considered an appropriate representation of regional background.

Based on the results of the ANOVA, acceptable background units will be compared to Buffer Zone and Lot 2A2 survey units via t-test, or other statistical analysis as discussed in the QAPP.

A discussion of sampling design and rationale, as well as data quality objectives associated with the background study, is included in the QAPP. The QAPP describes the decision-making process associated with determining if radionuclide concentrations in the Buffer Zone and Lot 2A2 are reduced to background (PSQ-2).

Surface soils will be sampled in accordance with the FSP, and all laboratory analytical samples will be prepared and submitted in accordance with the DMP and QAPP.

3.2.5 Investigation of Potential Impacts to Drainage Areas (DIO #6)

The potential exists for radionuclides associated with the site to have been transported from Areas 1 and 2 through erosion of surficial RIM during rain events and subsequently deposited in drainage areas adjacent to the site.

In Area 1 surficial runoff flows into the perimeter drainage ditch, which ultimately feeds into the surface water body to the north of Area 2 (Northern Surface Water Body), as discussed in the RIA (ESMI 2018a) and as shown on Figure 14.

The majority of surface water runoff from Area 2 ultimately flows into either the Northern Surface Water Body or on to the Buffer Zone, beyond which lies the Earth City Flood Control Channel (ESMI 2018a).

Sediment samples from the areas discussed below will be collected and submitted for laboratory analysis to address Section 3.6 of the SOW. Sediment sampling details and methods are described in the FSP. Laboratory samples will be collected and submitted for analysis in accordance with the procedures outlined in the QAPP and DMP.

Further discussion of surface water flow patterns and sediment deposition is included in the RIA. A discussion of sampling design and rationale, as well as data quality objectives associated with evaluating impacts to drainage areas (PSQ-3), is included in the QAPP.

3.2.5.1 Northern Surface Water Body

The Northern Surface Water Body is a catchment area for the majority of surficial runoff from Areas 1 and 2 via the perimeter drainage ditch. Historical sediment samples were collected from the banks of this drainage ditch as well as from other on-site drainage areas (Figure 14A). Radiological data will be recollected from these sediments to verify previous results during the design investigation.

A review of historical aerial imagery was performed during the RI and concluded that "the North Surface Water Body did not exist in 1941 but does appear on the 1953 aerial photograph" (EMSI 2018a). The RIA also states that the "perimeter of the North Surface Water Body has been inspected by the OU-1 Respondents, Bridgeton Landfill and EPA and no outlet structure or points of discharge from the North Surface Water body were identified" (EMSI 2018a). Based on this information, the extent of potential site-derived radiological impacts due to erosion of surficial RIM in Area 1 and from the southeastern portion of Area 2 are presumed to be topographically constrained to the perimeter drainage ditch conveying runoff to the impoundment, and the North Surface Water Body itself.

Deposition within the North Surface Water body must have begun following the formation of this feature, between 1941 and 1953, and likely continues into the present day. Sediment samples will be collected within the North Surface Water Body to measure the thickness of overlying sediment, which will then be used to calculate a range of possible deposition rates.

Historically sampled locations from the perimeter drainage ditch and new sediment samples are proposed for collection during the design investigation. Newly proposed sample locations maintain the approximate alignment and spacing of historical samples but extend from the mouth of the perimeter drainage ditch approximately 0.25 miles to the edge of the water feature (Figure 14B). New sediment sampling locations were proposed from the mouth of the perimeter drainage ditch where a decrease in water velocity may result in deposition of suspended sediments. The regular spacing of samples will allow for the delineation of the extent of new sediment deposition and any associated impacts. Sediment samples will be collected between the mid-line of the drainage ditch and the southwestern bank to account for deposition from both the drainage ditch and potential erosion from the landfill slope, unless otherwise dictated by the bathymetric survey or other direct evidence of sedimentation.

Relatively little current data (e.g., water depth) is available related to the Northern Surface Water Body, therefore a bathymetric survey will be performed to identify depositional features (outwash fans, ripples) and/or erosional features (channels, runnels) in the sediment surface. Bathymetric data may be used to shift proposed sample locations based on the identification of erosional/depositional features resulting from visual inspection/ measurements as well as the proposed bathymetric survey described below. Any proposed modification of sediment sample location will be considered in discussion with USEPA.

3.2.5.2 Earth City Flood Control Channel

Surficial runoff from the southwestern region of Area 2 flows down the western landfill slope and onto the Buffer Zone. According to the RIA surficial runoff ponds "unless sufficient water accumulates such that the water reaches the western portion of the Buffer Zone where it can flow overland onto the southwest portions of Lots 2A2 and 2A1, and from there into a culvert that conveys stormwater to the large Earth City stormwater basin located adjacent to Area 2 and the AAA Trailer property," (EMSI 2018a). The investigation of potential impacts to the Buffer Zone and Lot 2A2 is discussed in Section 3.2.4.

Sediment samples will be collected from the influent and effluent ends of the culvert that feeds into the Earth City stormwater basin, as shown on Figure 14B.

3.2.5.3 Bathymetric Survey of Northern Surface Water Body

A bathymetric survey of the sediment surface throughout the Northern Surface Water Body will be performed during the design investigation. Bathymetry data will be collected using a single-beam survey of east-northeast to west-southwest oriented transects along the length of the water feature, with a proposed transect spacing of approximately 15 feet. Additionally, a pole shot topographic/bathymetric survey will be performed along the shoreline to tie-in sediment surface elevations to the surrounding topography. Bathymetric data will be used in conjunction with radiological data collected from sediments to evaluate the potential for erosion of historically deposited materials based on the presence of erosional features.

3.3 Geotechnical Investigation

Geotechnical data and samples will be collected around the perimeters of Area 1 and Area 2 to support the RD objectives for cap design and construction of future stormwater drainage control pond features. Geotechnical data will also be collected from borings installed within waste to further characterize the waste in terms of implementing the remedy (e.g., waste stockpiling, sloping/benching, excavation design).

In addition to geotechnical data needs, these borings will also serve to fulfill the needs of DIOs 1 and 2 by delineating the extent of waste/RIM for boundary confirmation along the perimeters of Area 1 and Area 2, as well as confirm the boundaries of OU-1 and OU-2, as described in Section 3.22.

Proposed perimeter boring locations are shown on Figure 5A, and a detailed summary of data collection needs from each location is included in the FSP.

Geotechnical data will be collected and tested in accordance with applicable American Society for Testing and Materials (ASTM) standards.

3.3.1 Geotechnical Data Needs for Cap Design and Site Management (DIO #7)

Non-waste areas along the outer perimeter of Area 1 and Area 2 will be evaluated for suitability as a termination point for the proposed final cover boundary. Perimeter borings will be installed, and geotechnical samples will be collected to evaluate ground conditions and structural stability along the toe of the landfill. This data will be used during the design of the foundation of the toe berm and/or final cover anchor trench. If data collected during the design investigation indicates that toe conditions are "weak" or compressible, reconfiguration of landfill toe, excavation and replacement of soils, or other engineered methods may be required.

Perimeter borings will generally be installed to a depth of 25 feet BGS, as described in Section 3.2, in areas where site soils are being evaluated for geotechnical data needs pertaining to cap design and site management features (e.g., starter berm and temporary stormwater collection ponds). The expected target depth and data collection needs of each proposed boring is included in the FSP.

During boring installation, split-spoon soil samples will be collected continuously. All blow counts will be recorded, and soils will be visually described and, logged, and each sample will be field scanned with alpha, beta, and gamma detectors to allow for sample collection in accordance with Section 3.2.

Classical geotechnical design requirements such as strength and shear properties, and friction angles will be inferred from soil types and index properties, including organic content if organic soils are preserved and decomposed MSW. A summary of geotechnical analyses is included in the FSP.

Samples will be selected for laboratory testing based on field visual-manual classification (Unified Soil Classification System), as summarized in Section 2.4.1.5 of the FSP) to confirm field descriptions and provide estimates of strength and compressibility of soils using standard geotechnical engineering correlations of index properties and Standard Penetration Test blow counts with strength and compression parameters.

Boring installation and sample collection will be performed in accordance with the FSP, DMP, and QAPP. Once all data collection needs have been satisfied, the borehole will be decommissioned by removing the casing and grouting the borehole to grade, in accordance with applicable state regulations as discussed in the FSP.

3.3.1.1 Landfill Gas

Additional data on current landfill gas and radon gas emissions are not currently anticipated to be needed to advance the design. The final cover construction materials will be imported and their required properties will be designed and specified during the RD process with construction quality assurance testing to demonstrate acceptability.

3.3.2 Geotechnical Data Needs for Waste Evaluation (DIO #9)

Perimeter borings along waste-interface boundaries proposed for RIM delineation and to identify the extent of waste will also be used to collect geotechnical data for waste characterization. Waste material will be tested to provide data related to settlement characteristics, potential gas generation, and handling characteristics for use in the design and implementation of the RA.

Perimeter borings proposed within waste will generally be installed through the vertical extent of the waste and five feet into the alluvial substrate, as described in Section 3.2. The expected target depth for the majority of perimeter borings in waste is roughly estimated to be 60 feet BGS, except for borings proposed along the North Quarry boundary which are estimated to require installation to 100 feet BGS. The expected target depth and data collection needs of each proposed boring is included in the FSP.

Soil samples will be collected continuously during boring installation. Soils will be visually described and logged, and each sample will be field scanned with alpha, beta, and gamma detectors. A summary of geotechnical analyses is included in the FSP.

In addition, field density measurements will be taken during sample collection to evaluate waste settlement and aid in calculation of disposal volumes based on characteristics (moisture content and density) of site-specific waste material.

Geotechnical samples and field tests will be collected from specific proposed perimeter borings, as listed in the FSP, QAPP, and applicable ASTM standards. Once all data collection needs have been satisfied, the boreholes will be decommissioned by removing the casing and grouting the borehole to grade, in accordance with applicable state regulations as discussed in the FSP.

3.3.3 Evaluation of Liquid Levels in Proposed Excavation Areas (DIO 10 and DIO 11)

Leachate will likely be encountered during implementation of the RA. To quantify the volume of leachate that may be encountered and evaluate treatment and/or disposal options, seven locations within the proposed remedial excavation boundaries have been selected for installation of seven standpipe wells. These wells will also be used to evaluate the need for leachate management, as stated in the RAOs.

In addition to standpipe wells, borings have been selected adjacent to the previously observed seep south of the Buffer Zone and areas of perched water documented during the RI to supplement historical data collected and evaluate liquid levels during the design investigation. Standpipe wells are shown with seep and perched water locations on **Figure 15**. Prior to boring installation, these areas will be visually inspected, and the presence of leachate, staining, or iron flocculate will be documented through field notes and photographs.

Standpipe wells will be installed at two proposed boring locations in Area 1 and at five proposed boring locations that fall within, or adjacent to, the expected extent of excavation in Area 2. The locations of standpipe wells, as shown on **Figure 15**, were selected based on the location of proposed borings that may be reused following the collection of soil samples and subsurface measurements (e.g., downhole gamma logging) to provide coverage of proposed excavation areas.

Borings for proposed leachate standpipe wells will undergo data collection (sampling, core scanning, and downhole gamma logging) consistent with the other interior borings.

Proposed standpipe wells will be constructed using 2-inch PVC screen and installed to the maximum vertical extent of the proposed excavation. Construction details for standpipe wells are provided in the FSP.

Laboratory samples will be collected and submitted for analysis, and field tests will be conducted to evaluate leachate volumes and potential off-site disposal and/or on-site treatment methods as discussed in Section 2.6.5 of the FSP.

A list of the leachate parameters is included in the FSP and QAPP. Leachate parameters were selected based on likely permit discharge requirements, expected potential constituents, and treatment considerations. The base list of inorganic and organic parameters comes from Appendix I of 10 CSR (Missouri Code of State Regulations) 80.3 as likely MSW leachate constituents. Total phenols and total toxic organics were added to this as a check of potential elevated levels of less soluble organic compounds that are in Appendix II. Radiological compounds were also included due to their potential presence. Various parameters were added that are not otherwise required in Appendix I but could significantly impact water treatment, such as iron, potassium, dissolved and suspended solids, oil and grease, chemical and biological demand, and pH (field and laboratory), temperature (field and laboratory), and ultraviolet transmittance.

Leachate will be gauged monthly over the course of one year to assess seasonal fluctuation of liquid levels within proposed excavation areas which will, in combination with field testing, support estimation of leachate volumes within the proposed excavation.

During the monthly leachate gauging event, seeps and the “perched water and seepage” locations shown on **Figure 15** will be inspected and photographed. These “perched water and seepage” areas were estimated by McLaren Hart (1996) and may not reflect current conditions.

Standpipe wells will be installed and sampled in a manner consistent with the methods described in the FSP, and any laboratory analytical samples will be collected in accordance with the QAPP and the DMP.

3.4 Groundwater Investigation

No groundwater investigations will be conducted as part of the design investigation. A groundwater monitoring plan will be developed separately as part of the Sitewide Monitoring Plan. Groundwater monitoring requirements for OU-1 will be specified in the Sitewide Monitoring Plan, and the required monitoring will be implemented as part of the OU-3 sitewide groundwater investigations and monitoring activities.

3.5 Utility Investigation

3.5.1 Existing Site Management Utilities (DIO #8)

Current utilities related to site management of the Bridgeton Landfill are shown on **Figure 16A** (Area 1) and **Figure 16B** (Area 2) and primarily consist of gas and leachate collection wells and associated piping. Site management utilities generally exist outside of the proposed work zones of Area 1 and Area 2; however, two borings are proposed to be installed in the near the RIM margin abutting the North Quarry in order to better define RIM extent in the southwestern region of Area 1.

Boring installation is proposed in the vicinity of two landfill gas collection lines, a buried landfill gas lateral collection line as well as an aboveground, 6-inch landfill gas lateral collection line. The proposed boring locations are shown on **Figure 5A**, and care will be taken to protect these utilities during boring advancement.

Bridgeton Landfill representatives will be informed prior to commencement of drilling operations and will be present during proposed boring installation in the vicinity of the North Quarry. In addition, a geophysical survey using ground-penetrating radar will be used to clear the proposed borings in a manner consistent with the methods described in the FSP.

3.5.2 Historical Infrastructure (DIO #8)

In addition to utility infrastructure related to site management at Bridgeton Landfill, the OU-1 Respondents have been directed to investigate and evaluate historical infrastructure in Area 1 for potential removal. Historical utility infrastructure consists of an old underground storage tank, which previously contained diesel fuel, and an existing septic waste holding tank, as well as a utility access hole as shown on **Figure 16A**.

A geophysical survey will be conducted using ground-penetrating radar and electromagnetic induction to identify the footprint and approximate depth of these utilities. Following the precise locating of these utilities, soil borings are proposed throughout Area 1, as outlined above in **Section 3.2**. These borings may be used to evaluate the effect of the historical infrastructure, if any, on the subsurface environment.

Should additional investigation be required, proposed boring locations may be shifted to better evaluate the condition of historical infrastructure. Prior to any drilling operations taking place in the vicinity of the underground storage tank, liquid levels within the tank will be measured, if accessible. Residual liquid and/or product remaining in the tank it will be sampled and evaluated for treatment and/or disposal, if possible.

The utility access hole, a drainage pipe near Area 1, and associated private sewer system will be mapped and the depths to drainage inverts will be measured to the extent possible based on subsurface conditions. These depths will be translated to elevations and coordinates using the revised system discussed below. The outlet invert will also be surveyed and documented for design purposes.

Design information related to replacement/installation of future site septic infrastructure will be addressed in a later design document.

3.6 Topographic Survey

Aerial photography and a topographic survey of the site will be performed prior to drilling operations during the design investigation to better define the existing conditions at the site and to further the RD objectives. Elevation and depth data needs, particularly as they pertaining to the geostatistical model, are discussed in Section 2.2

The expected SOW for the topographic survey at the site includes installation of six concrete monuments with brass discs (i.e., three monuments per radiological area). These discs will be stamped with the control point number and coordinates in NAD83, with elevation referenced to NAVD88.

The newly installed monuments will also be surveyed with reference to the existing site coordinate system and elevation to allow for conversion of historical topographic data from NAD27 into NAD83/NAVD88.

The first phase of the topographic survey will be conducted in OU-1 areas currently free of vegetation and tree canopy in 50-foot grids and grade breaks. In addition, access paths will be demarcated in areas where vegetation clearing is required to survey topographic breaks/grade changes currently obstructed by vegetation.

The second phase of the topographic survey will consist of a survey of break lines after access pathways are cleared through vegetation/canopy areas.

Once the topographic survey is complete, it will be compared to 2005 and other previous data, and all requisite survey data will be converted as needed to meet the requirements outlined in the SOW Section 5.4 (b).

Topographic and land surveying tasks will be conducted to meet the technical requirements outlined in Missouri Department of Transportation Engineering Policy Guides 238.1 and 238.2 and performed by a Missouri-licensed professional land surveyor.

3.7 Wildlife Hazard Mitigation and Monitoring

While the design investigation is ongoing, monitoring will be conducted to evaluate if the investigation creates a potential bird hazard to the safety of aircraft utilizing the nearby St. Louis International Airport (STL). This plan and the associated mitigation of potential bird hazards, if such hazards occur, was prepared by LGL Unlimited. This plan has been submitted to STL personnel for review under separate cover and is summarized below.

Wildlife monitoring, specifically bird monitoring, related to the proposed design investigation work scope, will be focused on the specific areas where drilling is occurring at any given time. As there may be two or more drilling rigs operating simultaneously, a technician at each operating rig will record the location and start and stop times of each operation. The technician will note and record the presence or absence of any birds present within 100 yards of the rig during drilling activities at the start and stop times, including flyovers. Although all avian species will be recorded, the observations will focus on species that are potentially hazardous to aircraft safety and species that might be attracted to the drilling activity, including gulls, Canada geese, American crows, turkey vultures, and European starlings. Should potentially hazardous bird species be attracted to drilling operations, mitigation measures outlined in the Draft West Lake OU-1 Landfill Bird Hazard Monitoring and Mitigation Plan for Design Phase of Remediation Program will be implemented (LGL Unlimited 2020). Measures may include pistol-based pyrotechnics or other measures deemed necessary to deter birds from the area.

4.0 SUPPORTING PLANS

4.1 Field Sampling Plan

The FSP is included as **Appendix A** of this DIWP.

4.2 Quality Assurance Project Plan

The QAPP is included as **Appendix B** of this DIWP.

4.3 Data Management Plan

The DMP is included as **Appendix C** of this DIWP.

4.4 Project Safety, Health, and Environmental Plan

The PSHEP is included as **Appendix D** of this DIWP and includes the Parsons *Project Safety, Health and Environmental Plan*, Feezor's *Subcontractor Safety, Health and Environmental Plan* (SSHEP), and Ameriphysics' SSHEP. Additionally, the PSHEP includes the *West Lake Radiation Safety Plan*, *Emergency Response Plan*, and *Site Management Plan*.

4.5 Geostatistics DIWP Technical Memorandum Evaluation

The Geostatistics DIWP Technical Memorandum Evaluation is included as **Appendix E** of this DIWP.

4.6 Design Investigation Boring Placement Summary

A summary of interior RIM boring placement based on location selection metrics is included as **Appendix F** of this DIWP.

5.0 REFERENCES

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TABLES

TABLE 1 SUMMARY OF INVESTIGATIONS IN OU-1

Type of Work	Year	Conducted By	Scope of Work	Reference Doc
Site Reconnaissance	1994	McLaren/Hart	Identify changed features since 1994 RI/FS Work Plan & conditions that may affect remedial investigations & development of alternatives	RI Addendum (EMSI 2018)
Gamma Surveys	1977	EG&G, DOE	Aerial survey identified 2 areas with external radiation levels up to 100 microR/hour	RI Addendum (EMSI 2018)
	1980-1981	RMC, NRC	Walkover surveys using grid system in Areas 1 & 2 - Levels in both areas had decreased significantly due to added waste & construction fill	
	1994	McLaren/Hart, SEG	Overland survey along transects to identify & delineate (i) areal extents of Areas 1 & 2 and (ii) areas with elevated rad needing additional investigation work	
	2013	EPA-OEM, ASPECT	Rad survey to identify areas with elevated gamma (gamma above background) - 10 of 800 measurements (all in Area 2) indicated elevated level of rad	
	2013-2015	EMSI, et al	Overland surveys of areas with potential for site worker rad exposures during RI investigations which included vegetation clearing, drill pad/road construction, etc.	
	2013-2015	EPA, MDNR	Three off-site radiation surveys including the Bridgeton Municipal Athletic Complex (BMAC)	
	2020 (in progress)	EMSI, et al	Overland surveys to delineate areal extent of non- combustible cover (NCC) over Areas 1 & 2 surface RIM	
Drilling & Sampling	1981	RMC, NRC	43 auger borings in Area 1 & 2, downhole gamma logging, field analyses (61 samples) for U, Ra, and Pb, lab analyses (10 samples) for Th & U isotopes	RI Addendum (EMSI 2018)
	1995	McLaren/Hart, Geotechnology	66 drilled/hand-augered borings, downhole gamma logging, lab analyses of surface/subsurface samples for Priority Pollutants, VOCs, & radioisotopes	
	1997-2000	EMSI, CoLog, Quanterra	12 drilled/hand-augered borings from Area 1 & Ford Property, downhole logging, analyses for radioisotopes, sampling/analyses of Lot 2A2/Buffer Zone	
	2013	FEI, et al	Phase 1A – 68 GCPT soundings in Area 1, no sampling	
	2014	FEI, et al	Phase 1B – 26 GCPT soundings in Area 1, no sampling	
	2014	FEI, et al	Phase 1C – 16 rotosonic & 14 direct-push borings in Area 1, downhole gamma logging, gamma core scans, lab analyses (82 samples) for radioisotopes	
	2015	EMSI, et al	Phase 1D – 18 GCPT + 20 rotosonic borings in Area 1, downhole gamma logging, alpha & gamma core scans, lab analyses (46 samples) for radioisotopes & non-rads	
	2015	EMSI, et al	Additional characterization of Areas 1 & 2 – 27 rotosonic borings, downhole gamma logging, alpha & gamma core scans, lab analyses (64 samples) for radioisotopes & non-rads	
	2015	SSP&A, et al	Fate & Transport study – 10 rotosonic borings in Areas 1 & 2, gamma core scans, lab analyses (22 samples) for radioisotopes, major cations/anions, pH & redox, TOC, XRD, SEM/EDS, CEC, SBLT, & SPLP	

TABLE 1 SUMMARY OF INVESTIGATIONS IN OU-1 (CONTINUED)

Type of Work	Year	Conducted By	Scope of Work	Reference Doc
Drilling & Sampling (Cont'd)	2015-2016	Cotter Corp, et al	Additional characterization of Areas 1 & 2 – 5 rotosonic borings, downhole gamma logging, alpha & gamma core scans, lab analyses (39 samples including archived core samples) for radioisotopes, TCLP, XRD, & non-rads, and independent analyses on behalf of EPA	
Surface Soil Sampling	2016-2018	EMSI, et al	Perimeter & step-out surface soil grab sampling/analyses in conjunction with 2016 NCC installation in Areas 1 & 2 and Area 2 steep slope work in 2018 & lab analyses (130+ samples) for Th-230	Final Report Installation of NCC over RIM (EMSI et al 2019)
Sediment Sampling	1995-1997	McLaren/Hart, EMSI	Assessment of chemical transport potential via sediments & lab analyses of sediment samples (collected from weirs and stormwater drainage) for radioisotopes and non-rads	RI Addendum (EMSI 2018)
	2016-2017	EMSI, et al	10 sediment samples collected from stormwater drainage along west side of St. Charles Rock Road and 3 samples collected Mar 2016 with EPA splits, all analyzed for radioisotopes	

TABLE 2-1
DESIGN INVESTIGATION OBJECTIVES

DIO	Objective	Solution
1	Delineate the extent of waste and RIM associated with OU-1 Areas 1 and 2 sufficiently to confirm the OU-1/OU-2 boundaries.	Installation of 60 perimeter borings Continuous downhole gamma logging Continuous radiological core scanning Targeted laboratory analytical sample collection
2	Further Characterize RIM >52.9 pCi/g	See Table 2-2 for GSMO summary table
3	Further characterize RIM between 7.9 and 52.9 pCi/g	Borings proposed outside the 52.9 pCi/g RIM shell (located by comparing 25-50-75% probability)
4	Compare analytical results of soil samples from off-site reference units to support calculation of a statistically valid background concentration for the Buffer Zone and Lot 2A2	Perform random sampling of four reference areas Perform statistical analysis of analytical results using ANOVA to determine if means represent a viable background activity
5	Determine whether or not the concentrations of radionuclides in the Buffer Zone and Lot 2A2 decision units are statistically greater than background.	Perform random-start sampling of 2,000m2 survey areas Collect samples from 0 - 12 inches below paved/fill horizon Continuous gamma core scan of soil samples. Collect deeper samples if impacts observed at depth.
6	Estimate radionuclide concentrations in drainage areas, including the Northern Surface Water Body and Earth City Flood Control Channel	Recollect subset of historical sediment samples Perform bathymetric survey Collect sediment samples from newly proposed locations
7	Collect geotechnical data needed to further design objectives, such as waste density, moisture content, and oil properties.	Collect geotechnical samples from perimeter borings from in-situ soils and from waste
8	Collect data to assess site infrastructure requiring removal during the RA	Perform full utility markout to identify old infrastructure Use GPR to identify buried infrastructure (e.g. UST)
9	Collect data to characterize materials related to waste acceptance criteria	Collect samples for waste characterization from subset of borings proposed within RIM from highest radiological core scan intervals
10	Evaluate liquid levels within the potential excavation footprint and previously identified seeps	Install 6 standpipe wells within the proposed excavation and 1 standpipe well in seep southeast of Buffer Zone. Gauge all (7) monitoring wells monthly to evaluate seasonal fluctuation in liquid levels Perform monthly inspection of onsite seeps
11	Estimate baseline concentrations of constituents that are important to leachate treatment system design	Collect laboratory analytical samples from new monitoring wells
12	Assess impact of the RA on wildlife attractiveness	West Lake OU-1 Landfill Bird Hazard Monitoring and Mitigation Plan for Design Phase of Remediation Program (LGL Unlimited, 2020)
13	Perform a detailed topographic survey of Areas 1 and 2	Topographic survey to be performed prior to design investigation

Note: Boring count represents the currently proposed design investigation program. The final boring count is subject to change based on document approval and results of the field investigation.

TABLE 2-2
GEOSTATISTICAL MODELING OBJECTIVES

GSMO	Objective	Key Component	Solution
1	Improve correlations between radium, thorium, and gamma	Core Data	Increase sampling density in 40,000 - 500,000 cpm gamma ranges
			Collect samples from randomly selected depth intervals/Standard Deviation Warranted to Sample
		Correlation between core scan and downhole gamma	Sonic drilling combined with short (4-ft) runs
			2020 Sitewide Topo Survey
2	Improve boring/sample spacing and geometry to reduce model uncertainty	Boring Density	2,000 m2 overlay (Figure 6A)
			Standard Deviation Warranted to Sample
		Reduce Standard Deviation throughout Areas 1 and 2	Strategically Placed Borings to reduce standard deviation (Figures 6A-B)
		Evaluating Differential Settlement	Recollect gamma and surface elevation data from NRC PVC borings and compare to historical data sets.
3	Further define activities and extent of RIM	Thorium-driven areas	Lateral Extent - gridded borings and borings placed based on Standard Deviation Warranted to Sample
			Vertical Extent - Random samples if low/no gamma response.
		Isolated Pockets (<12 ft B2005GS)	Borings Proposed inside and around isolated pockets (Figure 8B).
		Deeper RIM (16 - 20 ft B2005GS)	All borings drilled to 20-ft, with downhole gamma through total depth (Figure 8B).
		52.9pCi/g boundary	Visual comparison of 25%, 50%, 75% boundaries (Figure 8A).
			Increase boring density along margin (Figure 8A).
			Borings placed where elevated overland gamma counts exist outside modeled RIM shell (Figure 8A).

TABLE 3

DESIGN INVESTIGATION DATA COLLECTION SUMMARY

Description	Number of Borings/Sample Locations	Number of Samples (Radiological)	Number of Samples (Geotechnical)
Interior RIM (Area 1)	46	230	0
Interior RIM (Area 2)	111	603	0
Enclosure A Borings	6	150	17
Area 1 Perimeter Borings (Geotechnical)	17	238	17
Area 2 Perimeter Borings (Geotechnical)	23	336	22
Area 1 Perimeter Borings (Waste Evaluation)	2	80	4
Area 2 Perimeter Borings (Waste Evaluations)	18	450	36
Liquid Level and Seep Evaluation (Monitoring Wells)	7	7	0
Buffer Zone and Lot 2A2 RIM Investigation	154	308	0
Buffer Zone and Lot 2A2 Background Study	60	120	0
Sediment Areas Investigation	14	41	0
TOTAL BORINGS(1)(2)	223	-	-
TOTAL SAMPLES(3)	-	2,563	96

Notes:
1. Total borings only reflects borehole count and does not include sums for Buffer Zone, Lot 2A2, or sediment sampling locations.
2. Thorium-driven and hybrid borings and associated samples are encompassed in "Interior RIM (Area 1)" and "Interior RIM (Area 2)" categories. See FSP for further breakdown.
3. Total sample count does not include QA/QC samples, duplicate samples (collected 1 per perimeter boring in waste), or paired nugget/variance samples (collected 1 pair per 20 samples), or any additional samples collected following duplicate analysis. Additionally, sample counts must be considered approximate, since number of samples may be impacted field conditions such as core/spoon recoveries.

FIGURES

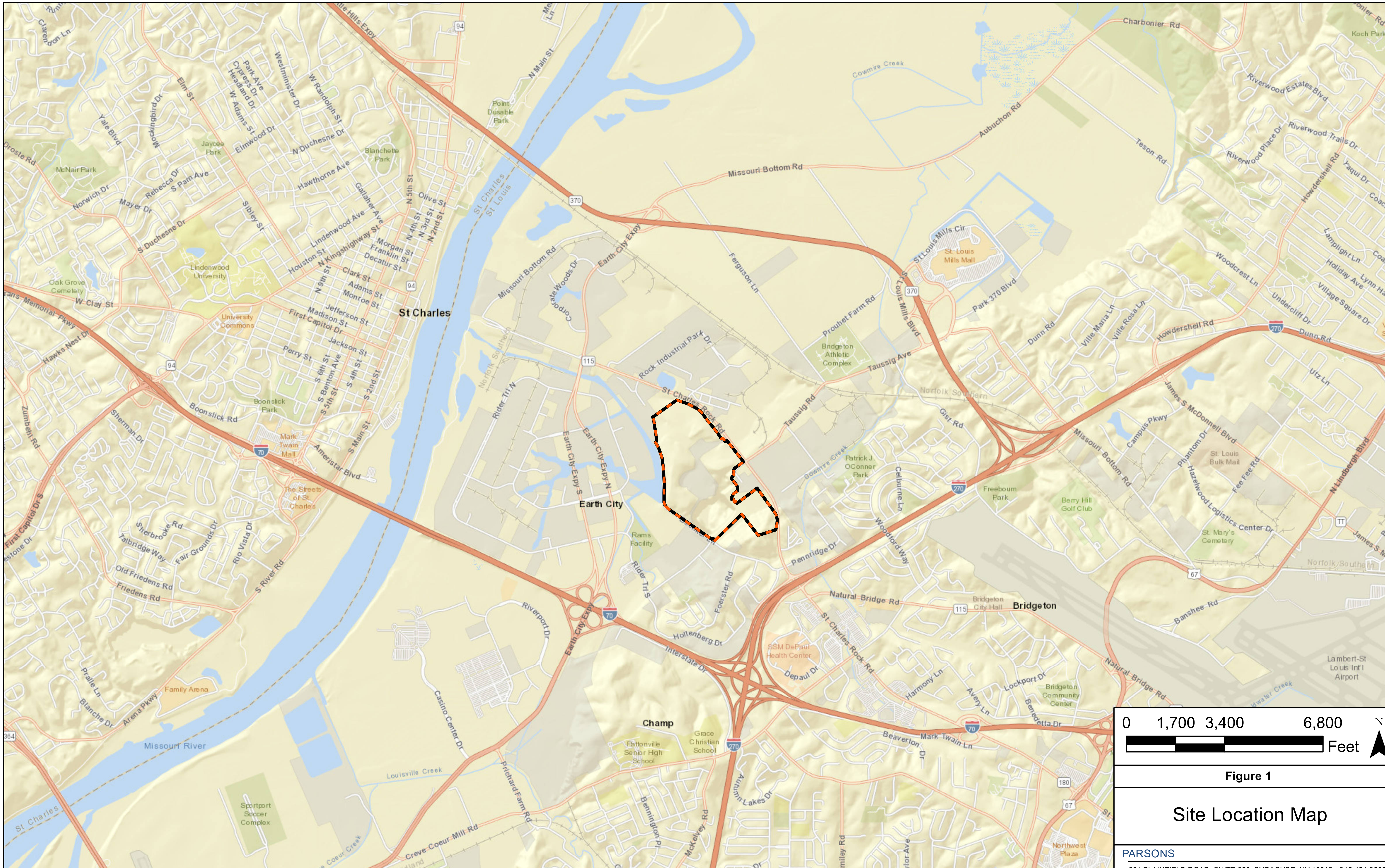

Figure 1

Site Location Map

PARSONS

301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 * 315-451-9560

Plotted By: CS

Plot Date: 9/11/2020

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Figure 2

Site Aerial Map

Plotted By: CS

Plot Date: 9/11/2020

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On Site Soil and Borrow and Stockpile Area
Stormwater Retention Basin
Bridgeton Landfill
Closed Demolition Landfill
Inactive Sanitary Landfill
Landfill Boundary
Superfund Site
Lot 2A2 B & C, Buffer Zone
OU-1 Area Boundary

Figure 3

Site Areas

PARSONS
301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 ● 315-451-9560

Plotted By: TS
Plot Date: 6/4/2020

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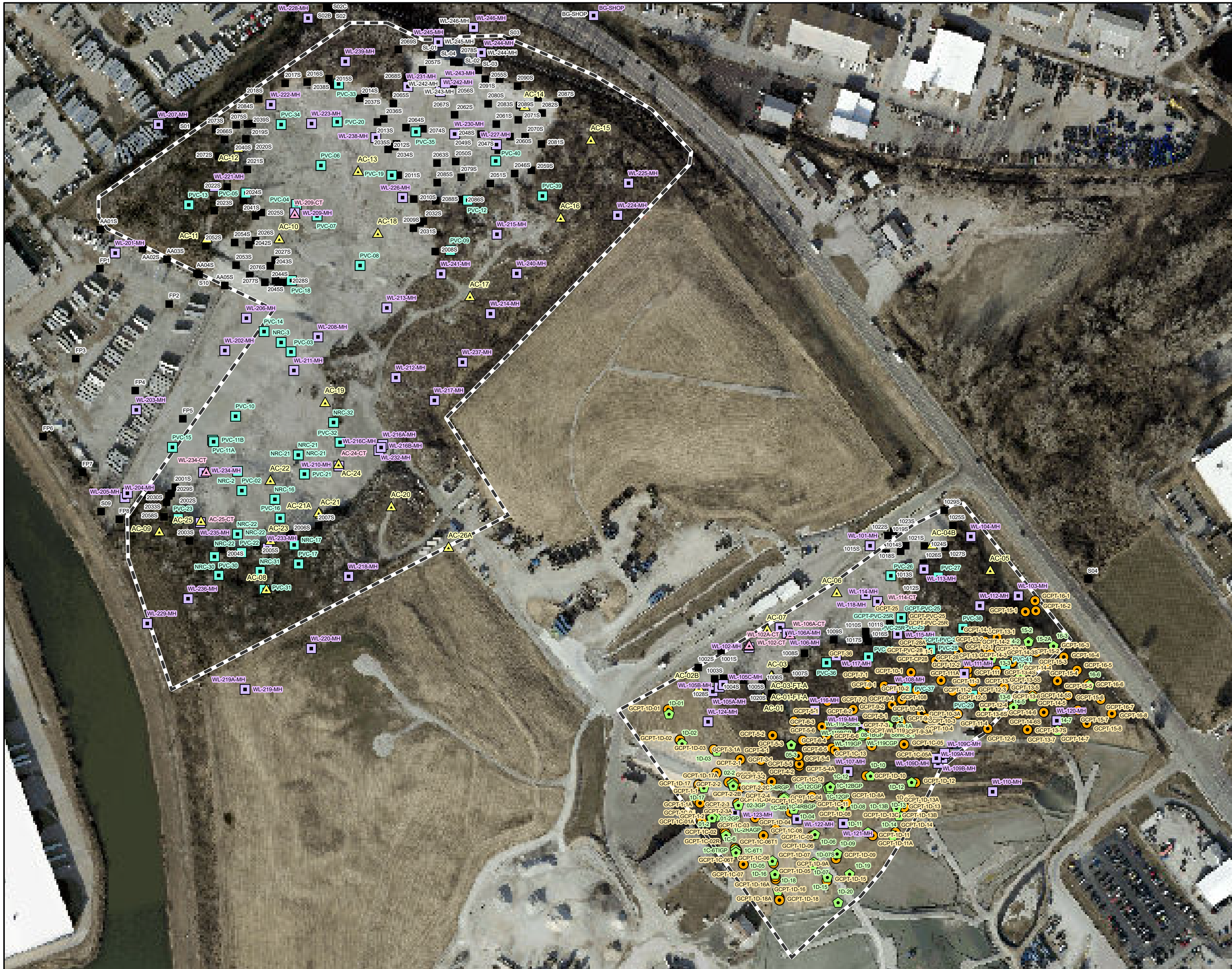

Historical Data

- Additional Characterization Data
- Phase1 Data (no GCPT)
- Cotter Data
- McLaren/Hart Data
- NRC Data
- GCPT Locations
- Surface Samples
- OU-1 Area Boundary

0 120 240 480 Feet

N

Figure 4

Historical Data

PARSONS
301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-451-9560

Plot Date: 9/11/2020 Plotted By: CS

Document Path: C:\Users\p002737e\Documents\West Lake\ArcMap Data\DIWP Figures\West Lake Package.aprx

Proposed Borings

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings
- OU-1 Area Boundary

0 120 240 480 Feet

N

Figure 5A

Proposed Area 1 and Area 2 Borings

PARSONS
301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-451-9560

Plot Date: 9/11/2020 Plotted By: CS

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Figure 5B

Estimated Inert Fill Areas

PARSONS

301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 * 315-451-9560

Plotted By:

Plot Date: 9/11/2020

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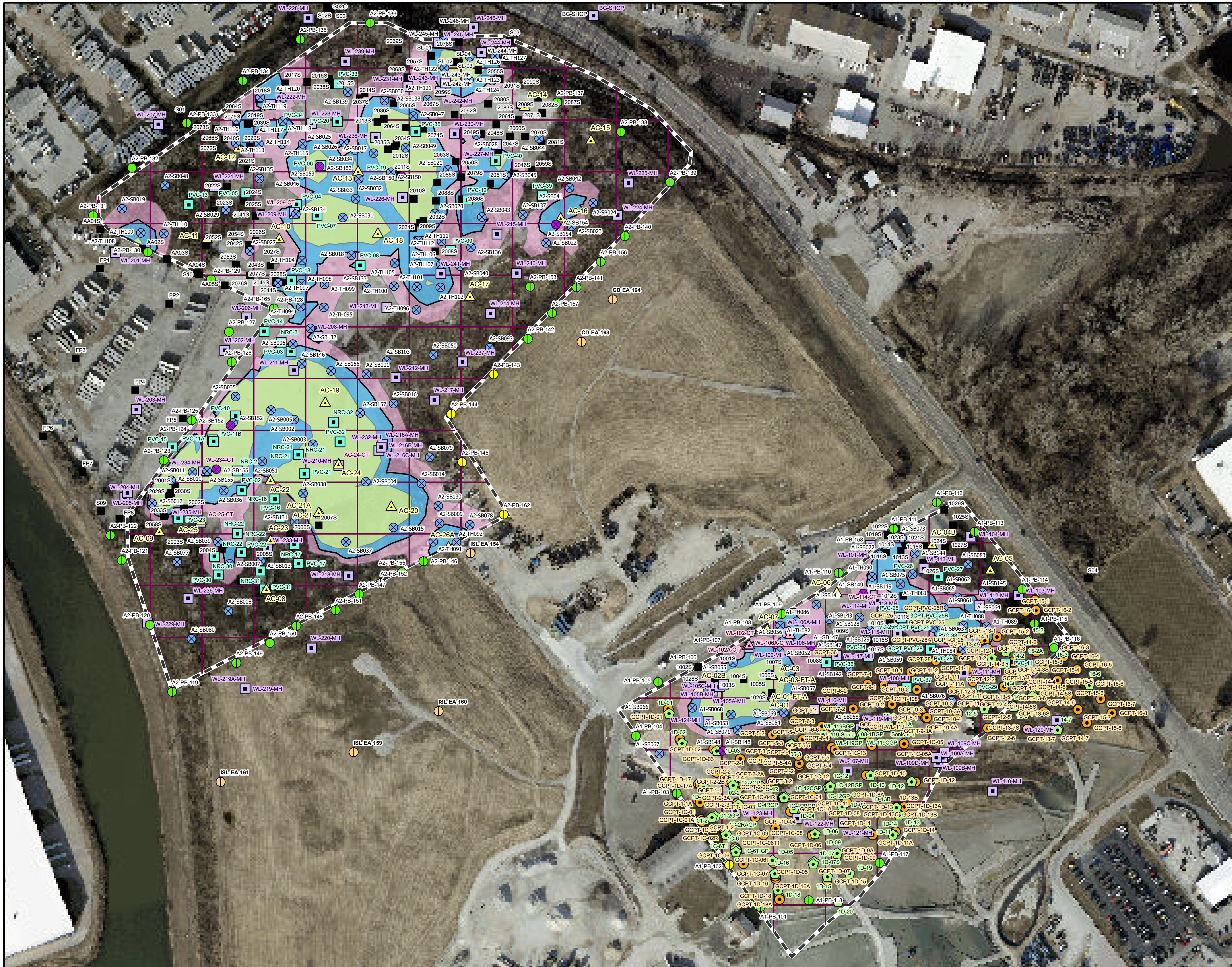

Proposed Borings

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings

Historical Data

- Additional Characterization Data
- Phase1 Data (no GCPT)
- Cotter Data
- McLaren/Hart Data
- NRC Data
- GCPT Locations
- Surface Samples
- Grid

25%, 50%, 75% Probabilities

- 75% probability of being RIM >52.9pCi/g
- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- 25% probability of being RIM >52.9pCi/g
- OU-1 Area Boundary

0 120 240 480 Feet

N

Figure 6A

Proposed Area 1 and Area 2 Borings and Historical Data

PARSONS

301 PLAINFELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-451-9560

Plot Date: 9/11/2020 Plotted By: CS

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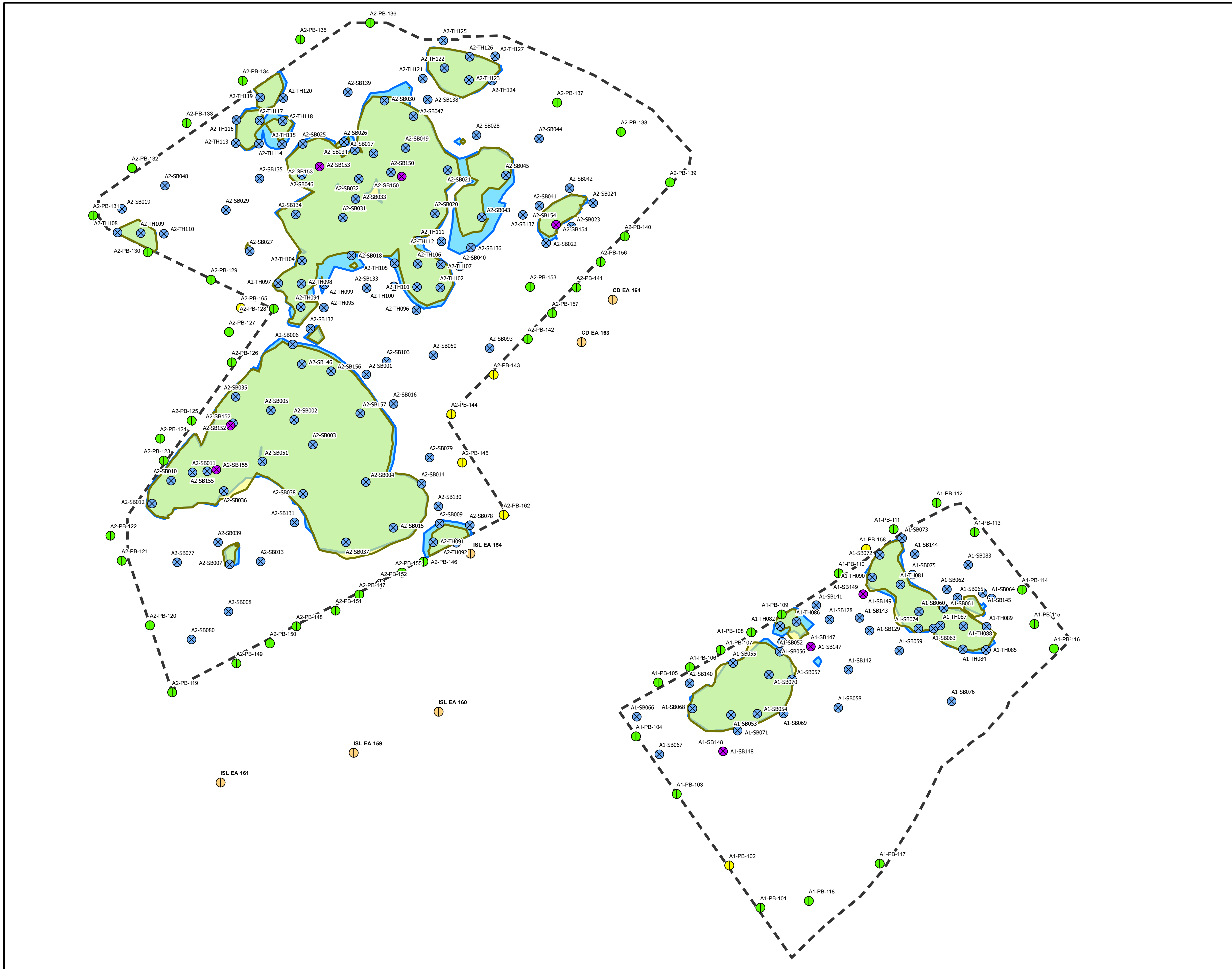

Proposed Borings

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings

Final vs. Intermediate Cumulative Distribution Functions (CDFs)

- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS (Final CDF, 50% Probability)
- Intermediate CDF - Maximum extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- OU-1 Area Boundary
- Overlap between Final and Intermediate CDFs appear green

0 120 240 480 Feet

N

Figure 6B

Comparison of Final and Intermediate Cumulative Distribution Function (CDF) RIM >52.9 pCi/g Extents

PARSONS
301 PLAINF ELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-451-9560

Plot Date: 9/11/2020 Plotted By: CS

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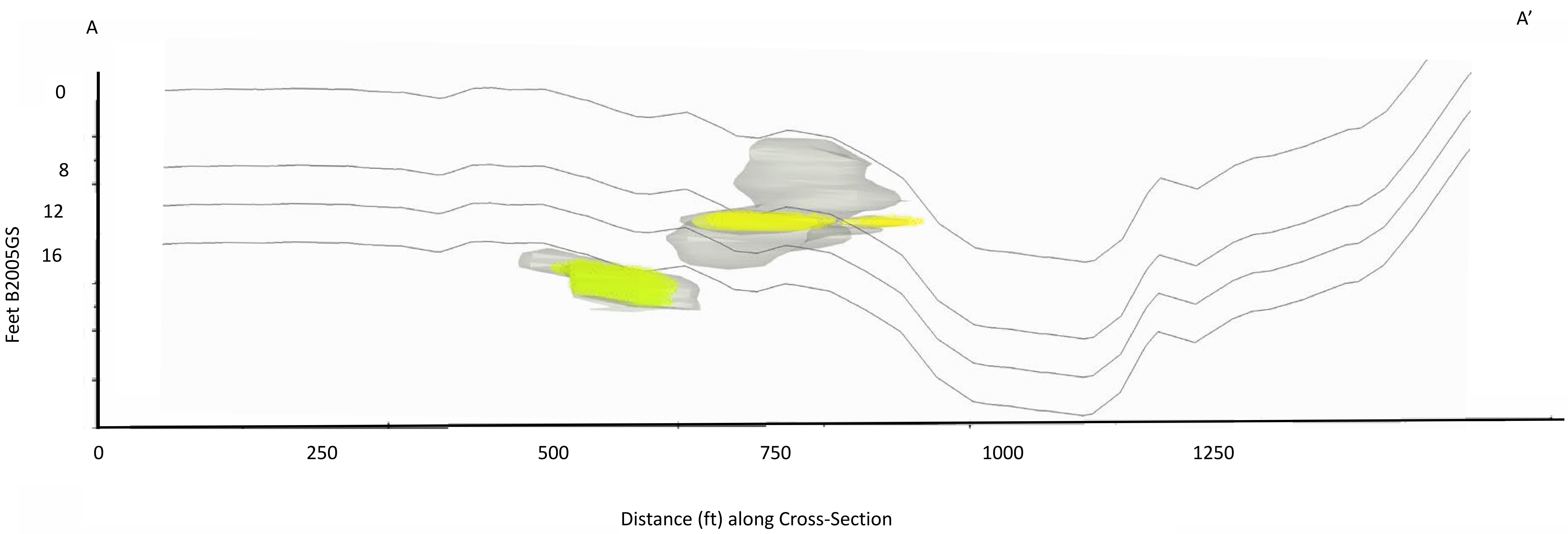
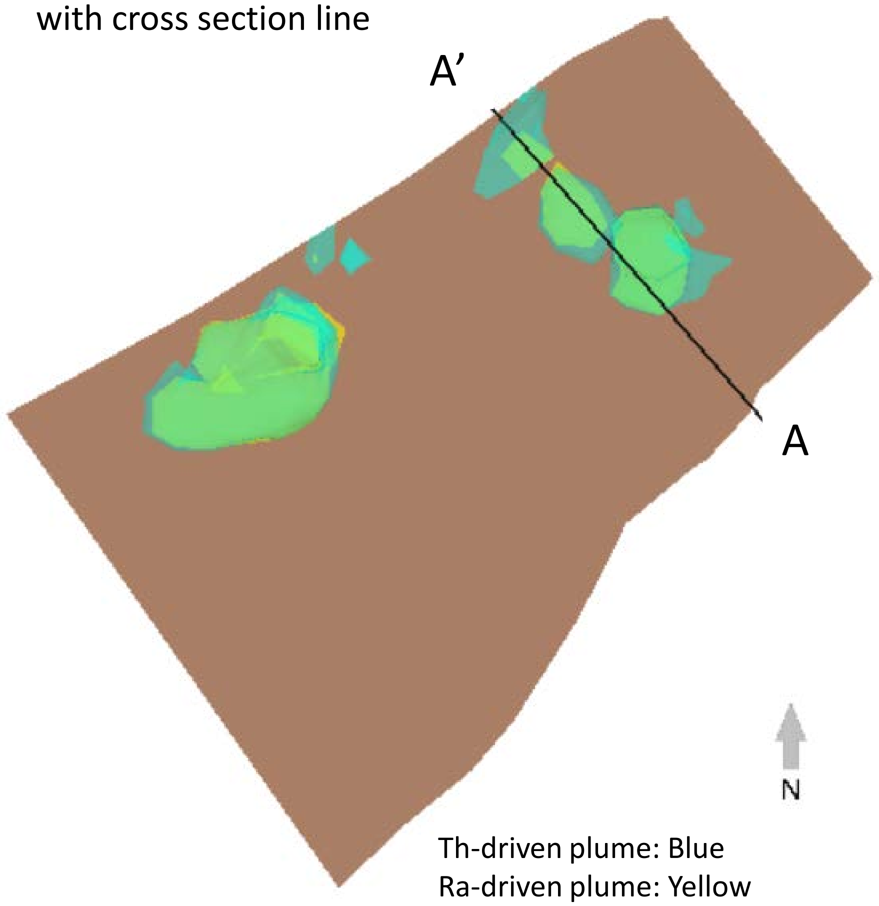


Plan view of 50% probability of RIM > 52.9 pCi/g with cross section line



Notes:

1) Color Ramp is probability of non-exceedance (<50%) of analyte-specific (radium or thorium) RIM (52.9 pCi/g) that intersects cross section.
2) Transparent light-gray is analyte-specific RIM (52.9 pCi/g) with <50% probability of non-exceedance in modelspace adjacent to cross section.
3) Vertical exaggeration is 8x.
4) Extent of RIM shown is 0-20 feet B2005GS.

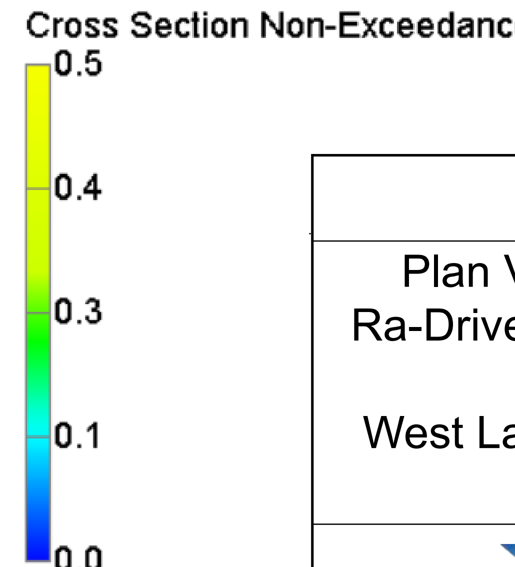
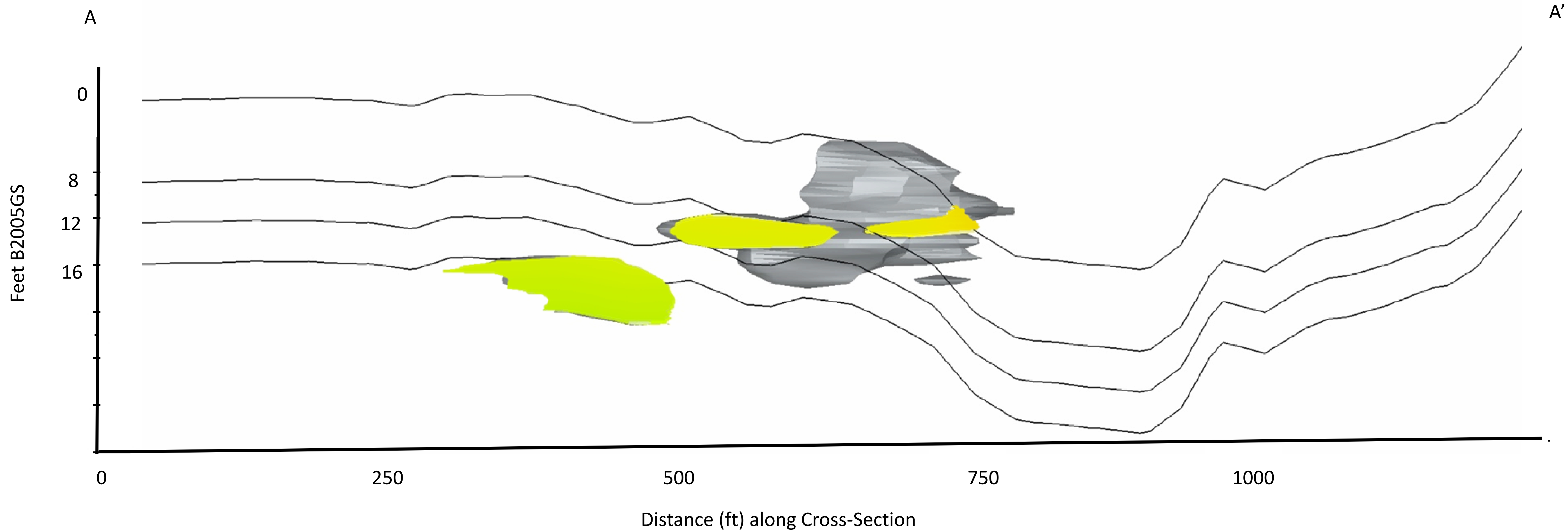


FIGURE 7A

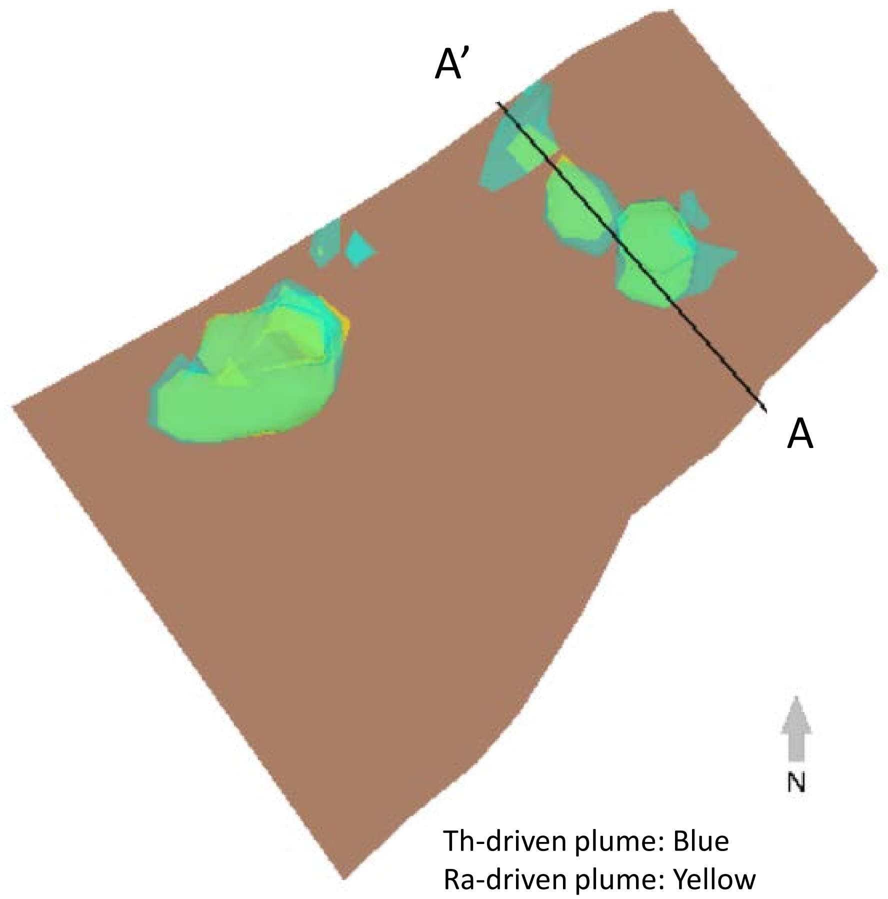
Plan View and Cross Section of Ra-Driven RIM >52.9 pCi/g in Area 1 Cross Section A-A’
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Plan view of 50% probability of RIM > 52.9 pCi/g with cross section line



Notes:

1) Color Ramp is probability of non-exceedance (<50%) of analyte-specific (radium or thorium) RIM (52.9 pCi/g) that intersects cross section.
2) Transparent light-gray is analyte-specific RIM (52.9 pCi/g) with <50% probability of non-exceedance in modelspace adjacent to cross section.
3) Vertical exaggeration is 8x.
4) Extent of RIM shown is 0-20 feet B2005GS.

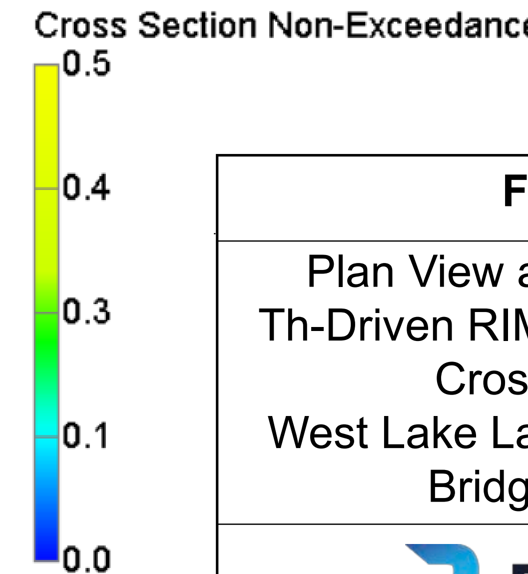
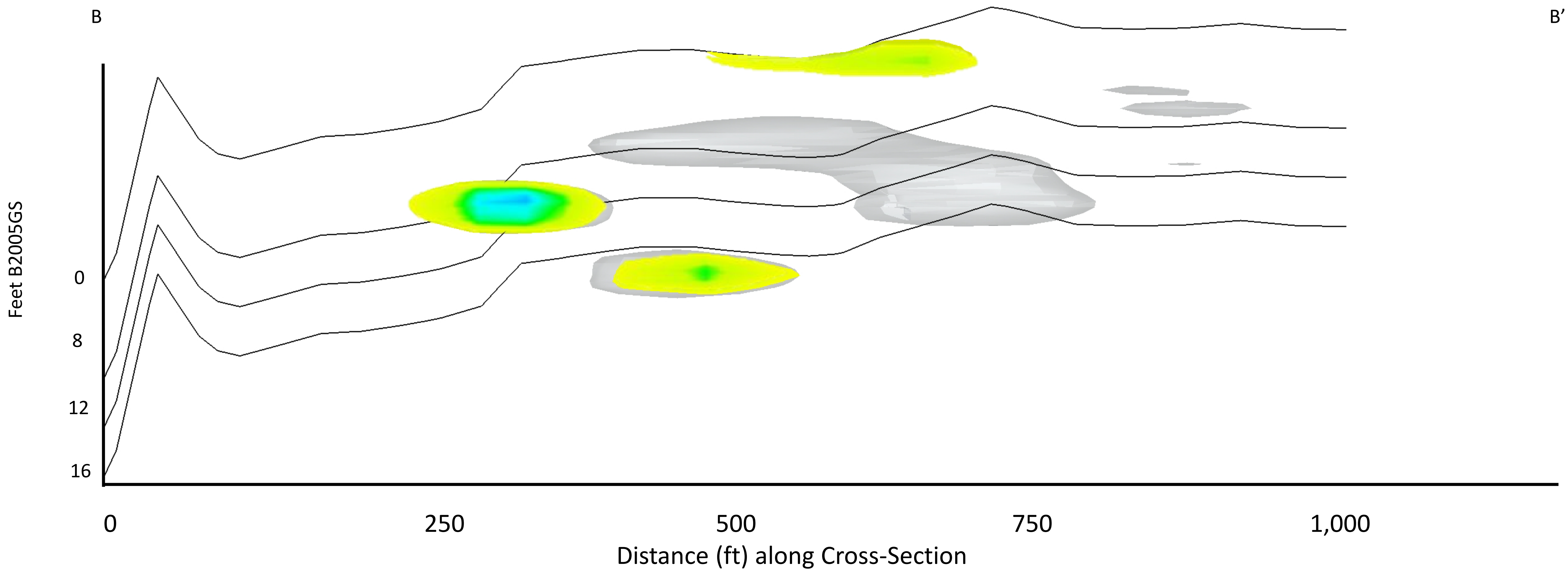


FIGURE 7B

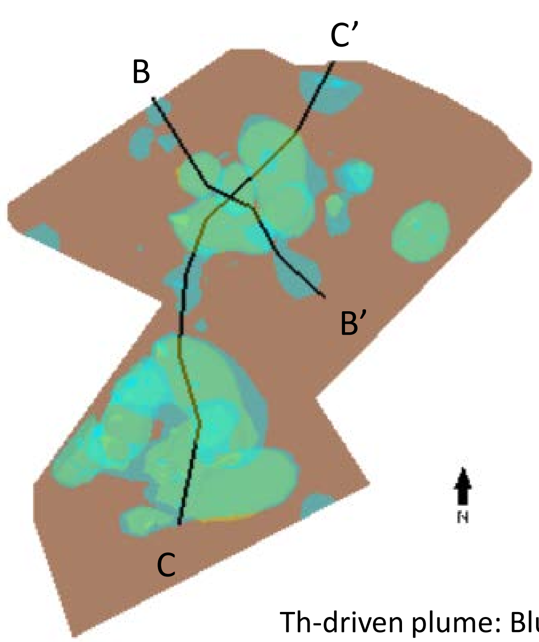
Plan View and Cross Section of Th-Driven RIM >52.9 pCi/g in Area 1 Cross Section A-A’ West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Plan view of 50% probability of RIM > 52.9 pCi/g
with cross section line



Th-driven plume: Blue
Ra-driven plume: Yellow

Notes:

1) Color Ramp is probability of non-exceedance (<50%) of analyte-specific (radium or thorium) RIM (52.9 pCi/g) that intersects cross section.
2) Transparent light-gray is analyte-specific RIM (52.9 pCi/g) with <50% probability of non-exceedance in modelspace adjacent to cross section.
3) Vertical exaggeration is 8x.
4) Extent of RIM shown is 0-20 feet B2005GS.

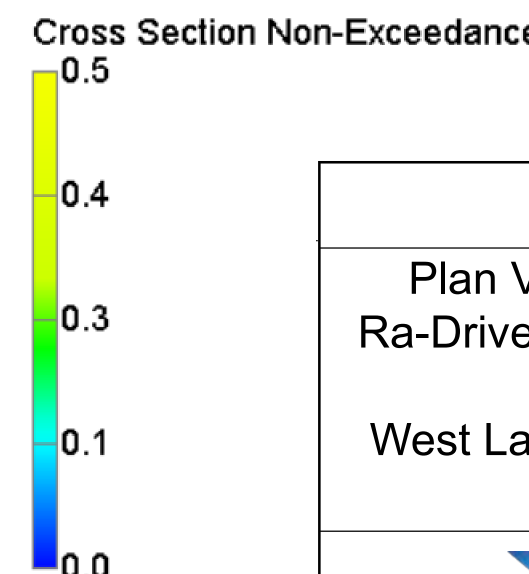
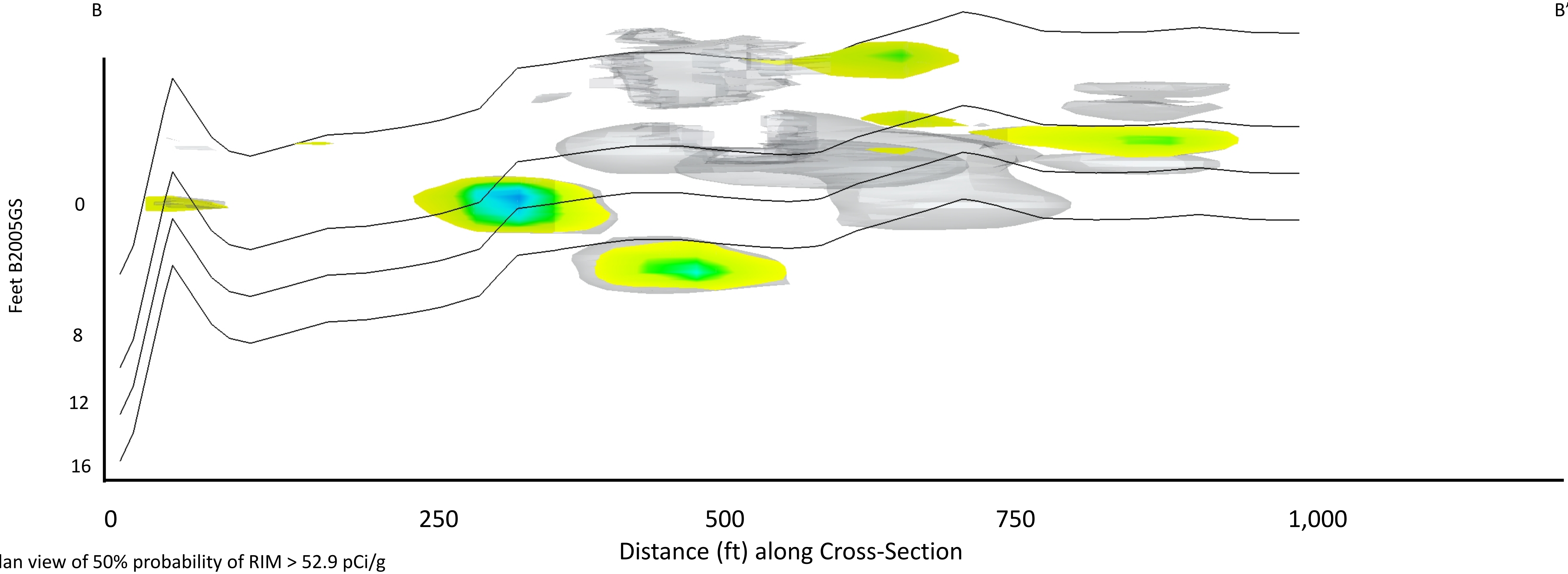


FIGURE 7C

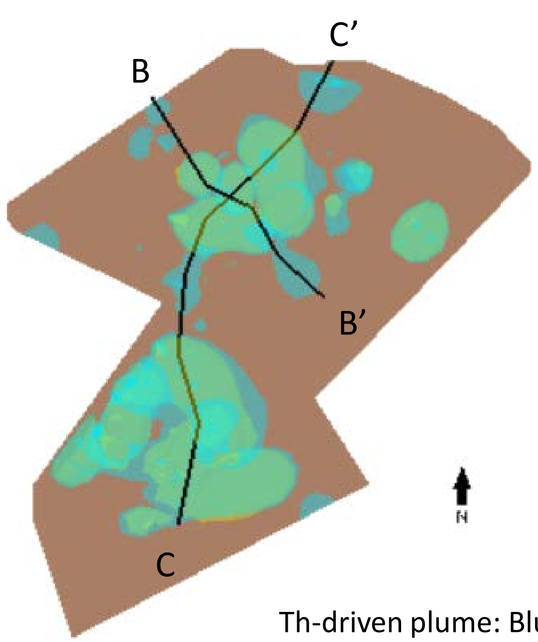
Plan View and Cross Section of Ra-Driven RIM >52.9 pCi/g in Area 2 Cross Section B-B’
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Plan view of 50% probability of RIM > 52.9 pCi/g
with cross section line



Th-driven plume: Blue
Ra-driven plume: Yellow

Notes:

1) Color Ramp is probability of non-exceedance (<50%) of analyte-specific (radium or thorium) RIM (52.9 pCi/g) that intersects cross section.
2) Transparent light-gray is analyte-specific RIM (52.9 pCi/g) with <50% probability of non-exceedance in modelspace adjacent to cross section.
3) Vertical exaggeration is 8x.
4) Extent of RIM shown is 0-20 feet B2005GS.

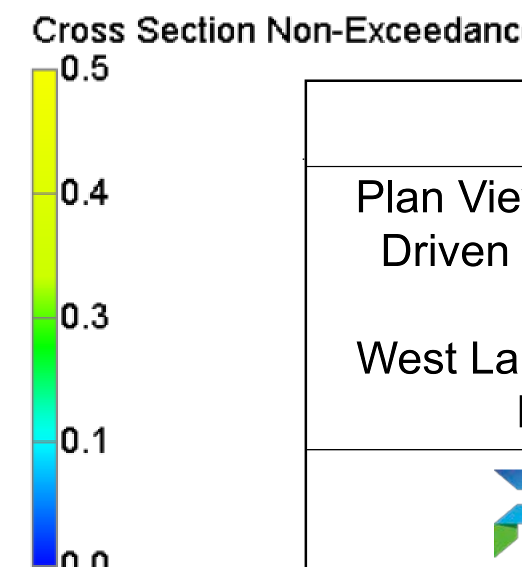
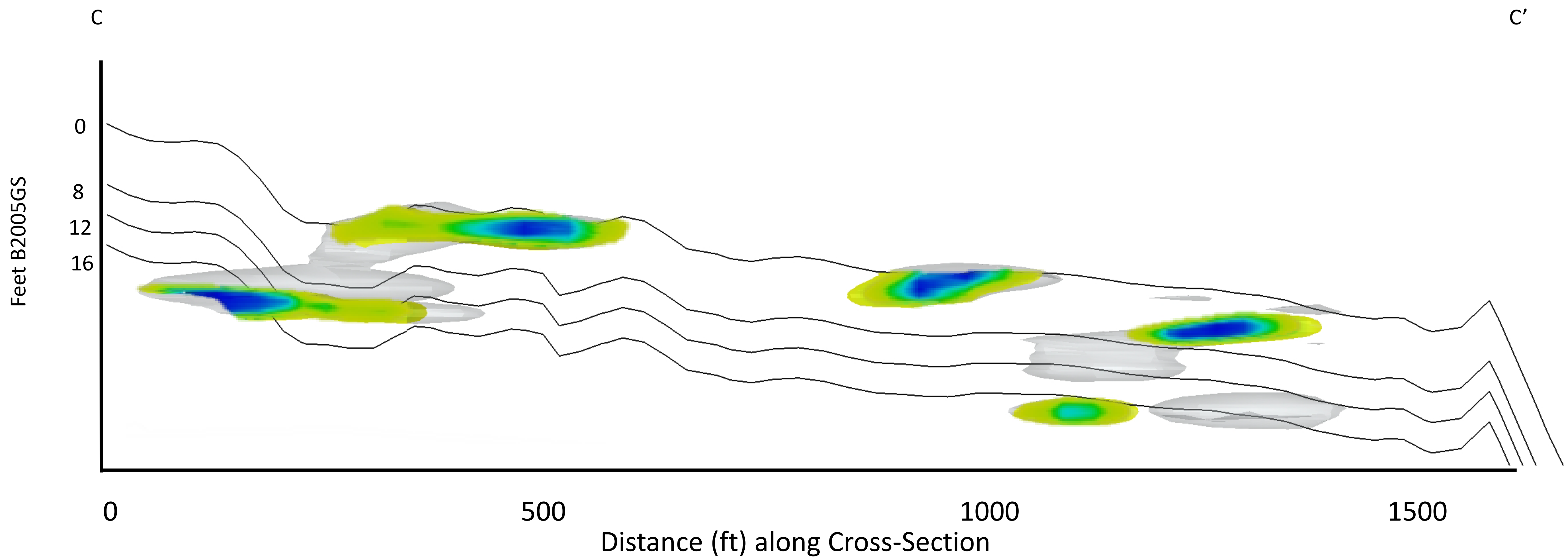


FIGURE 7D

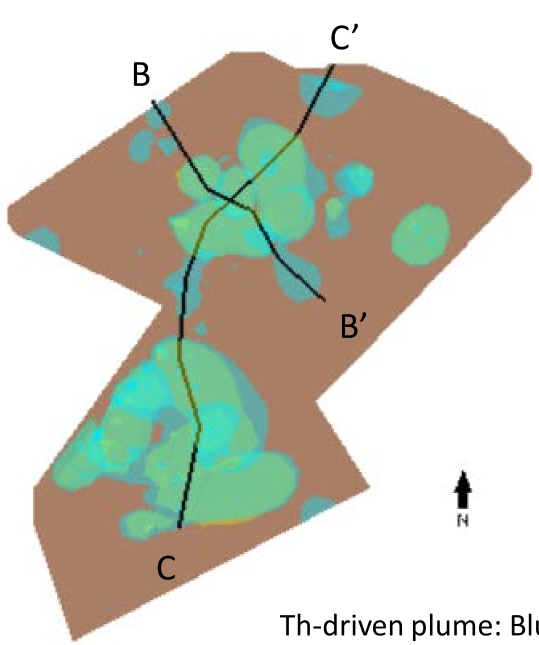
Plan View and Cross Section of Th-Driven RIM >52.9 pCi/g in Area 2
Cross Section B-B'
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY



Plan view of 50% probability of RIM > 52.9 pCi/g
with cross section line



Th-driven plume: Blue
Ra-driven plume: Yellow

Notes:

1) Color Ramp is probability of non-exceedance (<50%) of analyte-specific (radium or thorium) RIM (52.9 pCi/g) that intersects cross section.
2) Transparent light-gray is analyte-specific RIM (52.9 pCi/g) with <50% probability of non-exceedance in modelspace adjacent to cross section.
3) Vertical exaggeration is 8x.
4) Extent of RIM shown is 0-20 feet B2005GS.

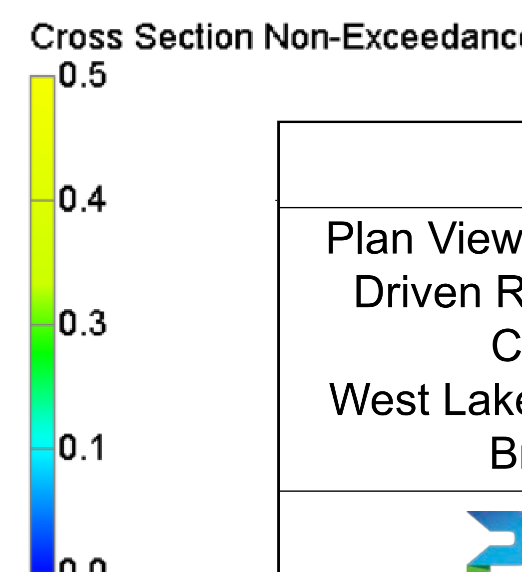
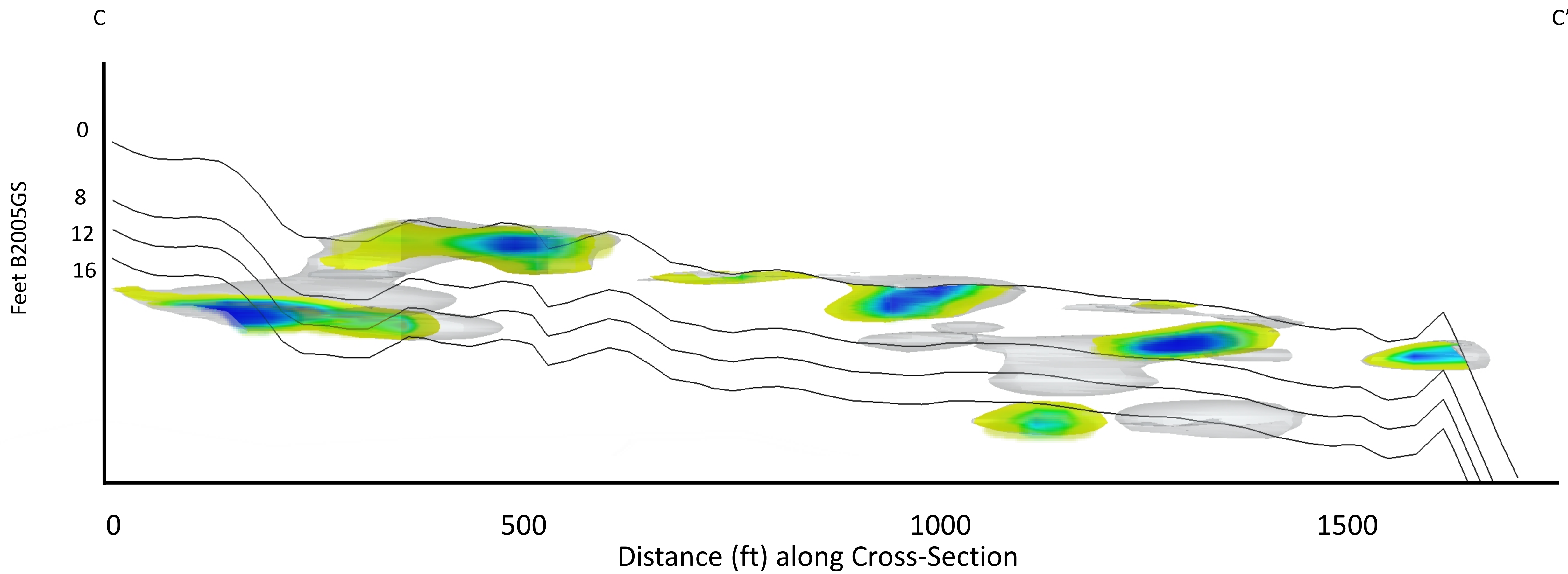


FIGURE 7E

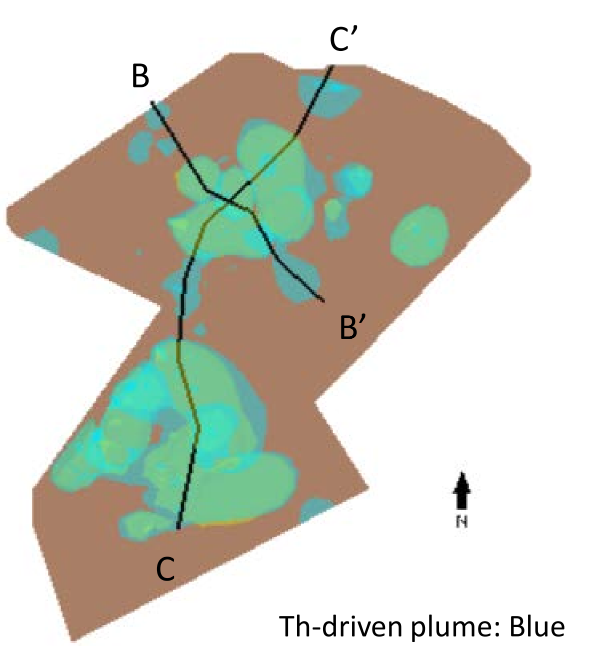
Plan View and Cross Section of Ra-Driven RIM >52.9 pCi/g in Area 2
Cross Section C-C’
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Plan view of 50% probability of RIM > 52.9 pCi/g with cross section line



Th-driven plume: Blue
Ra-driven plume: Yellow

Notes:

1) Color Ramp is probability of non-exceedance (<50%) of analyte-specific (radium or thorium) RIM (52.9 pCi/g) that intersects cross section.
2) Transparent light-gray is analyte-specific RIM (52.9 pCi/g) with <50% probability of non-exceedance in modelspace adjacent to cross section.
3) Vertical exaggeration is 8x.
4) Extent of RIM shown is 0-20 feet B2005GS.

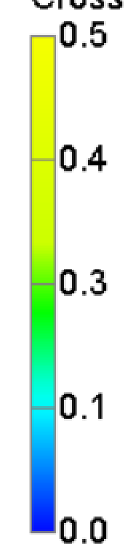


FIGURE 7F

Plan View and Cross Section of Th-Driven RIM >52.9 pCi/g in Area 2
Cross Section C-C’
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY

Proposed Borings

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings

Overland Gamma Survey

- Overland Gamma Survey >1000 μR/hr
- Overland Gamma Survey 250-1000 μR/hr
- Overland Gamma Survey 40-250 μR/hr

25%, 50%, 75% Probabilities

- 75% probability of being RIM >52.9pCi/g
- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- 25% probability of being RIM >52.9pCi/g
- OU-1 Area Boundary

0 120 240 480 Feet

N

Figure 8A

RIM greater than 52.9 pCi/g Boundaries

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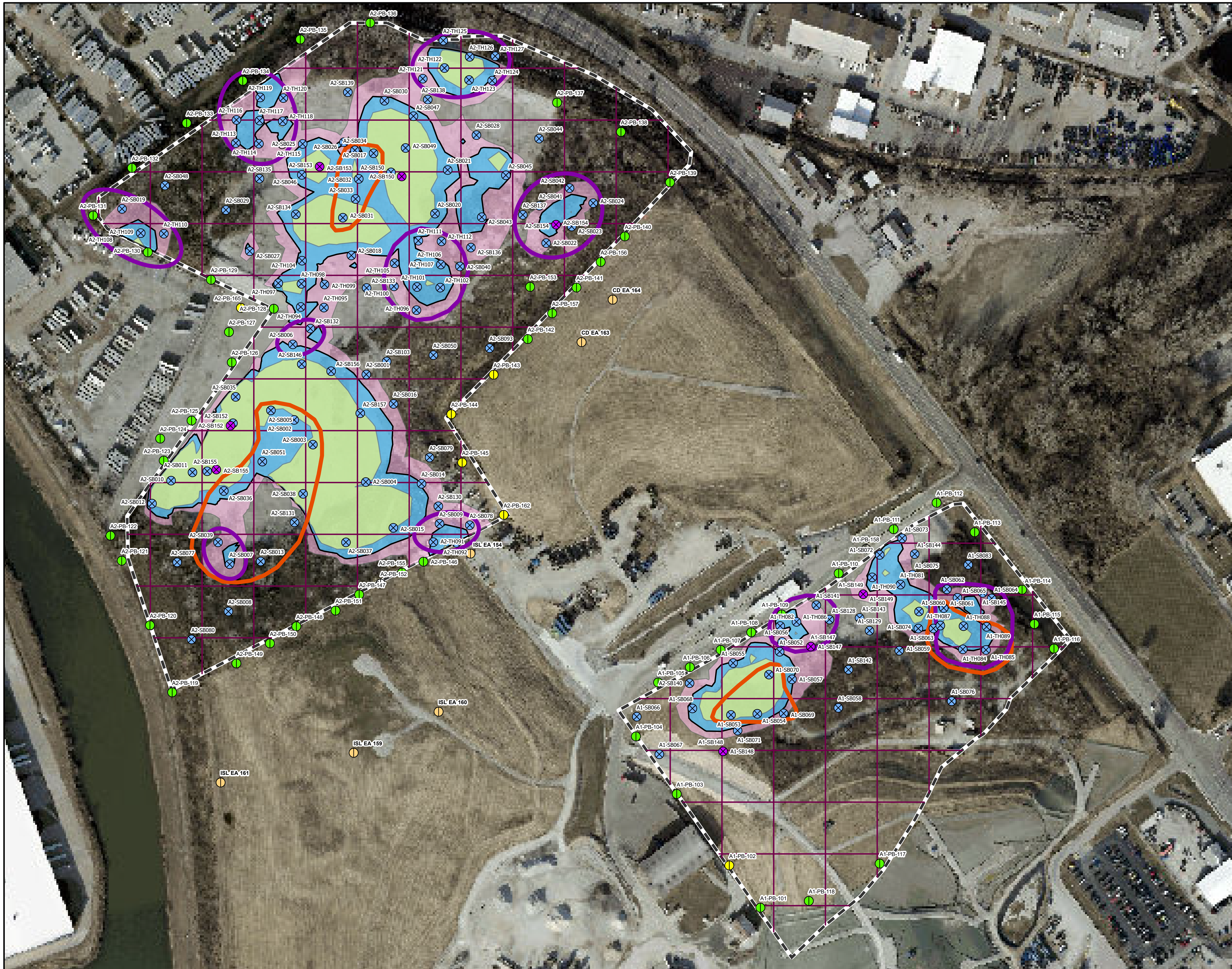
Plot Date: 9/11/2020 Plotted By: CS

Document Path: C:\Users\p002737e\Documents\West Lake\ArcMap Data\DIWP Figures\West Lake Package.aprx



Proposed Borings

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings
- Isolated Pockets
- Deeper RIM
- Grid

25%, 50%, 75% Probabilities

- 75% probability of being RIM >52.9pCi/g
- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- 25% probability of being RIM >52.9pCi/g
- OU-1 Area Boundary

0 120 240 480 Feet

N

Figure 8B

Isolated Pockets and Areas of Deeper RIM

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Plot Date: 9/11/2020 Plotted By: CS

Document Path: C:\Users\p002737e\Documents\West Lake\ArcMap Data\DIWP Figures\West Lake Package.aprx

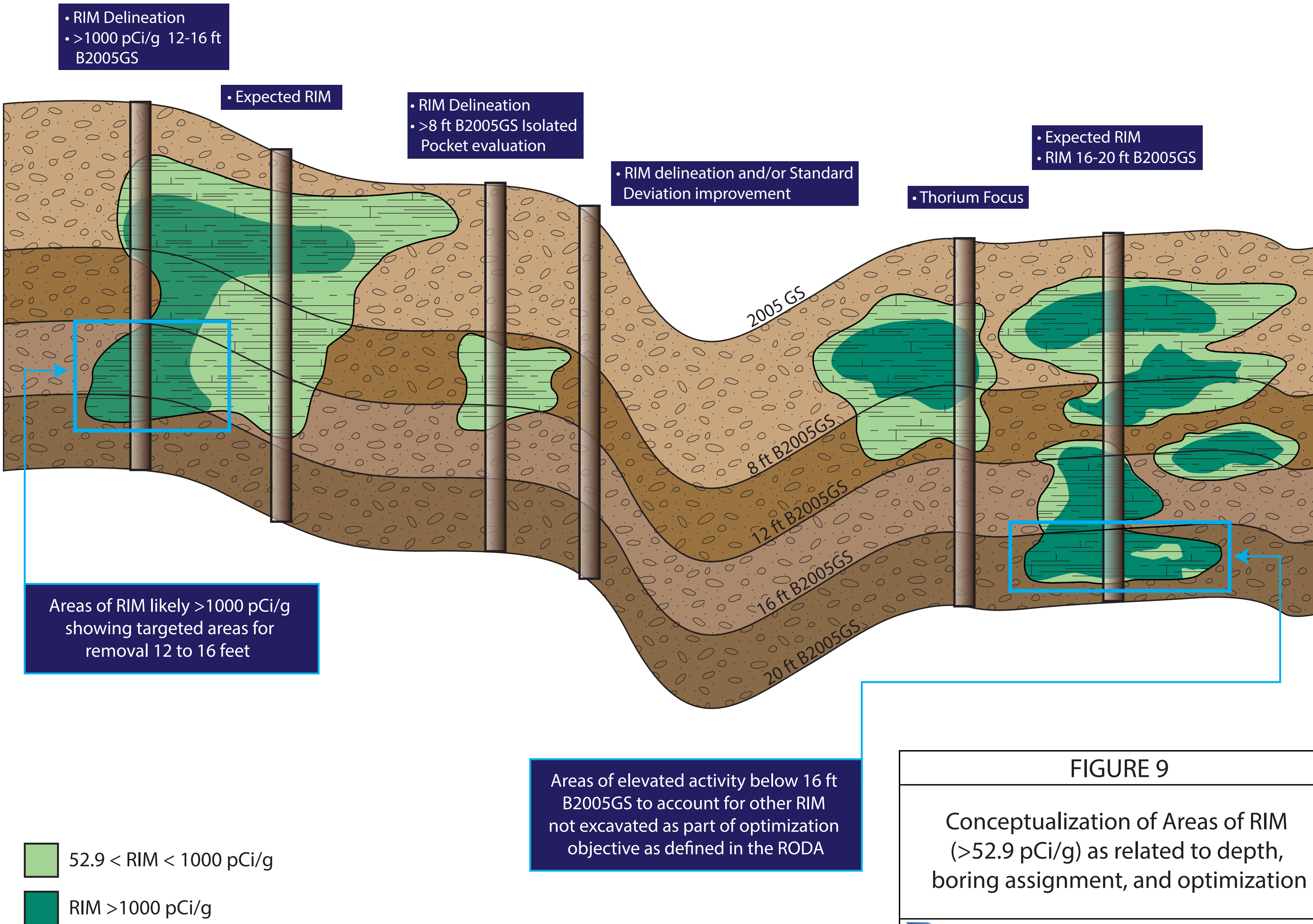

FIGURE 9

Conceptualization of Areas of RIM (>52.9 pCi/g) as related to depth, boring assignment, and optimization

PARSONS

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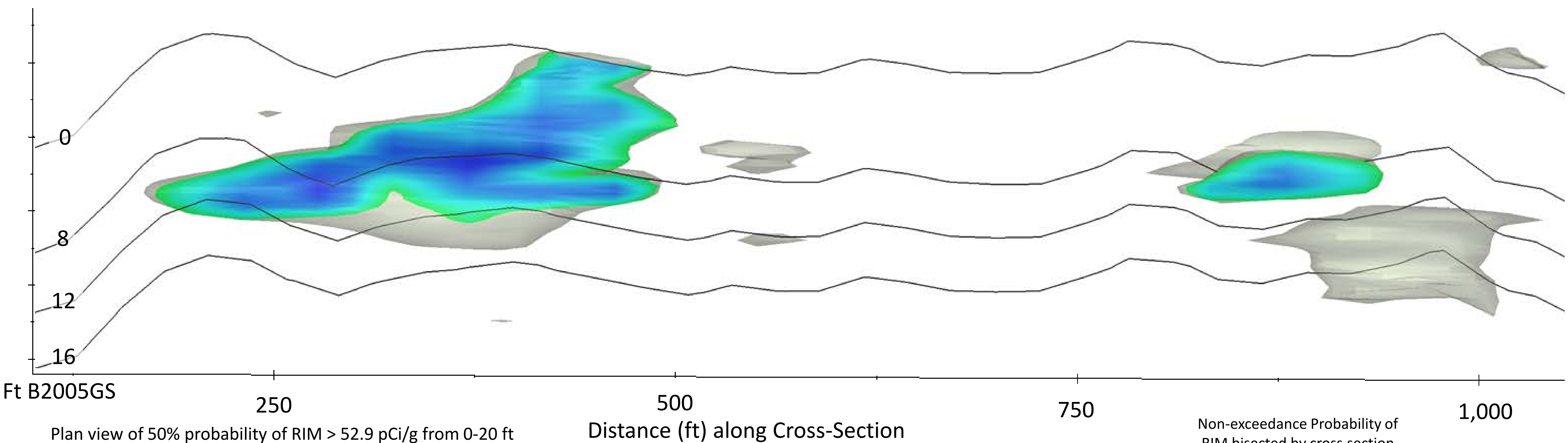
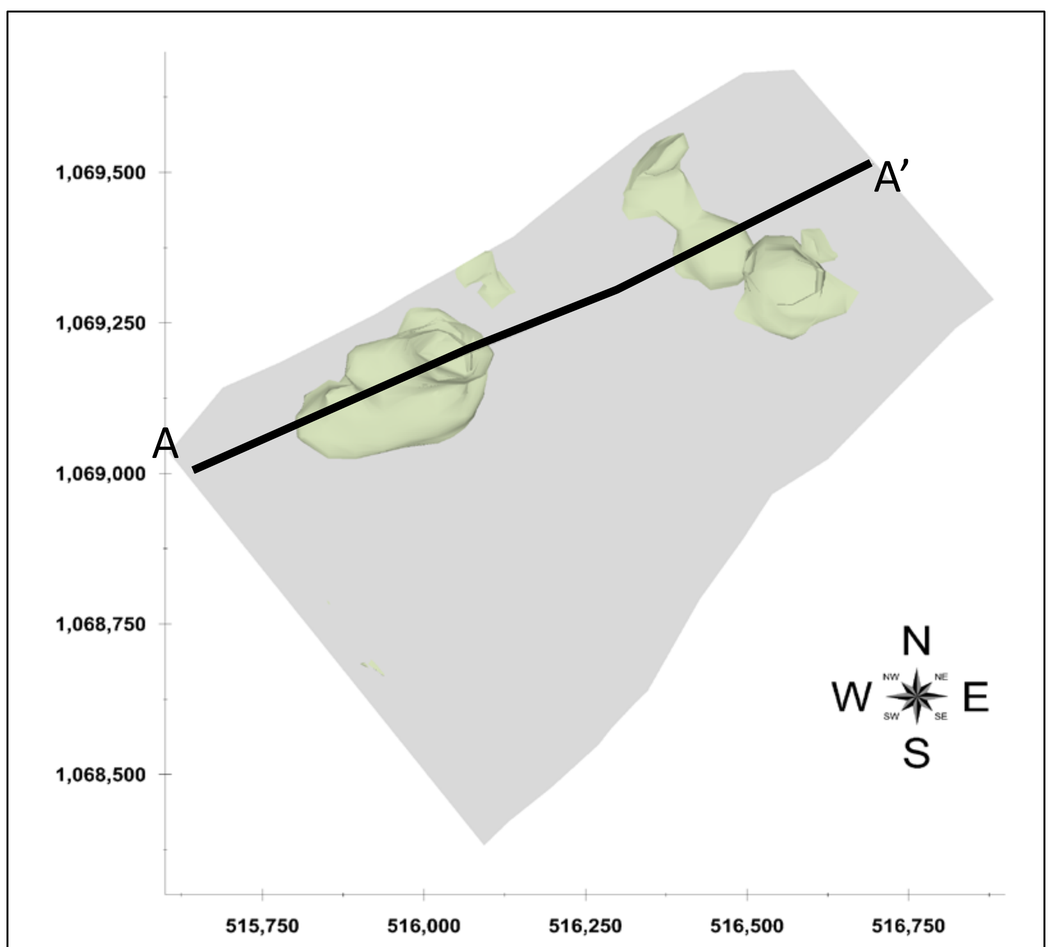
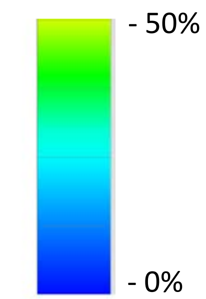
A – A’: Slice view looking in the west direction. RIM 0-20 ft B2005GS.



Plan view of 50% probability of RIM > 52.9 pCi/g from 0-20 ft B2005GS with cross section line



Non-exceedance Probability of RIM bisected by cross section



Gray shaded plume extent is >50% probability of being RIM, but the cross section does not bisect the RIM expression.

Notes on items on cross section:

1) Color Ramp is 0 - 50% probability RIM non-exceedance 52.9 pCi/g.
2) Transparent light-green-gray plume shell is RIM 50% probability of exceeding 52.9 pCi/g.
3) Vertical exaggeration is 8x.
5) RIM plumes show depths from 0 to 20 feet B2005GS.

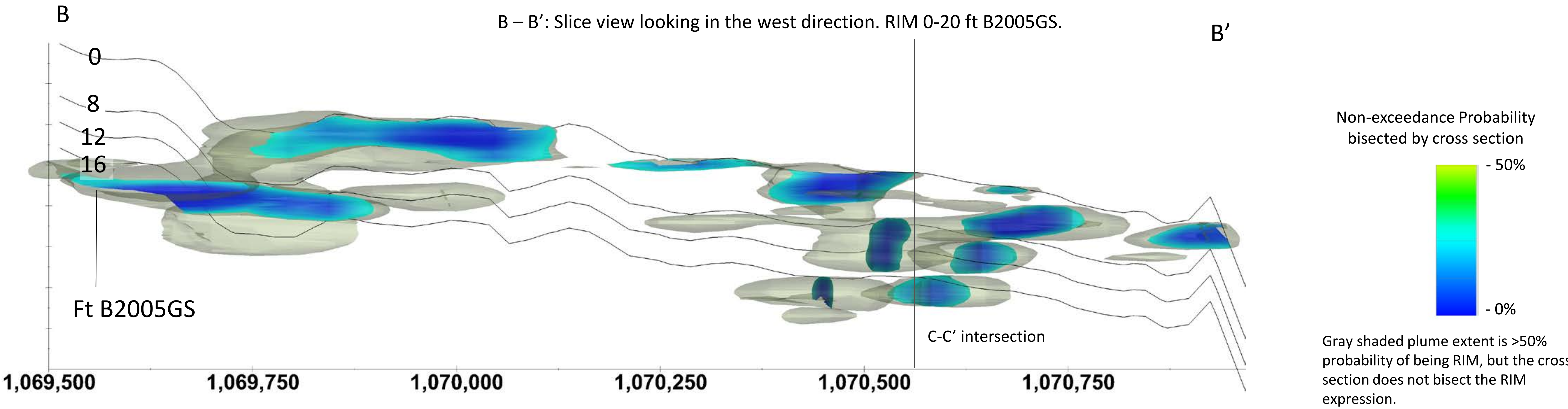
FIGURE 9A

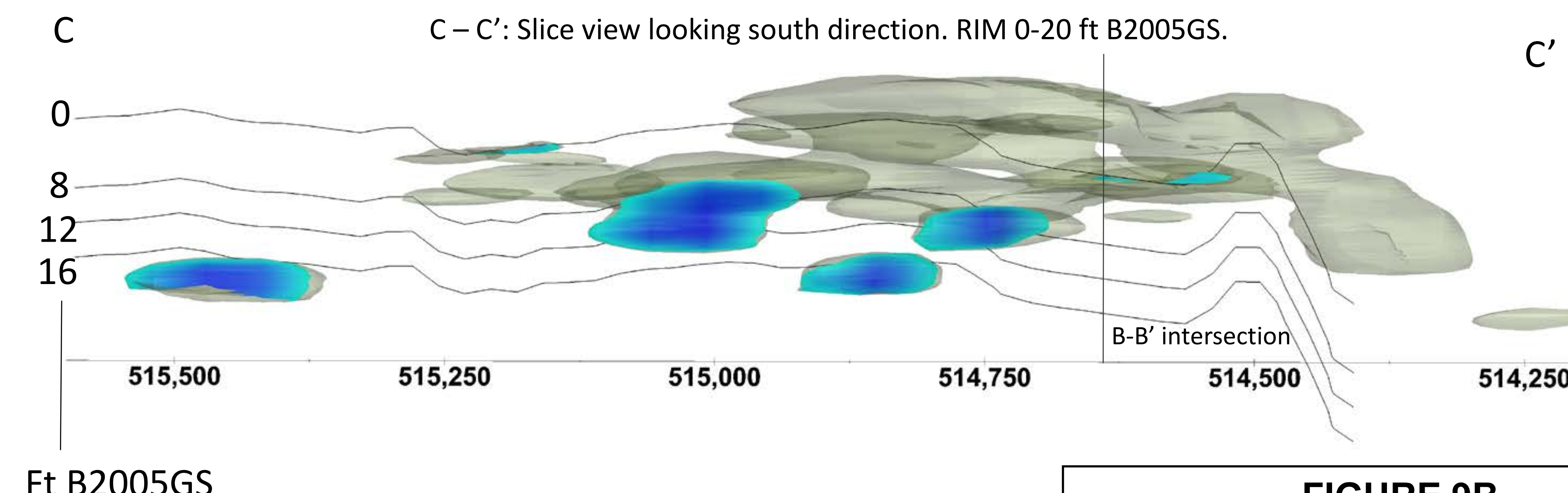
Plan View and Cross Section of RIM in Area 1

West Lake Landfill Operable Unit 1, Bridgeton, Missouri

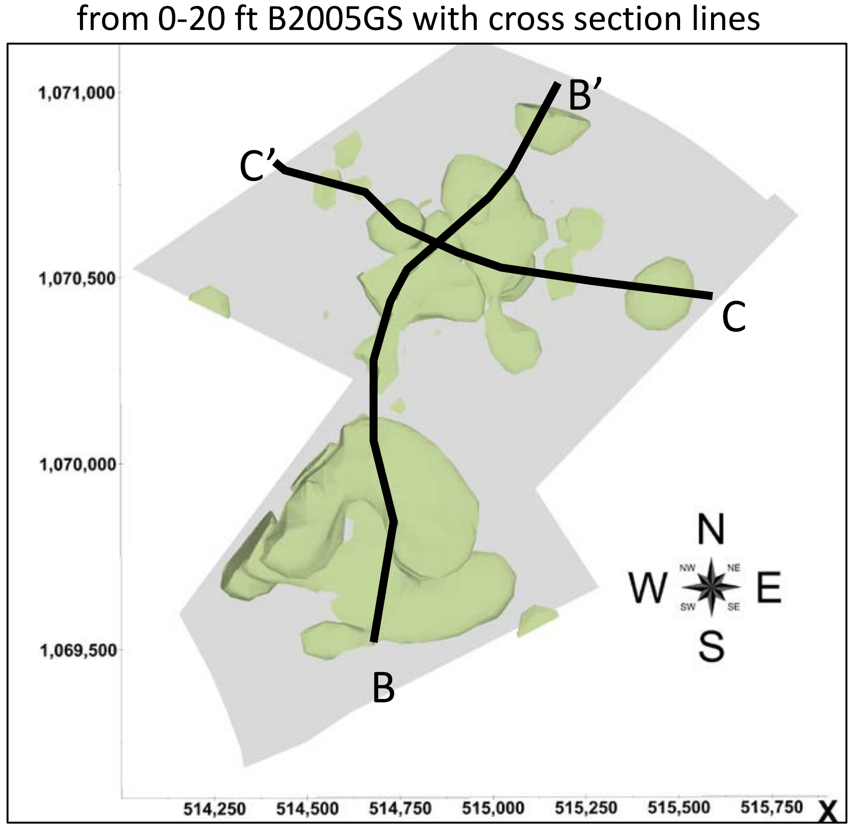
PARSONS

Syracuse, NY





Plan view of view of 50% probability of RIM > 52.9pCi/g from 0-20 ft B2005GS with cross section lines



Notes on items on cross sections:

1) Color Ramp is 0 - 50% RIM probability of non-exceedance of 52.9 pCi/g.
2) Transparent light-green-gray plume shell is RIM 50% probability of exceeding 52.9 pCi/g.
3) Transect intersections are approximate.
4) Vertical exaggeration is 8x.
5) RIM plumes show depths from 0 to 20 feet B2005GS.

FIGURE 9B

Plan View and Cross-Section of RIM in Area 2

West Lake Landfill Operable Unit 1, Bridgeton, Missouri

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Figure 10

Historical Site Activities

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Plotted By:
Plot Date: 9/11/2020

Document Path: C:\Users\p002737e\Documents\West Lake\ArcMap Data\DIWP Figures\Figure 10.aprx

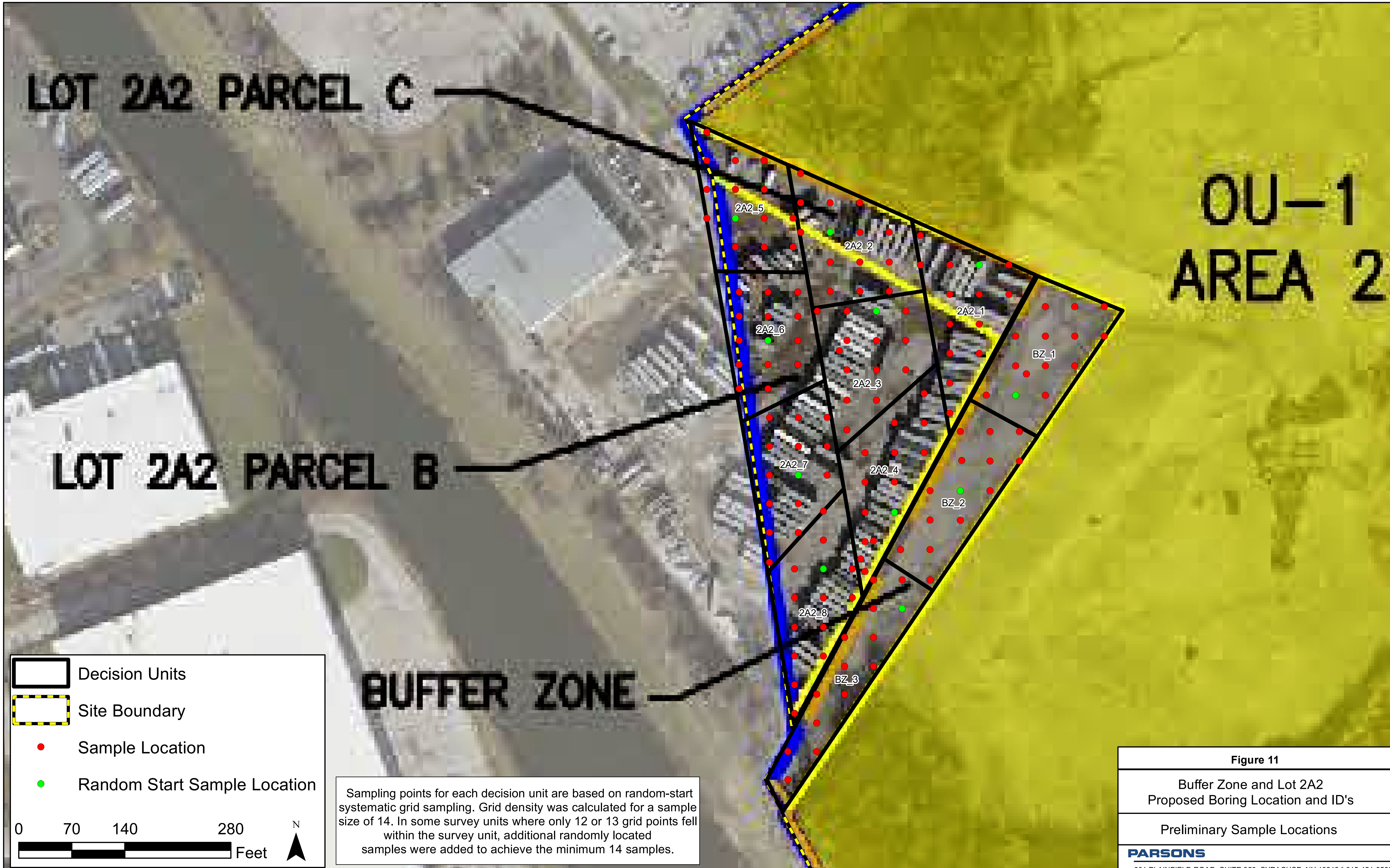


Figure 11

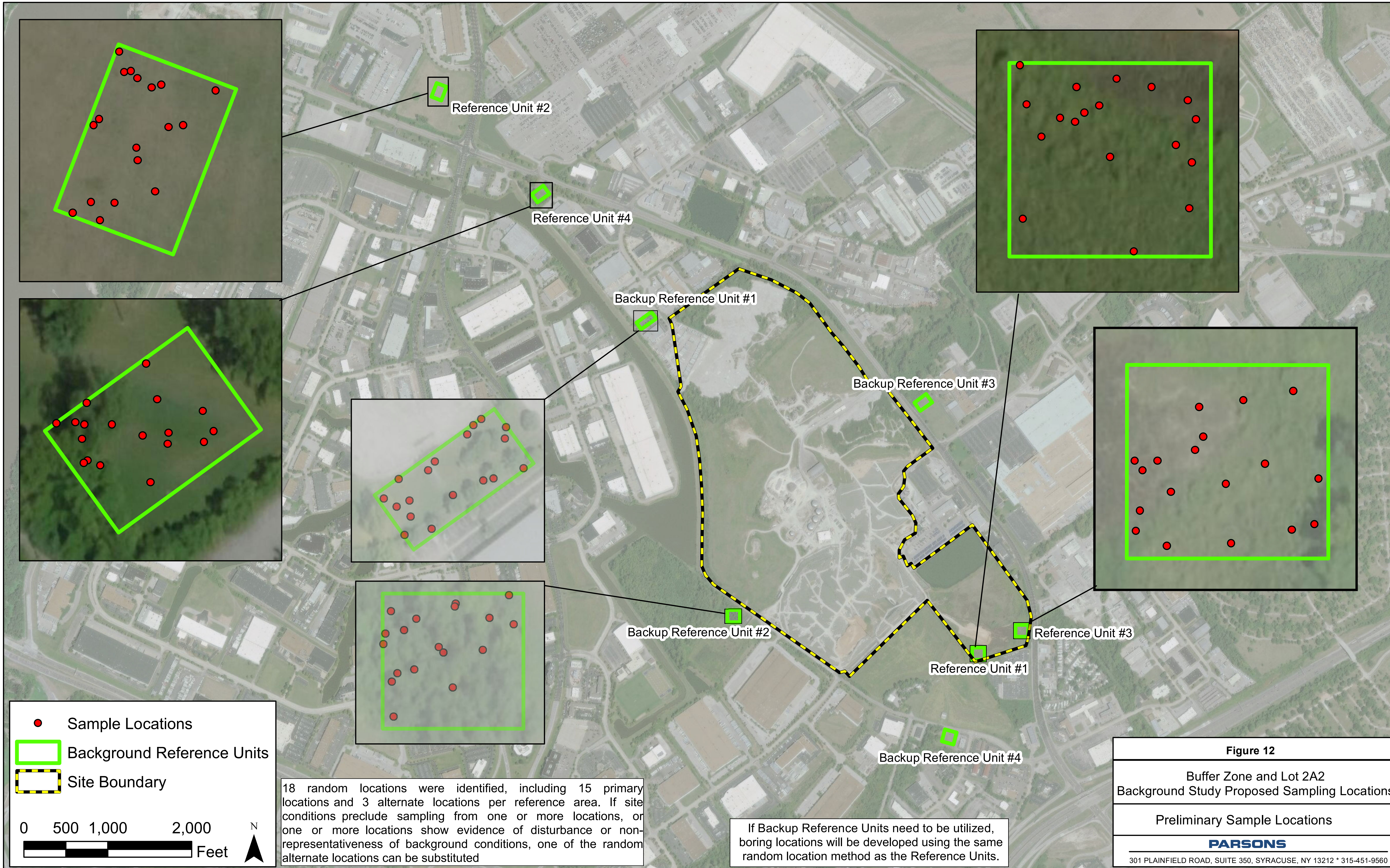
Buffer Zone and Lot 2A2
Proposed Boring Location and ID's

Preliminary Sample Locations

Plotted By: CS/CH

Plot Date: 9/5/2020

Document Path: P:\10.0 Technical Categories\10.19 Geodata\ArcMap Data\Buffer Zone and Lot 2A2\Sample Areas 2A2 and Buffer_CH.mxd



18 random locations were identified, including 15 primary locations and 3 alternate locations per reference area. If site conditions preclude sampling from one or more locations, or one or more locations show evidence of disturbance or non-representativeness of background conditions, one of the random alternate locations can be substituted

If Backup Reference Units need to be utilized, boring locations will be developed using the same random location method as the Reference Units.

Figure 12

Buffer Zone and Lot 2A2
Background Study Proposed Sampling Locations

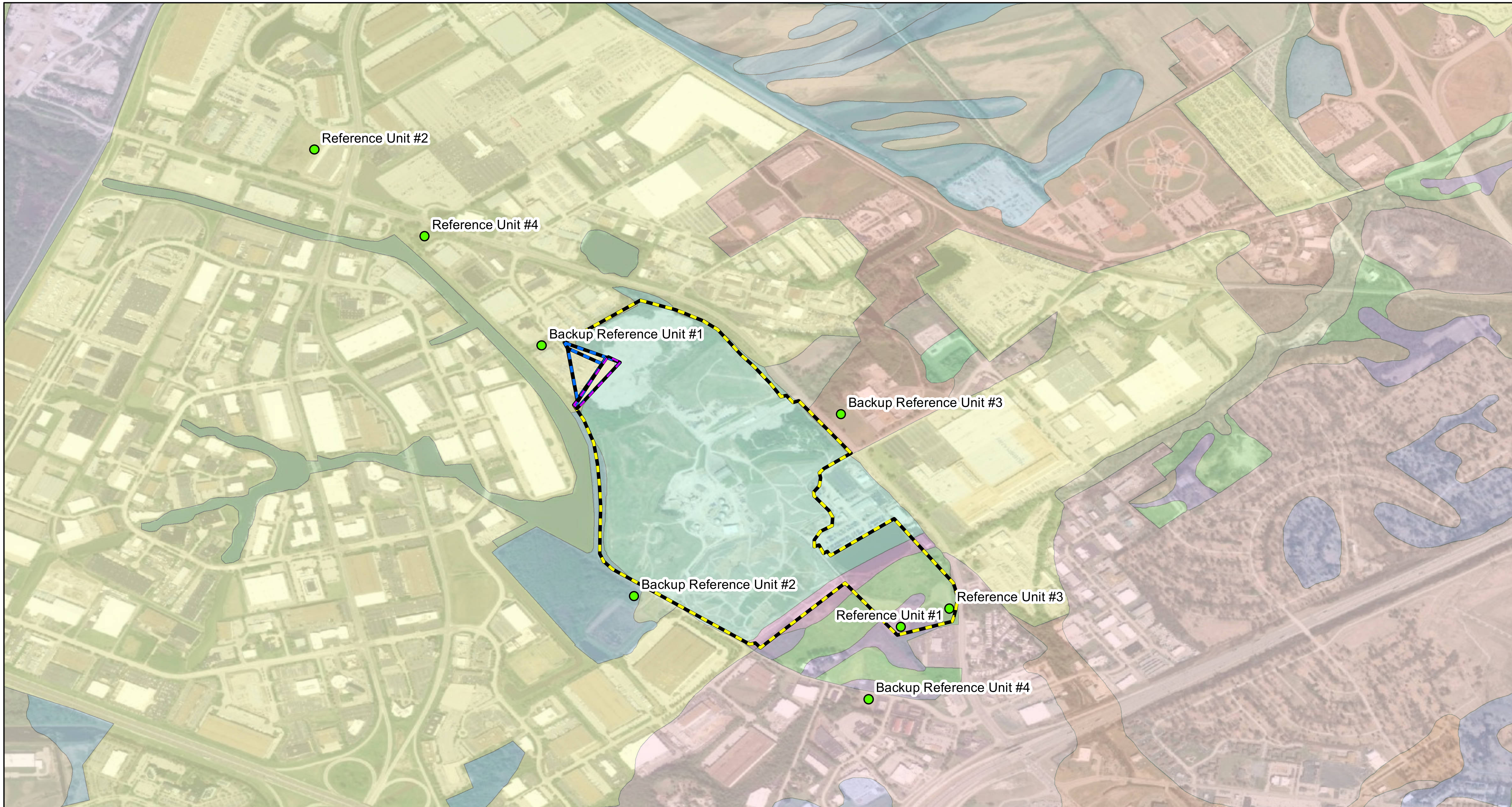
Preliminary Sample Locations

PARSONS

301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 * 315-451-9560

Plot Date: 9/1/2020 Plotted By: CS/CH

Document Path: P:\10.0 Technical Categories\10.19 Geodata\ArcMap Data\Buffer Zone and Lot 2A2\Sample Areas_CH.mxd



Reference Unit Locations
Lot 2A2 Boundary
Site Boundary
Buffer Zone Boundary
Menfro silt loam, 5-9% slope, eroded
Menfro silt loam, 14-20% slopes, eroded
Menfro silt loam, 20-45% slopes, eroded
Urban land – harvester complex, 2-9% slopes; Harvester – Urban Land complex, 2-9% slopes
Fishpot – Urban land complex, 0-5% slopes,
SansDessein silty clay, 0-2% slopes
Pits, Quarry
Urban land – bottomland, 0-3% slopes, rarely

Figure 13

West Lake Soil Map

Surface Soils

PARSONS
301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 * 315-451-9560

Plotted By: CS
Plot Date: 8/31/2020

Document Path: P:\West Lake\10.0 Technical Categories\10.19 Geodata\ArcMap Data\Buffer Zone and Lot 2A2\Surface Soils-revised CS.mxd

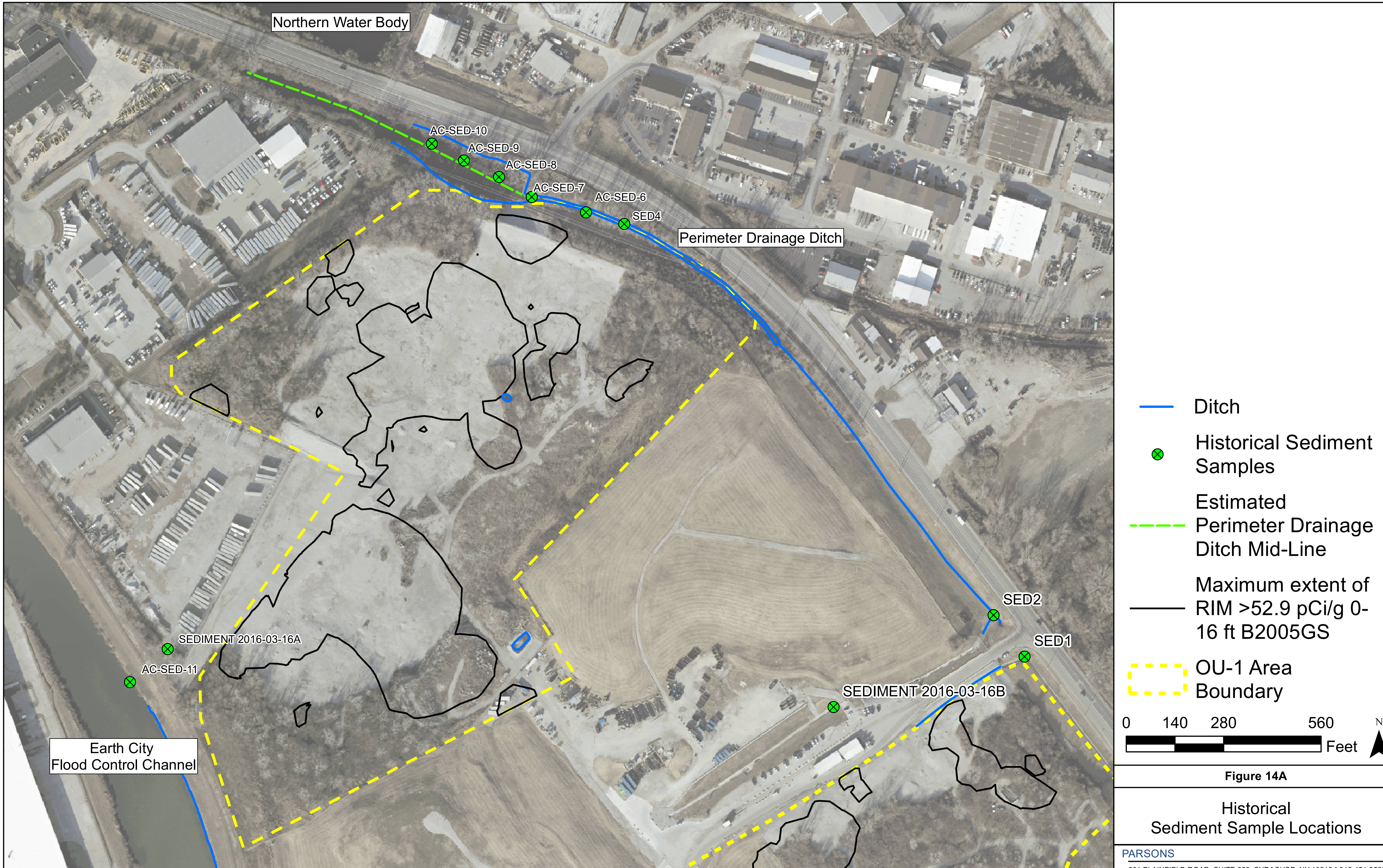


Figure 14A

Historical Sediment Sample Locations

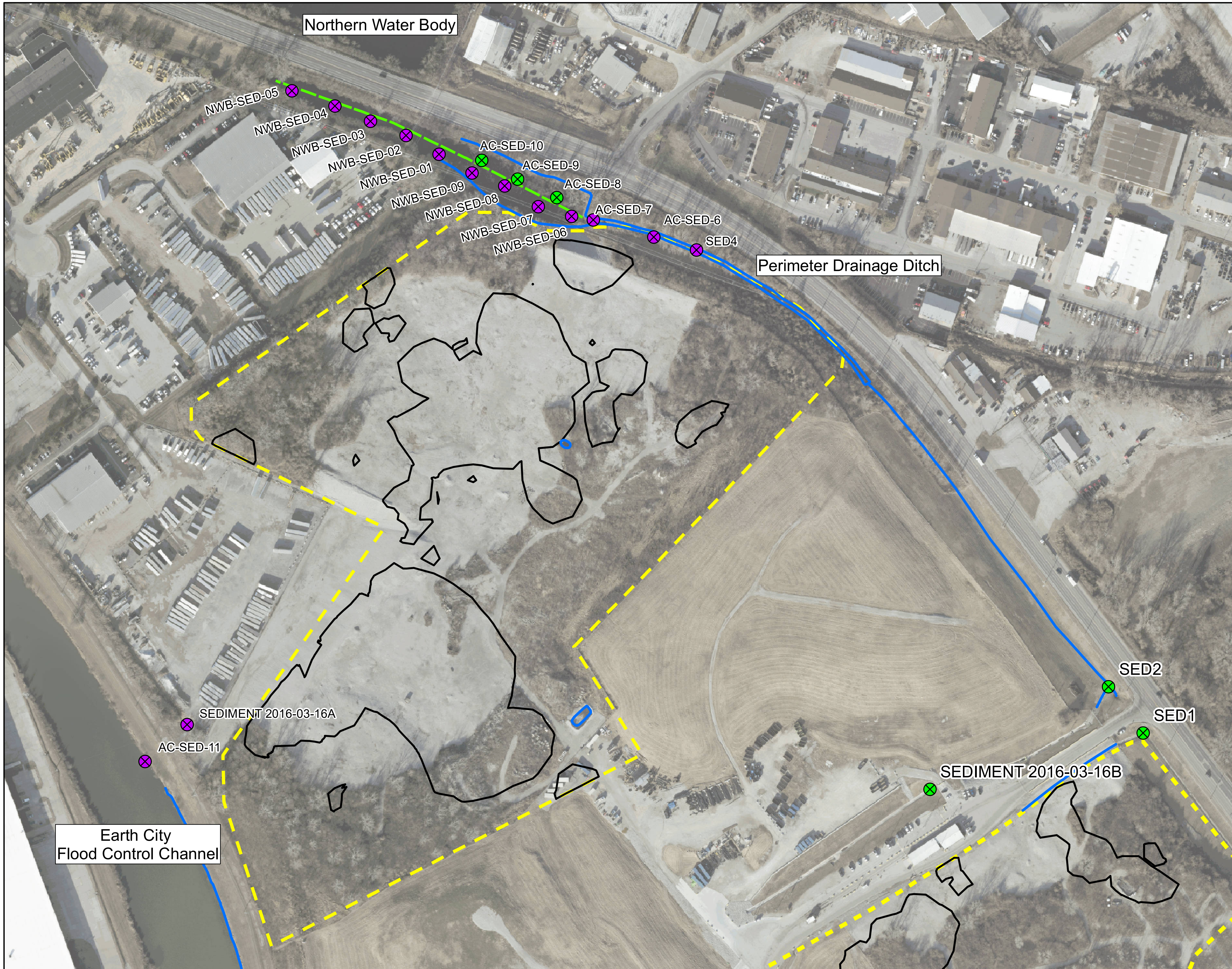
PARSONS

301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 * 315-451-9560

Plotted By: CS

Plot Date: 9/11/2020

Document Path: P:\West Lake\10.0 Technical Categories\10.19 Geodata\ArcMap Data\Sediment Samples.mxd



- Ditch
- Historical Sediment Samples
- Proposed Sediment Samples
- Estimated Perimeter Drainage Ditch Mid-Line
- Maximum extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- OU-1 Area Boundary

0 140 280 560 Feet

N

Figure 14B

Historical and Proposed Sediment Sample Locations

PARSONS

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Plot Date: 9/11/2020 Plotted By: CS

Document Path: P:\West Lake\10.0 Technical Categories\10.19 Geodata\ArcMap Data\Sediment Samples.mxd

Seeps
Standpipe Well Locations

Proposed Borings

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings

Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS
OU-1 Area Boundary

0 120 240 480 Feet

N

Figure 15

Evaluation of Liquid Levels

PARSONS
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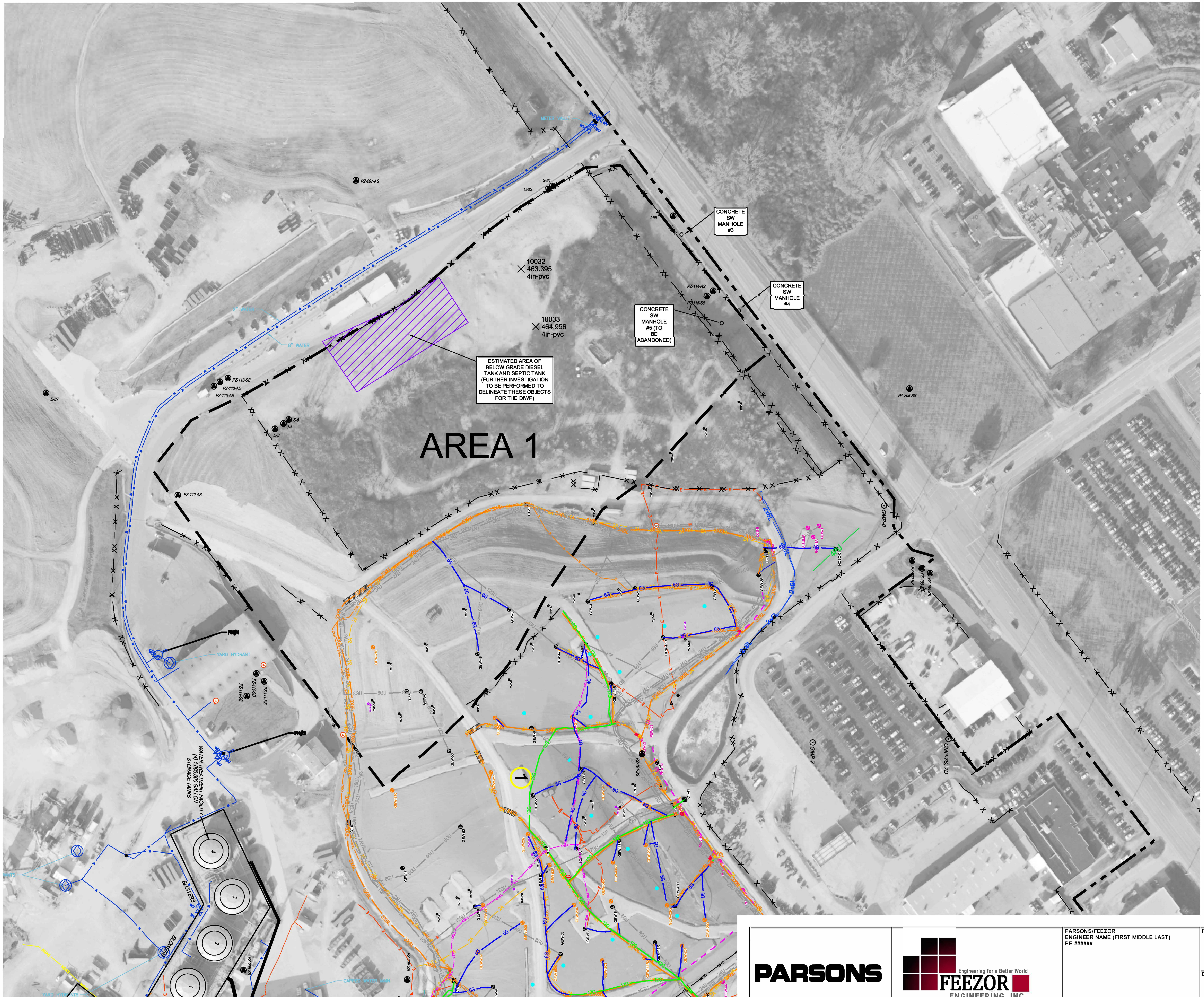
Plot Date: 9/11/2020 Plotted By: CS

Document Path: C:\Users\p002737e\Documents\West Lake\ArcMap Data\DIWP Figures\West Lake Package.aprx



LEGEND

- PROPERTY BOUNDARY
- PERMITTED WASTE BOUNDARY
- GAS MONITORING PROBE
- PIEZOMETER MONITORING WELL
- GAS EXTRACTION WELL
- INTERCEPTOR TRENCH SUMP
- SURFACE EXTRACTION WELL
- PERIMETER GAS EXTRACTION WELL
- LFG ISOLATION VALVE
- LEACHATE ISOLATION VALVE
- FLOW METER
- GRIT CHAMBER
- LIFT STATION
- CONDENSATE SUMP
- CONDENSATE TRAP/HEADER CONNECTION SUMP
- LEACHATE COLLECTION SUMP
- PERIMETER LEACHATE COLLECTION SUMP
- LEACHATE COLLECTION SUMP
- SURFACE COLLECTOR
- TEMPERATURE MONITORING PROBE
- SUBSURFACE RCP WELLS
- TRENCH SUMP
- INTERCEPTION TRENCH RISER
- PERIMETER LEACHATE SUMP
- WELL HEAD RISER
- WELL BORE BOOT
- TRENCH SUMP
- OVER LINER TIE IN POINT
- GAS INTERCEPTOR WELL
- GAS INTERCEPTOR WELL/HEAT EXTRACTION POINT
- CLEAN OUT
- GAS EXTRACTION WELL WITH 4" STINGER
- EXTRACTION POINT - ABANDONED
- EXTRACTION POINT - TEMPORARILY DECOMMISSIONED
- CONTAINMENT SUMP PUMP STATIION FOR TOE STRIP DRAIN
- DOWNSLOPE STRIP DRAIN COLLECTOR 6" RISER STUB
- QUADRANT #
- POWER PANEL
- THERMOCOUPLE
- QUARRY WALL
- LEACHATE COLLECTION PIPING
- DUAL CONTAINED LCS FORCEMAIN (SIZE VARIES)
- DUAL CONTAINED PERIMETER FORCEMAIN (SIZE VARIES)
- LEACHATE COLLECTION PIPING (SIZE VARIES)
- TOE DRAIN
- 4" PERFORATED TRENCH DRAIN
- BUBBLE SUCKER
- AIR LINE (PRESSURIZED BELOW GROUND)
- AIR LINE
- BURIED LFG COLLECTION PIPING (SIZE VARIES)
- 2" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 4" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 6" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 8" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 10" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 12" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 18" ABOVE GROUND LFG COLLECTION HEADER PIPING
- 24" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 2" PRESSURIZED AIR / 2" FORCEMAIN IN COMMON TRENCH
- ABOVEGROUND ELECTRIC LINE
- UNDERGROUND ELECTRIC LINE
- SANITARY SEWER
- MSD DISCHARGE FORCEMAIN
- WATERMAIN
- NATURAL GAS LINE
- PROPANE GAS LINE
- FIBER OPTIC LINE
- TELEPHONE
- FENCE LINE
- INTERCEPTOR TRENCH
- HEAT EXTRACTION EFFLUENT PIPING
- HEAT EXTRACTION INFLUENT PIPING

NORTH

0 100 200 Feet

DRAWING IS HALF-SIZE IF PLOTTED 11x17

NOTE:

1.) AERIAL TOPOGRAPHY PROVIDED BY COOPER AERIAL SURVE ~~CEMBER 10-20~~

PARSONS
301 Plainfield Rd, Ste 350, Syracuse, NY, Ph: 315-451 9560
Missouri State Certificate of Authority #: 2019041541

FEEZOR ENGINEERING, INC. Engineering for a Better World
3377 Hollenberg Dr, Bridgeton, MO 63044, Ph: 217-483 3118
Missouri State Certificate Of Authority #: E-200912211

PARSONS/FEEZOR
ENGINEER NAME (FIRST MIDDLE LAST)
PE ######

PROJECT: WEST LAKE LANDFILL SUPERFUND SITE, OU-1 REMEDIAL DESIGN, BRIDGETON, ST. LOUIS COUNTY, MO

PREPARED FOR: WEST LAKE LANDFILL OU-1 RESPONDENTS

FEBRUARY 2020
DESIGNED BY: AMR
APPROVED BY: DRF

FIGURE # **16A**

REVISIONS:	DATE	DSN.	APV.
#_	_/_/_	__	__

DRAWING TITLE

AREA 1
EXISTING UTILITIES PLAN VIEW (1:100)

PROJECT NUMBER: BT 191 | FILE PATH: C:\Users\arobe\Dropbox (Feezor Engineering)\Bridgeton\BT-191 (RDWP Design And Management)\00000 - Project Management\08 - AMR Working Utility Map\West Lake Template 2020-02-26

FILE NAME: C:\USERS\AROBE\DROPBOX (FEEZOR ENGINEERING)\BRIDGETON\BT-191 (RDWP DESIGN AND MANAGEMENT)\00000 - PROJECT MANAGEMENT\08 - AMR WORKING UTILITY MAP\WEST LAKE TEMPLATE 2020-02-26.DWG
PLOT DATE: 2/27/2020 11:39 AM PLOTTED BY: ANDREW ROBERTS

LEGEND

- PROPERTY BOUNDARY
- PERMITTED WASTE BOUNDARY
- GMP-4 — GAS MONITORING PROBE
- PZ-204-AS — PIEZOMETER MONITORING WELL
- GEW-38 — GAS EXTRACTION WELL
- ITS1 — INTERCEPTOR TRENCH SUMP
- SEW-63 — SURFACE EXTRACTION WELL
- PEW-20 — PERIMETER GAS EXTRACTION WELL
- LFG ISOLATION VALVE
- LEACHATE ISOLATION VALVE
- FLOW METER
- GRIT CHAMBER
- LIFT STATION
- CT-1 — CONDENSATE SUMP
- CT/HC-1 — CONDENSATE TRAP/HEADER CONNECTION SUMP
- LS 1, LS-6 — LEACHATE COLLECTION SUMP
- PS-15 — PERIMETER LEACHATE COLLECTION SUMP
- LCS-2D — LEACHATE COLLECTION SUMP
- SC-B1 — SURFACE COLLECTOR
- TMP-9 — TEMPERATURE MONITORING PROBE
- GC-3 — SUBSURFACE RCP WELLS
- ET-2 — TRENCH SUMP
- IT-7 — INTERCEPTION TRENCH RISER
- PL 7 — PERIMETER LEACHATE SUMP
- WELL HEAD RISER
- WB-1 — WELL BORE BOOT
- TS 1 — TRENCH SUMP
- OL-12 — OVER LINER TIE IN POINT
- GAS INTERCEPTOR WELL
- GIW-4 — GAS INTERCEPTOR WELL/HEAT EXTRACTION POINT
- CO — CLEAN OUT
- GEW-38 (S) — GAS EXTRACTION WELL WITH 4" STINGER
- GEW-38 — EXTRACTION POINT - ABANDONED
- GEW-38 — EXTRACTION POINT - TEMPORARILY DECOMMISSIONED
- CS-1 — CONTAINMENT SUMP PUMP STATIION FOR TOE STRIP DRAIN
- DOWNSLOPE STRIP DRAIN COLLECTOR 6" RISER STUB
- 1 — QUADRANT #
- P — POWER PANEL
- THERMOCOUPLE
- QUARRY WALL
- L — LEACHATE COLLECTION PIPING
- L — DUAL CONTAINED LCS FORCEMAIN (SIZE VARIES)
- L — DUAL CONTAINED PERIMETER FORCEMAIN (SIZE VARIES)
- L — LEACHATE COLLECTION PIPING (SIZE VARIES)
- 6TD — TOE DRAIN
- 4PU — 4" PERFORATED TRENCH DRAIN
- BUBBLE SUCKER
- 2AU — AIR LINE (PRESSURIZED BELOW GROUND)
- 2A — AIR LINE
- 6GU — BURIED LFG COLLECTION PIPING (SIZE VARIES)
- 2G — 2" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 4G — 4" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 6G — 6" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 8G — 8" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 10G — 10" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 12G — 12" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 18G — 18" ABOVE GROUND LFG COLLECTION HEADER PIPING
- 24G — 24" ABOVE GROUND LFG COLLECTION LATERAL PIPING
- 2" PRESSURIZED AIR / 2" FORCEMAIN IN COMMON TRENCH
- E — ABOVEGROUND ELECTRIC LINE
- UE — UNDERGROUND ELECTRIC LINE
- SAN — SANITARY SEWER
- FM — MSD DISCHARGE FORCEMAIN
- W — WATERMAIN
- NGAS — NATURAL GAS LINE
- GAS — PROPANE GAS LINE
- FO — FIBER OPTIC LINE
- T — TELEPHONE
- X — FENCE LINE
- 4G — INTERCEPTOR TRENCH
- HEAT EXTRACTION EFFLUENT PIPING
- HEAT EXTRACTION INFLUENT PIPING

NORTH

0 100 200 Feet

DRAWING IS HALF-SIZE IF PLOTTED 11x17

NOTE:

1.) AERIAL TOPOGRAPHY PROVIDED BY COOPER AERIAL SURVEYS, INC. AND IS DATED DECEMBER 10, 2019

PARSONS
301 Plainfield Rd, Ste 350, Syracuse, NY, Ph: 315 451 9560
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Missouri State Certificate Of Authority #: E-200912211

PARSONS/FEEZOR
ENGINEER NAME (FIRST MIDDLE LAST)
PE-######

PROJECT
WEST LAKE LANDFILL SUPERFUND SITE
OU-1 REMEDIAL DESIGN
BRIDGETON, ST. LOUIS COUNTY, MO

PREPARED FOR
WEST LAKE LANDFILL
OU-1 RESPONDENTS

FEBRUARY 2020
DESIGNED BY: AMR
APPROVED BY: DRF

FIGURE #
16B

REVISIONS:	DATE	DSN.	APV.
#_	_/_/_	___	___

DRAWING TITLE
AREA 2
EXISTING UTILITIES PLAN VIEW (1:100)

PROJECT NUMBER: BT-191 FILE PATH: C:\Users\arobe\Dropbox (Feezor Engineering)\Bridgeton\BT-191 (RDWP Design And Management)\00000 - Project Management\08 - AMR Drawing Files\1 - Utility Figure\BT-191 - A1 And A2 Utilities

FILE NAME: C:\USERS\AROBE\DROPBOX (FEEZOR ENGINEERING)\BRIDGETON\BT-191 (RDWP DESIGN AND MANAGEMENT)\00000 - PROJECT MANAGEMENT\08 - AMR DRAWING FILES\1 - UTILITY FIGURE\BT-191 - A1 AND A2 UTILITIES.DWG
PLOT DATE: 2/29/2020 12:29 PM PLOTTED BY: ANDREW ROBERTS

APPENDIX A FIELD SAMPLING PLAN

APPENDIX B QUALITY ASSURANCE PROJECT PLAN

APPENDIX C DATA MANAGEMENT PLAN

APPENDIX D PROJECT SAFETY, HEALTH AND ENVIRONMENT PLAN (INCLUDING RADIATION SAFETY PLAN)

APPENDIX E UPDATED AND FUTURE GEOSTATISTICAL PROCESSES AND MODELING

TABLE OF CONTENTS

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LIST OF ACRONYMS

ACRONYM	Definition
>	greater than
<	less than
amsl	above mean sea level
B2005GS	below 2005 ground surface
CDF	cumulative distribution function
CI	confidence interval
CL	confidence level
cpm	counts per minute
CY	cubic yard(s)
DI	Design Investigation
DIWP	Design Investigation Work Plan
DQO	data quality objectives
EVS	Earth Volumetric Software
FFS	Final Feasibility Study
GCPT	Gamma Cone-Penetration Testing
GSMO	geostatistical model objective
IK	indicator kriging
IK*	indicator kriging for this project is completed as ordinary kriging on a set of probabilities as defining by CDF development. While typically IK suggests the data are strictly binary for this project the definition of IK includes other probabilities between zero and one.
IVM	indicator variability metric
m^2	square meters
MDNR	Missouri Department of Natural Resources
MVS	Mining Visualization System
NaI	sodium iodide
NEP	non-exceedance probability (RIM >52.9 pCi/g)
NRC	Nuclear Regulatory Agency
OK	ordinary kriging
pCi/g	picoCurie/gram
PEP	Preliminary Excavation Plan
PSQ	Principle Study Question
QAPP	Quality Assurance Project Plan
RD	Remedial Design
RI	Remedial Investigation
RIM	radiologically impacted material
RODA	Record of Decision Amendment
SD	standard deviation
SDWS	standard deviation warranted to sample
SSP&A	S.S. Papadopulos & Associates, Inc.
USEPA	U.S. Environmental Protection Agency

1.0 INTRODUCTION

The geostatistical analysis components, in support and development of the West Lake OU-1 Remedial Design (RD), include a system of modeling analyses. Data needs and modeling improvements are identified in this appendix with the goal of converging on a representative model that meets the expected precision for decision-making during RD. The model is tested and enhanced throughout this process with the objective of minimizing limitations and improving confidence in the approach. These improvements have included, and will continue to include, in-depth review of the data pre-processing steps as well as the interpolation algorithms. Beyond the current reviews and analyses focused on model improvements, a significant additional data collection effort for spatial and depth refinement is scoped in the Design Investigation Work Plan (DIWP), which is designed to improve the model for RD.

The intent of this appendix to the DIWP is to provide additional detail on the logic and progression of model development since the Preliminary Excavation Plan (PEP) (Parsons 2020), and address agency comments from the United States Environmental Protection Agency (USEPA) and Missouri Department of Natural Resources (MDNR). The components of the geostatistical process in this Appendix are:

- Expanding details on model development and model improvement since the PEP, such as sensitivity testing, variogram adjustments, and other components.
- Addressing further model improvement opportunities discussed in the Focused Feasibility Study (FFS) model developed by S.S. Papadopulos & Associates, Inc. (SSP&A), as the model is transitioned from FFS to RD.
- Analyzing historical boring locations and kriging standard deviations (SDs) as related to radiologically impacted material (RIM) extent, to support the location of additional borings. The tools presented in this appendix and provided in the DIWP Figure 6 series and Figure 7 series demonstrate the use of these tools while Appendix F (including Figures F-1 and F-2) provides categorical boring justification summary and layered PDF maps for providing comparable demonstration of the tools and the boring program.
- Improving the remedy optimization process as related to total relative activity estimations.
- Identifying design investigation (DI) model-specific data collection needs.

Plans for future sensitivity testing and general model refinement for inclusion in the Revised Excavation Plan and 90% design documents are discussed below. This appendix has been written partly in response to specific requests from the USEPA in the February 13, 2020, comment letter on the PEP, discussion points conveyed during meetings on February 19 and 20, 2020, the May 6, 2020, comment letter on the draft DIWP, and additional correspondence from USEPA on May 27 and May 29, 2020.

This appendix was developed to align with the DIWP Geostatistical Model Objective (GSMOs), which were developed based on anticipated updates to the model for RD once the additional data are collected, as well as comments from USEPA and MDNR. The GSMOs were developed using a process similar to the Data Quality Objective (DQO) methodology; however, as the GSMOs involve qualitative and semi-quantitative data methodology, they are not considered DQOs. This concept of using a variety of data to make decisions with multiple lines of evidence approach is documented in USEPA guidance. For example, the Office of Nuclear Regulatory Research within the United States Nuclear Regulatory Commission (NRC) provides guidance and direction for inclusion of USEPA Triad approaches to radiological sites (NRC 2012). NRC (2012) discusses difficulty of subsurface sites and suggests: “we must move away from methods that result in simple precise statements (e.g., standard hypothesis testing) that operate under narrowly defined assumptions (often violated within a spatial context). We must move toward more sophisticated analyses that yield meaningful outcomes and improve the decision quality." Furthermore, "in a perfect world," 'decision quality' would be equivalent to 'decision correctness.' However, decision correctness is often unknown (usually even unknowable) at the time a decision must be made. In many cases, correctness may never be known, due to the situational complexity and conditions that evolve over time. The term 'decision quality' therefore means that decisions are defensible against reasonable scientific or legal challenges (Crumbling 2002) given the best available information and knowledge afforded by financial and professional resources at the time."

While this appendix supports the GSMOs, it is organized more generally in terms of modeling processes, updated model details, future activities, and anticipated improvements. The remainder of this appendix will address the following topics:

- Geostatistical Pre-Processing and Regression Analyses
- Indicator Kriging (IK) at Multiple Thresholds (IK*) – RIM Boundary Model Enhancements
- Activity Concentration Estimates
- General RIM Uncertainty
- Excavation Optimization
- Spatial and Depth Uncertainty of Current Data

* IK for this project is completed as ordinary kriging (OK) on a set of probabilities as defining by cumulative distribution function (CDF) development. While IK typically suggests the data are strictly binary for this project, the definition of IK includes other probabilities between zero and one.

Figures are provided to support the discussion points addressing model areas of potential improvements, with elaboration on the suggested concepts from SSP&A in the current context of the project RD. Discussion is provided regarding how these concepts will be addressed.

1.1 Geostatistical Pre-Processing and Regression Analyses

Previously, SSP&A examined the correlation between soft data and hard data. Soft data are gamma-response measurements collected in the field, whereas hard data are the laboratory analytical data for combined radium and combined thorium activity concentrations. SSP&A observed a relationship between gamma and radium, which is expected given that radium is a gamma emitter. While thorium is not a gamma emitter, the data also supported a positive correlation between gamma and thorium because there is an observable correlation at the site between radium and thorium despite not being in secular equilibrium as they would be in a natural deposit. The following sections review the methodology and detail the analysis and improvement of the soft data versus hard data regressions. A technical memorandum (Attachment E-1) attached to this appendix provides responses specifically addressing limitations and areas of model improvement identified in *Estimated Three-Dimensional Extent of Radiologically Impacted Material, West Lake Landfill Operable Unit 1, Bridgeton, Missouri* (SSP&A 2017).

1.2 Pre-Processing Methodology

Linear regressions were developed for gamma response, radium activity concentrations, and thorium activity concentrations for the purpose of estimating a CDF based on the relationship between the soft and hard data. The types of soft data collection methods employed were gamma cone-penetration testing (GCPT), downhole gamma, core-scanned gamma, and downhole gamma values digitized from the original McLaren Hart borings (digitized gamma). Since coincident hard and soft data were needed to establish the relationship, only downhole and core-scanned gamma (not GCPT) were used to establish the regressions.

The regressions were developed following gamma data set normalization. The normalization process involved estimating a background gamma count for each boring, subtracting the background, and then dividing by the highest gamma count measurement for each soft data type. Once the gamma data were normalized, they were plotted against the combined radium and combined thorium on logarithmic axes, and the regressions were subsequently developed on the logarithm of the hard sample data and normalized gamma value. The development of the linear regressions is discussed in detail in Appendix D of the *Estimated Three-Dimensional Extent of Radiologically Impacted Material, West Lake Landfill Operable Unit 1, Bridgeton, Missouri* (SSP&A 2017).

SSP&A (2017) described the established relationships between radium, thorium, and gamma:

> *In relative terms, the correspondence appears very good for combined Ra versus normalized core gamma, good for combined Ra and combined Th versus normalized downhole gamma, and fair for combined Th versus normalized core gamma. The least satisfactory region of correspondence is for intermediate concentrations of combined Th versus normalized core gamma; however, in this region, the fitted line tends to under-estimate rather than over-estimate concentrations of combined Th (i.e., biased low rather than biased high).*

The following aspects of the relationship between combined radium, combined thorium, normalized core and downhole gamma are noteworthy as being observable from the regression plots or from knowledge regarding the collection of the data in the field:

1. Spatial uncertainty. While the relationships with downhole gamma were described as “fair” to “very good” by SSP&A, there is a subjective component to the depth assignment for both the hard data sample and the corresponding gamma count value. For example, sometimes poor recovery occurs during the extraction of core from the borehole, which leads to uncertainty regarding the exact depth (elevation) of a sample retrieved for laboratory analysis, and how this depth corresponds with the downhole gamma response profile. This is discussed further in Section 6 of this appendix.
2. Increased data density as related to gamma counts. In the mid-range portion of the regressions (40,000 – 500,000 counts per minute [cpm]), there are data gaps and the need for confirmation to better quantify the relationship between data types (hard versus soft data, radium versus thorium), and allow for the identification of outliers. Further discussion by data type, analyte, and specific areas of improvement is provided in Section 3 of the DIWP text. This is also discussed further in Sections 1.3.1 through 1.3.3 of this appendix.

3. Poorer correlation at lower activity concentrations. The relationship between both types of soft data and the hard data is better defined at higher concentrations. At lower concentrations, particularly less than (<) 10 picocuries per gram (pCi/g), there is a large amount of scatter in the data distribution. This may represent the influence of background concentrations or instrument measurement error, discussed further in Section 1.3.4.

1.3 Areas Targeted for Improved Distribution of Samples Related to Gamma and Activity

The following subsections detail the areas of improvements in current regression plots, and the data collection objectives that will be employed during the DI to address identified areas of weakness in the regressions.

1.3.1 Correlation Between Radium and Thorium

In Figure 2-1 (SSP&A 2017), there is a positive correlation between combined radium and combined thorium. This relationship has been vital to the previous investigation for determining extent of RIM. As stated in Section 1.1, several factors influence this relationship, including but not limited to the background radiation levels, measurement error, and the role of non-detects. Improving the confidence in the derived correlation will decrease uncertainty in the estimation of RIM extent. The following approaches will be applied during the DI field data collection to further evaluate the relationship between combined radium and combined thorium:

- All borings related to model improvement will be used to collect both hard and soft data. The increased co-located hard and soft data sampling locations will add data to the regressions which may improve the confidence in the derived correlation.
- Existing hard data has high data density at concentrations below 7.9 pCi/g, but between 7.9 and 10,000 pCi/g there is insufficient data density because laboratory analytical samples were typically sampled from the highest core gamma scan intervals in previous investigations. This reduced the quantity of samples in this range because higher activity samples were typically selected. These ranges will be targeted for sample collection in the field using related gamma counts to improve quantified relationships of radium and thorium.

Following the DI, newly collected hard data will undergo processing related to measurement error and data censoring, and the correlations between combined radium and combined thorium will be updated.

1.3.2 Correlation Between Radium and Gamma

There is an established relationship between combined radium and both core-scanned and downhole gamma that is supported by the underlying physics, as radium is a gamma emitter. The relationship between combined radium and core-scanned and downhole gamma was established in SSP&A (2017); however, there are areas of the regression that require increased data density. Additional data collection, especially of core data in the mid-range of gamma counts, will support re-evaluation of the regressions between gamma and radium.

The radium versus core-scanned gamma and downhole gamma regressions will be revisited and re-analyzed with the inclusion of the data collected during the DI.

1.3.3 Correlation Between Thorium and Gamma

While site-specific data suggest that there is a positive correlation between combined thorium and gamma, there is uncertainty regarding this relationship because the RIM material was anthropogenically processed (uranium tailings leaching), which disrupted the secular equilibrium between thorium-230 and radium-226. Nonetheless, both isotopes are expected to be present and co-located, and therefore thorium occurrences are expected to have an indirect correlation with the gamma signature. This is reflected in the observed relationship between thorium and gamma explained by the observed correlation between thorium and radium, a gamma emitter, although the correlation is shifted and has substantially more variability compared to a natural deposit.

Currently, mid-range areas of the regressions could be improved with additional data. By targeting specific ranges, and collecting more data, the desired outcome is an improved regression between the analytes and soft data. Therefore, additional data will be gathered in the DI to refine this relationship to allow for more confident prediction of areas of RIM within the landfill. In order to further evaluate the relationship between thorium, radium and gamma, the following approaches will be applied during the DI fieldwork:

- Borings will be used for the collection of hard data (combined thorium and combined radium) and soft data (core-scanned gamma and downhole gamma). This will add coincident hard and soft data to the existing data set used in the regressions, as well as confirm the existence of thorium that is derived from the relationship of gamma to combined thorium.
- Areas where IK has identified RIM extent driven by thorium (without radium) will be thoroughly investigated with closely spaced borings throughout the pockets of RIM.
- Areas in the mid-range of the regression, where data gaps or insufficient line fit is observed, will be targeted during the DI data collection process. Specific areas targeted for increased data collection include thorium-specific data collection in the gamma count target range of 40,000 to 500,000 cpm (approximately 250 to 10,000 pCi/g combined thorium), and radium-specific data collection in the gamma count target range of 40,000 to 500,000 cpm (approximately 100 to 1000 pCi/g combined radium) (**Figure E-1**). These regions have insufficient data to support the estimated relationship between combined thorium, combined radium, and gamma. Additionally, it is recognized that additional data generally above 40,000 cpm will potentially decrease the standard error of the slope estimate of the regression. Given the large number of samples for comparison (greater than [>] 1,400), the population density in many areas of > 40,000 cpm will be available for further development of these regressions. As described in the Field Sampling Plan, a plan is in place to track sample collection and revised sampling in sub-categories to better distribute the sample location within the 40,000 cpm and greater range.
- Digitized historical downhole gamma will be further assessed when analyzing the combined radium, combined thorium, and normalized gamma regressions. With the collection of a significant amount of comparable hard and soft data, the sample population will increase markedly. This increase in population will allow for additional statistical analyses to evaluate previous anomalies for their validity. On a case-by-case basis, previous anomalies can be reviewed for quality and rationale.

The thorium versus core-scanned gamma and downhole gamma regressions will be revisited and re-analyzed with the inclusion of the data collected during the DI.

1.3.4 Background Radiation Analysis

In reviewing regression relationships between the data sets in Sections 1.3.1 through 1.3.3, data clustering is observed near the lower threshold of 7.9 pCi/g. Close to, and below this threshold, greater scatter in the relationship is evident, and no relationship can be identified. At least one factor in this relationship scatter is the influence of background radiation, including (a) the value for background assumed at each boring, and (b) the assumption that the background value is constant for the full depth of each boring (core).

To assess the influence of background radiation on soft and hard data, there will be a background radium and thorium investigation. This investigation will involve sampling four regions around, but not within, Areas 1 and 2. Fifteen distinct locations will be sampled within each region. At each sample location soil will be collected from a minimum of two depth intervals: 0 to 6 inches and 6 to 12 inches. Each soil sample will be analyzed for thorium and radium concentrations, as well as scanned for gamma counts. As stated above, the data from this background investigation will be considered for an evaluation of the influence of background radiation on soft and hard data if it is demonstrated that these data are representative of Area 1 and Area 2.

2.0 INDICATOR KRIGING AT MULTIPLE THRESHOLDS (IK*) – RIM BOUNDARY MODEL ENHANCEMENT

2.1 Prior Analyses

SSP&A (2017) performed distinct variogram analysis on the data sets by area (Areas 1 and 2 separately) and by analyte (radium and thorium). A variogram is a function that quantifies the spatial correlation of a measured quantity with separation distance. When employing kriging, weights are assigned when interpolating an unknown location based on the relationship put forth by the variogram. Ideally the empirical variogram demonstrates a strong correlation (i.e., small variance) between data points at small separation distances with gradually increasing variance at greater separation distance.

As part of the uncertainty analysis, SSP&A examined different variograms and their subsequent effects on the indicator kriging model (SSP&A 2017). Variogram modeling involves fitting a theoretical variogram to an empirical variogram. This process results in determining three main kriging parameters (**Figure E-2**):

- The effective range, or the maximum separation distance at which sample data correlates.
- The sill, or the total variance where the variogram plateaus. This is the variance equivalent of the range.
- The nugget, or the y-intercept of the variogram, representing the short-range variance.

While the values of the range and the nugget affect the kriging interpolation, the value of the sill has no effect on estimation, or the relative spatial distribution of the kriging variance. The value of the sill does, however, affect the absolute values of the kriging variance and SD. This is discussed in detail by SSP&A, since they primarily focused on range length determination and did not intend to use the absolute values of kriging variance. Kriging SD can be used qualitatively to identify areas of “high” SD relative to areas of “low” SD, which can be particularly useful when identifying regions to target for data gap sampling. When using the kriging SD for estimation of confidence intervals, greater importance is placed on accurately estimating the sill.

SSP&A (2017) fit a spherical variogram model to the indicator data by looking at the spatial correlation horizontally and then vertically. The data were assumed to be isotropic in the horizontal direction and anisotropic when comparing horizontal to vertical correlation. This approach required the variograms to be analyzed in two dimensions for the horizontal and one dimension for the vertical. This allowed for a determination of the horizontal-vertical anisotropy.

2.2 Additional Variogram Modeling

As part of the transition from GSLIB's IK3D to C-Tech's Earth Volumetric Software (EVS), the established range lengths, sills, and anisotropy were initially maintained. The values initially remained unchanged in order to achieve confirmation that the IK3D model could be reproduced in EVS. Obtaining this confirmation was an integral part of the PEP process and determining that EVS is the appropriate software to use for analyzing the previous model, and dynamic enough to use moving forward into the remedy design phase. However, once this IK3D model replication process was confirmed, the variograms were revised by Parsons for the following reasons:

- In EVS, the variogram is calculated as a best-fit function using the spatial distribution and number of data points in three dimensions, rather than developed separately for the horizontal and vertical directions. SSP&A (2017) developed the vertical range based on all soft data types, including alpha response, which was not used in the final indicator model. However, because EVS variogram methodology is different, only the data set that is included in the IK estimation of RIM was used for establishing range-length and sill.
- The sill was revised/updated for the DIWP (adjusted from the values used during the PEP [Parsons 2020]) to better quantify SD and confidence intervals (CI) as part of the uncertainty evaluations. Since the SD and CI were not part of the PEP, there was no attempt to update them during that stage. The sills differ between the IK3D and EVS models due to the differing variogram methodologies, in particular the method in which anisotropy is included in EVS. Additional consideration was placed on accurately fitting the spherical model to the data. Once more data are collected, additional variogram analysis will be performed and the parameters will be updated based upon the new data collected.
- The nugget value was set to zero (default value for EVS) which assumes the short-range variance is equal to zero at the sample location. The nugget is discussed further in Section 2.2.1.

In order to better explain the process and updates of the range and sill (as described above), the following summarizes the current and future processes:

- PEP – range was updated from IK3D to EVS to more appropriately fit a 3D variogram. Sill was unchanged from IK3D due to lack of emphasis on uncertainty in PEP.
- DIWP – range remained the same from PEP, but sill was updated in order to use SD. Since the sill does not affect the spatial/depth distribution of RIM (only the range does), it was appropriate to maintain the PEP range yet update the sill during the DIWP analyses provided herein.
- Revised Excavation Plan – a significant amount of additional data will be collected and the variograms will be further analyzed and updated.

The resulting variograms from sensitivity testing are presented in Figure E-2 for both Areas 1 and 2, and the radium and thorium indicator data sets. The revised variogram parameters are presented in Table E-1.

TABLE E-1 INDICATOR KRIGING – UPDATED VARIOGRAM PARAMETERS

	Area 1	Area 2
Range	175	235
Radium Sill	0.0072	0.03
Thorium Sill	0.01	0.036
Nugget	0	0

Collection of additional data during the DI should improve the confidence in the range and sill values due to the higher future data density.

2.2.1 Ongoing Variogram Improvements

The nugget is representative of a short-range variance. The underlying kriging theory assumes that the variance of co-located samples, where the separation distance is small, is zero or close to zero. High nugget values, which are > 50% of the total variance or sill, are typically difficult to assess and can be attributed to multiple factors, including sampling error (Dominy 2010). Nugget values that are < 50% of the sill could be evaluated to assess if these are related to sampling error or if they are representative of the site conditions. The data are highly variable even at small separation distances across the site; therefore, a non-zero nugget may be appropriate.

Before including a nugget in the variogram model, a thorough investigation of the data is required to evaluate the source of the nugget effect. For simplicity and consistency, at this phase of the project the nugget is assumed to be zero (consistent with SSP&A). However, GSMO #2, as defined in the DIWP, is specifically related to further exploring the use of a non-zero nugget through vertical hard data variograms and additional sample analyses.

Borehole variograms look at the variance of data in the vertical direction, and can be used to assess the nugget effect (Camana and Deutsch 2019). Since hard data is being collected at a variety of depths (within each boring), the future data set will include higher data density at short lag distances. Higher data density at short lag distances allows for a more accurate variogram model fit close to a lag distance of zero. Borehole variograms were previously investigated by SSP&A; however, these were estimated using soft data. Both soft data and hard data vertical variograms will be assessed during the future nugget analyses.

In addition to vertical variograms, at 5% of sample locations a pair of “duplicate” samples will be collected from the same boring both one foot above and below the primary sample. These samples, although not true “duplicates,” will provide insight into data variability within short lag distances, to support the variogram analyses described previously.

At all borings advanced in and adjacent to Areas 1 and 2, samples for hard data as well as soft data will be collected in support of the geostatistical model. Following the DI, each step in the indicator assignment process will be reviewed and revised, as needed. The current variograms will undergo evaluation and further variogram modeling may be necessary to identify the updated range length, sill, and nugget that reflect the post-DI data set.

2.2.2 Sensitivity Testing

Sensitivity testing employs the manipulation of model inputs to observe the effect that parameters have on the model output. Sensitivity testing is performed iteratively to compare how parameter changes affect kriging estimations. Through sensitivity testing, parameters can be refined based on the model purpose, spatial array of data, accurate representation of existing data, and feasible approximation of modeled analytes (RIM extent and activity concentration). Sensitivity testing is an ongoing process in model development, and parameter values will continue to be reviewed for their effect on the model results as more data are incorporated into the model. The activities described below review past, current, and future sensitivity testing. Most sensitivity testing is based on a relative comparison, so that efforts can focus on parameters that have more influence on the outcome (i.e., those that the model is more sensitive to).

2.2.2.1 Previous Sensitivity Testing (SSP&A 2017)

Sensitivity testing of certain parameters is presented in Appendix I of the SSP&A Geostatistical Report (2017). Parameters that typically have the greatest impact on RIM extent and volumes were focused on during the sensitivity testing. These included the CDFs and the variograms. As presented in Figure I-3 from Appendix I of the SSP&A Geostatistical Report (2017), similar RIM volumes were calculated regardless of variogram or CDF method used. This could indicate that, in general, small differences may occur when using alternate methods, but in general the same volume of RIM is modeled.

As part of the transition from IK3D to EVS, additional sensitivity was performed and is reported in the Appendix A of the PEP (Parsons 2020) This sensitivity testing included the grid size in IK3D model, and the range. Changes in volume were used to quantify the effect of the parameter change on the model output. During the grid size evaluation, it was judged that 225 square-meter grid cells would be appropriate for this stage of the investigation (**Figure E-3**). This was based on multiple factors, including the RIM volume and extent differences (Parsons 2020).

2.2.2.2 Current Sensitivity Testing

Sensitivity testing has been recently employed to review some of the parameters carried over from IK3D to EVS to evaluate their applicability in the excavation design phase of the model. Recent sensitivity testing activities have focused on range length and grid size for Areas 1 and 2, as described below.

<u>Range</u>

As part of the transition from IK3D to EVS, the range length and the sill were slightly altered. This is due to the differing variogram methods as related to horizontal and vertical variance. The distances between pairs at which the variogram is calculated are called “lags.” SSP&A developed two separate variograms during their variogram analysis to address the vertical anisotropy:

- A horizontal variogram that only considered lag distances and variances in the horizontal direction
- A vertical variogram that only considering lag distances and variances in the vertical direction

This resulted in an anisotropic “correlation” distance between the horizontal and vertical direction. This is conventional practice for using IK3D for kriging, developing the range lengths in the X, Y, and Z directions and then defining the variogram using the three range lengths. Furthermore, the anisotropic nature of the variograms agrees with the site conceptual model and disposal methods at the landfill.

EVS creates a variogram in three dimensions, thus lag distances are calculated using the X, Y, and Z distances. Within the lag distance equation, anisotropy is accounted for directly, and is therefore an input parameter in the software. In other words, while IK3D address anisotropy with two separate variograms, one for horizontal and one for vertical, EVS has an assigned anisotropy value which is a component of the variogram equation(s). For three-dimensional lag distance equations and example calculations, see Appendix D-2 of the Geostatistical Report (SSP&A 2017).

At this stage in the investigation, modification to the anisotropy value is not warranted, as it was based on the individual variogram analysis performed by SSP&A. Additionally, altering the anisotropy affects the EVS variogram, potentially resulting in a different range length and sill. As discussed elsewhere in this document, anisotropy will be examined after the collection of new data during the revised variogram analysis.

Due to the slightly different range lengths between the IK3D model and the EVS model, the range-length sensitivity was analyzed by comparing RIM volumes between 0 and 16 feet below the 2005 ground surface (B2005GS) using IK3D (Parsons 2020). Results from the PEP (Parsons 2020) indicated the volumes were comparable when the range was above 100 feet. This is logical, since the range of 100 likely results in nearby samples being weighed less in the kriging calculation and thereby not correlating potentially related samples. Although the volumes were similar, the geostatistical team recognizes that the spatial distribution needs to be compared in future model testing, particularly when new data are available.

While there is some subjectivity in this “model fitting” process, there are certain areas based on the data where the range length is not reasonable. As can be seen in Figure E-2, for each area and each analyte, there is very low variance below a lag distance of 100, indicating good correlation, as well as increasing variance with distance. Near the range / sill intersection, the data plateau. This is where the data variance is at its maximum because at this distance, the data are no longer correlated. Assigning a range length beyond this point allows for data beyond the correlation limit distance to be given a greater weight in the kriging calculation. Assigning a range length that is less than 100 results in nearby data points being assigned a lower weight in the kriging calculation, despite the variogram indicating there is good correlation at those distances. In general, the range, sill, and anisotropy should be selected by the practitioner through appropriately fitting the model variogram to the empirical variogram. When sensitivity testing, considering parameter values that are outside reasonable bounds as portrayed by the empirical data contradicts the kriging theory and creates erroneous results.

Grid Size

Grid size sensitivity testing, presented in the PEP (Parsons 2020), was performed using IK3D prior to transitioning to EVS. Since the transition to EVS (based on USEPA and MDNR comments), it was judged that the grid size should be re-evaluated in EVS to assess the effects on volume and extent. To calculate volume of RIM in IK3D, the data were post-processed, and each cell containing RIM was summed and multiplied by the constant cell volume in order to get a total volume of RIM, following the method described by SSP&A (2017). In EVS, which is a type of visual programing or data flow programming, the “Volumetric” module is used for volume calculations (in EVS “modules” are specific tools designed for particular purposes in the visual coding process); C-Tech describes their methods including volume and mass of the analyte in the following steps (C-Tech 2019):

- Each cell within the selected geologic units is analyzed.
- The mass of analyte within the cell is integrated based on concentrations at all nodes (corners of cells) and computed cell division points.
- The volumes and masses of all cells are summed.
- Centers of mass and eigenvectors (linear algebra transformations) are computed.
- For soil calculations, the mass of the analyte is directly computed from the computed mass of soil. This is affected by the soil density parameter.

The description above is generally summarized from the C-Tech manual and describes both mass and volume calculation within a tool called volumetrics. While the discussion in this Appendix is mostly related to volume, the mass calculations are related to activity calculations. Furthermore, the mass calculation assumes a density as described in detail in Section 5.1 below.

Using this process, the volume of material with a 50% likelihood of being greater than 52.9 pCi/g was calculated within four different model runs with different horizontal cell sizes: 25, 100, 225 (current and PEP size), and 400 square meters (m^2). Grid cell analysis was performed in Area 2 as an example of the sensitivity. **Figure E-3** provides the 225 m^2 grid for Areas 1 and 2 as a reference. **Figure E-4** shows the resulting maximum lateral extent of RIM from 0 to 16 feet B2005GS for the aforementioned grid sizes in Area 2. In general, the different grid sizes result in similar RIM extents and volumes. The largest change was observed at the largest grid size of 20-by-20 meters, resulting in a RIM volume of 68,900 cubic yards, roughly 10% lower than the RIM volume for 5-by-5 meters.

It should be noted that this concept of grid size affecting results has been discussed by others. C-Tech Corporation, the developers of EVS and their outdated Mining Visualization System (MVS) software, recognized that in previous versions of MVS the estimates of volume and mass increased with grid density. In fact, as part of the development of EVS, efforts were made to reduce this relationship of volume and cell density. The current version of EVS, which is the software for the current model, showed very little to no change in mass when grid density varied. A discussion and demonstration of the sensitivity is located on C-Tech's website: https://www.ctech.com/volumetrics-study-studio-vs-mvs/. This demonstration supports the concept of why the cell size in EVS is likely less sensitive than other parameters and/or other unknowns of the project (such as inhomogeneity of the landfill).

Cumulative Distribution Function

Sensitivity testing on the CDF was previously performed by SSP&A, in which both the "base case" CDF and the continuous CDF were both modeled to observe how the CDF affects RIM volume and extent. However, the "intermediate CDF" was not examined. Per SSP&A's Geostatistical Report (2017), the intermediate CDF is "…described here as intermediate, as they were then subject to further assessment via indicator kriging. A series of indicator kriging exercises was conducted using these intermediate base case CDFs to evaluate the sensitivity of the results – in terms of the estimated presence or absence or RIM at known borehole locations – to perturbations in these CDFs. The results obtained from these kriging exercises were compared with independent methods of RIM identification (results of which are summarized in Tables 7-1 and 7-2 of this [the SSP&A 2017] report and subject to cross-validation (results of which are summarized in Section 7 of this [the SSP&A 2017] report). At the conclusion of these comparisons, these intermediate base case CDFs were adjusted to final base case CDFs." Due to the uncertainty related to the manual adjustment of the CDF to develop the final base case CDF used in both the IK3D and EVS geostatistical models, the intermediate CDF was explored in EVS to observe changes in the extent of RIM > 52.9 pCi/g. The maximum extent from 0-16 feet B2005GS for both the intermediate and final CDFs is displayed in Figure 6B of the DIWP. As shown in Figure 6B, the intermediate CDF results in several regions where a larger area is defined as RIM > 52.9 pCi/g. The volumetric differences (as calculated in EVS) are provided below:

	Area 1 RIM >52.9 pCi/g Volume (Cubic Yards [CY])	Area 2 RIM >52.9 pCi/g Volume (CY)
	0-16 feet B2005GS	0-16 feet B2005GS
Final (PEP) CDF	12,000	74,000
Intermediate CDF	12,000	81,000
Volumes rounded to two significant digits		

2.2.2.3 Proposed Sensitivity Testing Post Additional Data Collection

As previously mentioned, sensitivity analysis is an ongoing process and the USEPA has suggested that further sensitivity analysis should be conducted. This is in part because previous sensitivity analyses have focused on large incremental changes. Analyses involving more discretization over a narrower range of values could improve the understanding of the effects of range length on the volume and extent. As more data are incorporated into the model, the kriging parameters will require review and possible revision. Upon the incorporation of DI data, the range, sill, search radius, and grid size will be re-evaluated to assess if the pre-DI values remain applicable to the updated data set. The new data will provide the opportunity for additional variogram modeling, during which the range and sill will likely be updated and use of a nugget will be examined. Furthermore, the grid size can be tested for truncation effects. As the model nears its final completion the run time will have less importance and grid size can be decreased. Grid size evaluation will occur post-DI.

Previously, SSP&A performed sensitivity testing on the CDF examining how the CDF affects the RIM volumes. The final CDFs were subjected to manual manipulation during a series of kriging exercises “to evaluate the sensitivity of the results – in terms of the estimated presence or absence of RIM at known boring locations” (SSP&A 2017). The manual adjustment of the CDFs involved subjectivity and therefore a source of uncertainty in the model. Following the DI data collection, the CDFs will be updated with the DI data incorporated. Several CDF methods will be explored (including but not limited to those previously analyzed by SSP&A) and additional CDF sensitivity testing will be performed. The manual adjustment of the CDFs will be avoided, to the extent practical, in lieu of statistical algorithms. However, if it is determined that the CDF is creating potentially erroneous results, and it is concluded that the CDF should be manually adjusted with professional judgement, the CDF will undergo modifications with the transparency and only upon client and agency concurrence.

3.0 ACTIVITY CONCENTRATION ESTIMATES

OK of estimated activity concentrations was used as a basis for obtaining an estimate of both total activity in a defined volume of RIM extent and supporting the optimization component of the RD. The following discussion provides a summary of the initial development, and ongoing variogram analyses.

3.1 Initial Development

There are several steps that are considered and explained in the development of this model beyond what was provided in the PEP (Parsons 2020). These include data processing, transformation of soft data to activities, and combining thorium / radium data during kriging.

Normalized gamma data were transformed using the equations outlined in the PEP (Parsons 2020). In the initial phase of the activity modeling, hard radium and thorium data, and transformed soft data were combined and the resulting data set was kriged. In the presence of duplicate samples, the lesser value was selected. This was initially done as a method for unbiasing some of the previous high-biasing steps. Previous investigations biased hard data sample collection based on the highest field screening values observed, therefore biasing the data to a higher-activity sample set.

In EVS, during the development of the IK* model for which RIM extent is determined, a decision point was encountered in how to manage duplicate sample results (e.g., field duplicates) where results were not equivalent. The handling of duplicate samples inherently incorporates bias in the dataset whether: 1) both samples are retained (EVS will average the two values); 2) the lower value is retained (indicating the sample is more likely to exceed 52.9 pCi/g); or 3) the higher value is retained (indicating the sample is less likely to exceed 52.9 pCi/g). The duplicate samples were resolved by taking the conservative approach and choosing the sample more likely to exceed 52.9 pCi/g (for both the IK3D and EVS model). Future modeling (both IK* and OK) will use the average values based on comments from the USEPA and MDNR.

The equations (Equations C-3 and C-4 from the Geostatistical Report [SSP&A 2017]) used for transforming the soft data to activities as outlined in the PEP (Parsons 2020) were developed by SSP&A and selected for use since the additional error matrix analysis performed for these regression equations may more closely represent the true correlation. An alternate method would be to use the same regressions, or base case, used for transforming the soft data into indicators (Equations D-1-1 and D-1-2 from the Geostatistical Report [SSP&A 2017]). Both methods are viable. However, as noted in the Geostatistical Report (SSP&A 2017), the base-case regressions tend to under-predict high activities and over-predict low activities. For the purposes of preliminary activity estimates, kriging with values from the error matrix regressions is believed to more accurately predict activity concentration. Since the soft data are used to predict the absolute activity values, the preferred approach was to use a more "cross-validated" regression. The regressions and CDFs will be revised upon further data collection, and, subsequently, the final regressions used for the activity model will also be revised. In summary, it is recognized that same regression equations will be used for IK and OK Activity model in the future models and consistency needs to be maintained once regressions are fully developed. That said, two different equations were used for the DIWP for the following reasons:

- Maintain consistency with PEP extent in the IK model

- Improve the activity estimates with the more up-to-date regression from SSP&A

Initially, for the activity model, the activities were combined prior to kriging. This was done for computational expediency as the concept of kriging activity concentration (not using IK* for total activities calculations) was developed. To evaluate the impacts on combining radium and thorium prior to kriging versus kriging the analytes separately and combining the kriged results, a preliminary separate model was developed for comparison using Area 2 data only. Based on the modeling workflow presented in the PEP (Parsons 2020), the activity concentrations were subset within the RIM plume and the total activity was calculated. No differences in OK variogram parameters were made between the two methodologies, and the autofit function was utilized in both models. The difference in total activity values from 0 to 16 feet B2005GS between the two methods (combining analytes and kriging versus kriging analytes separately and then combining) was 1.4%. After new data are obtained and incorporated into the model, the following method will be used to develop activity models:

- Krige each analyte separately, and then combines the kriged data sets for the total activity.
- Where there are duplicate soft data values, the duplicates will be evaluated for false positives and potential data collection issues.

3.2 Ongoing Variogram Analysis

Initially, within development of the activity concentration model, the “autofit” function was used to develop the range and sill, which is not considered a formal variogram analysis. The resulting autofit variograms are presented in **Figure E-5**. As can be seen from the variograms, the resulting ranges from autofit are significantly higher than the IK* model, since the autofit function is incorporating values at longer distances where the variance decreases. For this reason, the sill is within a large scatter of data resulting from the highly variable nature of the measured activity concentrations (ranging from < 100 to > 1,000,000 pCi/g).

Knowing that the autofit may under or overpredict RIM, an initial variogram analysis was completed after the PEP as part of this DIWP. These variograms are shown in **Figure E-6**. Here, a more reasonable fit is derived, as the sill is more related to where the variance is high, and the range is generally related to where the distance where the variance begins to “flatten” on the graph. That said, the variograms in **Figure E-6** also show a significant amount of scatter and do not represent a “good” fit. Furthermore, even though there is a smaller range, the variance is large, and the data are scattered and irregular. This is a common occurrence in environmental data sets, such as for pH or hydraulic conductivity, in which the analyte varies many orders of magnitude over small distances. Also, this is an observed condition of the site in terms of large changes in concentration over short distances, which is manifested in the variograms.

High variance does not necessarily mean that there is a low spatial correlation, rather it reflects the variogram being dependent upon the data being distributed normally. Often when concentration data change orders of magnitude in short distances, the data distribution can be considered log-normal. Given this data distribution, it is recommended that a log-transform be explored prior to kriging, then kriging the data set, and then back-transforming the data to get estimates of activity. This common transformation method for environmental data can be compared with untransformed data in terms of the activity calculation and optimization.

As part of the ongoing variogram analyses and activity calculation development, a log-transformed alternative variogram was developed for Area 1 and Area 2 and is provided as **Figure E-7**. When comparing **Figures E-6** and **E-7**, it can be readily observed how markedly improved the empirical variograms are; with use of the log transformations both the variance and the scatter of the data are greatly reduced. The relevance of this method for kriging the activity will be considered through the analysis of histogram plots during future activity model analyses. Once an entire data set is achieved, a histogram of the data will be reviewed before and after the transformation to verify that the raw concentrations appear log-normal.

3.3 Future Variogram Analysis

With the collection of new data, the activity models for each area will be updated. The following changes and additional analyses are expected to occur:

- Updated regressions and increased hard data collection
- Variogram analysis:
    - Maintaining non-transform variograms, while understanding that variograms will have more scatter and likely a poorer fit between the empirical data and the model
    - Log transform
- Comparison of RIM extent derived from the OK model used for the activity calculations as compared to the IK* model used for the RIM extent.

3.3.1 Updated Regressions and Increased Hard Data Collection

As outlined in the DIWP, there will be additional hard and soft data collected to fill in data gaps, which will be incorporated into the regressions. Then the regressions will be thoroughly analyzed to improve the correlation to the extent practical. This process of updating the regressions directly affects the transformation of soft data into activity concentration.

Additionally, it is proposed to collect more hard data at a higher sample density by depth than has been done in the past. As outlined in the PEP (Parsons 2020), the number of borings with hard data is being increased by more than a factor of 2, and proposed DIWP hard sample collection will increase the hard data by a factor > 3. This increased hard data density will allow for improvements to the activity model by providing additional activity concentrations for cross-validation of both the IK and OK models and allowing for a hard-data-only OK model to be considered.

3.3.2 Activity Model RIM Extent as Compared to IK Model

The current activity modeling process involves kriging the activities and then bounding them by the RIM extent, defined as 50% probability of exceeding RIM >52.9 pCi/g, as evaluated by the IK* model. This was a method proposed as the most feasible option in estimating activity concentrations spatially and at different depth intervals, to meet the Record of Decision Amendment (RODA) objective of "optimization." The activity model outside of the currently defined RIM boundary has not yet been considered.

The additional analyses for variogram modeling mentioned above, part of determining a correct method for the RD, will include evaluation of the activity concentration estimates and the model similarities / difference the IK* RIM extent compared to the activity concentration (ordinary) kriging model RIM extent (as requested by USEPA and MDNR).

3.3 Uncertainty related to the Activity Model

Activity concentration estimates in the modeling process were evaluated to ascertain if the sampling program includes borings in areas of high activity and/or high SD. In particular, the elevated activity between 12 and 20 is relevant to the optimization process of the RD. Attachment E-2 provides maps of the Area 1 and Area 2 modeled activity concentrations in the 0 to 8 and 12 to 20 feet B2005GS intervals to allow for graphical evaluation of boring placement.

4.0 GENERAL RIM UNCERTAINTY

The limit of RIM boundary developed during the PEP was defined as a 50% probability of exceeding 52.9 pCi/g activity (Parsons 2020). The boundaries were developed using geostatistical methods (IK) utilizing hard and soft data collected during previous investigations. The spatial distribution of data, as it relates to RIM boundaries used in the geostatistical model, was examined to select areas where limited, spatially discontinuous data are present, and where RIM extent is driven predominantly by either radium or thorium data. As part of the DIWP, three GSMOs were written to address many of the USEPA and MDNR comments and concerns about the development and use of the geostatistical model for identifying RIM extent and concentration. Please refer to the DIWP for direct information on these GSMOs and how they are designed to improve delineation of RIM >52.9 pCi/g. Below is a general discussion on the DIWP as related to the model. It should be noted that all borings within Area 1 and Area 2 will be advanced to 20 feet B2005GS as described in the DIWP.

While the processes identified above summarize the evaluation related to specific design investigation objectives and GSMOs, the following sequence describes the detailed step-by-step approach used to identify boring locations. This process began with qualitative comparisons and became more quantitative with the development and use of standard deviation to warrant sampling (SDWS) as a statistically based determination of the number of borings and locations necessary to meet the DIWP objectives.

1. Spatial areas were identified where the model estimated RIM >52.9 pCi/g and there were no borings already located in these areas. In other words, regions of predicted RIM >52.9 pCi/g that were not substantiated by hard or soft data were identified. Proposed borings were added to these areas.
2. Areas where thorium was estimated above 52.9 pCi/g, and radium was below 52.9 pCi/g were identified. Additional borings were added in these areas, if not coincident with proposed borings already added.
3. Additional borings were added in where:
    - The RIM shell geometry was complex, with irregular and/or lenticular shapes that were sometimes vertically separated by estimated material < 52.9 pCi/g
    - Areas that were predicted to contain high activities
    - Areas of RIM that were based on model estimates without previous borings
4. The SD field was mapped to graphically determine areas of highest error, while considering RIM activities. Additional borings were added in these areas, if not coincident with other proposed borings.
5. Areas of estimated activity between 7.9 and 52.9 pCi/g were identified, and proposed borings were located where no borings had been previously drilled.
6. Overland gamma survey results from the original Remedial Investigation (Engineering Management Support Inc. 2000) were compared to previous and proposed borings to ensure these areas were accounted for. Because these overland gamma data could not be incorporated into the geostatistical model, there were some discrepancies between the modelled extent of RIM and areas of elevated overland gamma results from this survey. As such, borings were added to areas that did not overlap with other proposed additional borings. In other words, the overland gamma results from the original RI were compared with the proposed borings defined above, and

if there were areas (of reasonable size) of overland gamma with no borings, additional proposed borings were added.

7. Comparison of existing and proposed borings (above) with a 2,000-square-meter grid; if there were any grid cells without a boring, an additional proposed boring was added to that grid cell center. The use of the 2,000-square-meter grid was chosen both as a qualitative reference point and as a mechanism for "infilling" areas without borings.
8. The SDWS tool was used for highlighting regions to target for sampling based on SD and RIM non-exceedance probability (NEP – RIM >52.9 pCi/g), as developed by the USEPA in response to Comment #17 of the USEPA's *Comments on 3/30/2020 Design Investigation Work Plan*.
9. The indicator variability metric (IVM), which combines SD and indicators with a weighted function that identifies areas of highest SD and RIM near 52.9 pCi/g, was used as a graphical comparison to other evaluation methods as discussed above.
10. Recommendations from USEPA, including Figures 17 and 18 from the RODA (USEPA 2018).

The above sequence of analyses represents a combination of graphical, analytical, and statistical methods used to support the identification of sufficient locations without excessive redundancy, thereby resulting in a resource-effective design investigation.

Borings are proposed at the lateral extent of the RIM boundary to acquire both hard and soft data at multiple depth intervals in each boring. The advancement of borings around the RIM extent boundary will provide increased hard data density at the distal extent of the RIM boundary that currently has sparse data. The collection of additional data in this area will refine the vertical and lateral RIM extent and the associated RIM volume and total activity developed in the PEP geostatistical model.

In areas of deep RIM, 12 to 20 feet B2005GS, borings to refine the RIM extent, RIM volume, and total activity present. It is important to have an accurate understanding of this deep RIM to allow for the activity accounting methods proposed in the PEP (Parsons 2020) and further expanded upon in the excavation optimization discussion (Section 5), specifically:

- RIM containing activities > 1,000 pCi/g that may be present from 12 to 20 feet B2005GS should be targeted.
- Isolated pockets of RIM from 8 to 12 feet B2005GS will be left in place that do not prove to be efficient for excavation (i.e., extensive overburden removal required). To offset the activity left behind in the isolated pockets, the base of excavation(s) will be dug deeper in areas where RIM (with elevated activity concentrations) exists below the bottom of proposed excavation areas.

Borings are also proposed in areas with sparse data distribution within the RIM boundary. The areas identified as being under-represented in the model due to low data density include:

1. Isolated pockets of RIM, where "lobes" of the RIM extent are attributed to data with limited density/spatial distribution
2. Locations where RIM extent is driven by a single analyte, predominantly either radium or thorium data (**Section 4.1**)
3. Areas of large kriging SD within the extent of the model (**Section 4.2**)

Borings are proposed in areas where isolated pockets of RIM are expected. The collection of hard and soft data from borings within and around these isolated pockets will refine estimates of RIM extent. Collection of data in these areas beyond what is present in historical data sets will assist in the determination of whether RIM is present and/or more contiguous than initially modeled. By refining the RIM extent in isolated pockets, further analysis of excavation feasibility can be conducted. Excavation feasibility includes volume, extent, and total activity of RIM in the isolated pocket as compared to the quantity of non-RIM overburden that lies directly above RIM and any associated set-back material that would be required for excavation of isolated pocket of RIM.

Utilizing kriging SD and single analyte-driven RIM extent is discussed in subsections below (Sections 4.1 and 4.2, respectively).

In Appendix B of the PEP (Parsons 2020), the presence of "unverified anomalies" was discussed and further elaboration is provided here. Previously identified unverified anomalies of RIM are regions of focus for collection of additional hard and soft data to confirm or invalidate these areas of RIM. The extent of RIM > 52.9 pCi/g is based on predictions and does not provide a "verified" presence/absence of RIM. The use of the term "unverified anomalies" can be better described as minor figments of kriging predictions that have little to no hard or soft data, for which a > 50% probability of the presence of RIM can be ascribed. Efforts are underway to further refine the variograms and kriging parameters used for indicator and ordinary kriging to better fit available data and reduce such minor kriging figments. The refinement of model variograms and parameters is an ongoing process in model development for Areas 1 and 2. As more hard and soft data inputs are available the variograms and model input parameters will require review and possible modification to provide quantitatively descriptive spatial distribution.

4.1 Thorium and Radium Distribution Analyses

Thorium is not a gamma-emitter at lower levels and therefore translation of normalized gamma data to thorium-based activity concentrations using SSP&A's Equation C-4 may result in an unreliable estimate of thorium activity in lower ranges. Separate interpolations were performed to investigate which analyte, radium or thorium, is the main driver of the RIM expression in Areas 1 and 2. The main driver of the RIM expression was evaluated by modeling a radium-only extent and a thorium-only extent using both hard and soft indicator data. The analyte-specific extents were compared to combined extent of RIM to identify areas where RIM is driven by one analyte. As shown in Figures E-8a and E-8b, there are specific areas of the RIM extent that are driven by detection of thorium, meanwhile the radium areas are mostly if not always coincident with the thorium. In review of thorium-driven RIM areas, most of the data are soft, or gamma, data.

To address the lack of a physical relationship between gamma response and thorium activity, high-resolution borings are proposed to be advanced during the DI to collect hard data for refinement of the thorium extent in thorium-driven RIM expressions. The high-resolution approach entails borings advanced to 20 feet B2005GS. Laboratory analytical samples will be collected with a frequency of one sample per 4-foot core run for a total of five (5) samples per boring. Soft data will be collected from high-resolution borings using two methodologies: core scans and downhole gamma logging. Results of the high-resolution activity samples may be used to improve the correlation between gamma and thorium or, if necessary, provide sufficient delineation data with less need for soft data to define the thorium occurrences and extent.

4.1.1 Variogram Analyses

As discussed above, future variogram analyses will compare the use and appropriateness of linear versus log-kriging as a means for estimating activity concentrations.

4.2 Standard Deviation and RIM Analyses

When a spatial data set is kriged, the solution of the kriging system of equations also provides the variance (and thus the SD) of the estimate associated with each kriged value. The kriging SD for a given estimated node is the square root of the variance that is calculated during the kriging estimation. The SD can be used to create a grid of confidence intervals for each estimated data point.

SD is a useful tool in assessing areas of uncertainty in the model. Areas with a higher SD have a lower confidence. Typically, the SD distribution can be used to assess areas of lower confidence *relative* to areas of higher confidence, for identification of new sample locations to improve model confidence. For the purposes of selecting boring locations, the relative distribution of SD, in comparison of model predicted probability of non-exceedance of 52.9 pCi/g, was used and compared with not only existing borings (as is done with SD), but also used qualitatively when considering where new borings should be located for delineation of RIM and/or further investigation into interior RIM margins. Figures E-9a through E-9ab demonstrate the SD for radium and thorium in Areas 1 and 2, where elevation-based slices of SD are shown every 2 feet. Figures for Area 1 show elevation slices from 444 to 466 feet above mean sea level (amsl), and 444 to 474 feet amsl for Area 2. Additionally, contours of the probability of non-exceedance of RIM (radium + thorium) > 52.9 pCi/g are overlaid on the SD at 0.2 increments from 0.1 to 0.9. These SD maps of the current model provided a quantitative demonstration of the variance and therefore were the preliminary guide for the identification of new borings, particularly the "primary" borings on GSMO #2. As the DIWP and 30% Design have progressed, additional analyses were conducted based, in part, on comments from USEPA. These analyses are provided below.

4.2.1 Proposed Boring Analysis

In order to determine the extent to which the SD will decrease with the collection of additional samples, the proposed borings were incorporated into the existing data set to produce a "proposed model estimation." The proposed boring analysis involved the following steps:

- For each proposed boring location, a "sample" point was placed at fixed intervals starting at the 2005 ground surface and ending at 20 feet B2005GS. A 1-foot interval was initially chosen, but a finer vertical sample density of 0.5 feet was ultimately implemented in Area 2. The finer resolution was chosen for Area 2 due to a larger range of SD values observed in comparison to the values observed in Area 1.
- The non-exceedance probabilities assigned to each sample were based on the current model prediction with the updated variogram values as presented in Table E-1. For example, if a sample intersected a grid cell node with the non-exceedance probability of 0.8, the sample was assigned an indicator value of 0.8. Since the analysis is only for the purposes of examining SD the value of the indicator was inconsequential. This is because the indicator value itself does not inform the SD and the focus was on the variability of the potential result and not the actual result.

- The proposed samples were added to the existing data set and the model process was re-executed with both the previous and the proposed indicator values.

Figures E-10a through E-10j demonstrate the SD for radium and thorium in Area 2, where elevation-based slices of SD are shown every 4 feet for the current model and the model utilizing the proposed boring analysis ("proposed model"). Figures for Area 2 show elevation slices from 450 to 462 feet amsl. Additionally, contours of probability of non-exceedance of RIM (radium + thorium) > 52.9 pCi/g are overlaid on the SD at 0.2 increments from 0.1 to 0.9. Each figure shows a comparison of the existing model to the proposed model estimation. Similar to the above, this exercise provides a depiction of where the existing SD is relatively high, but also demonstrates the decrease in error once this DIWP (as currently designed) is implemented.

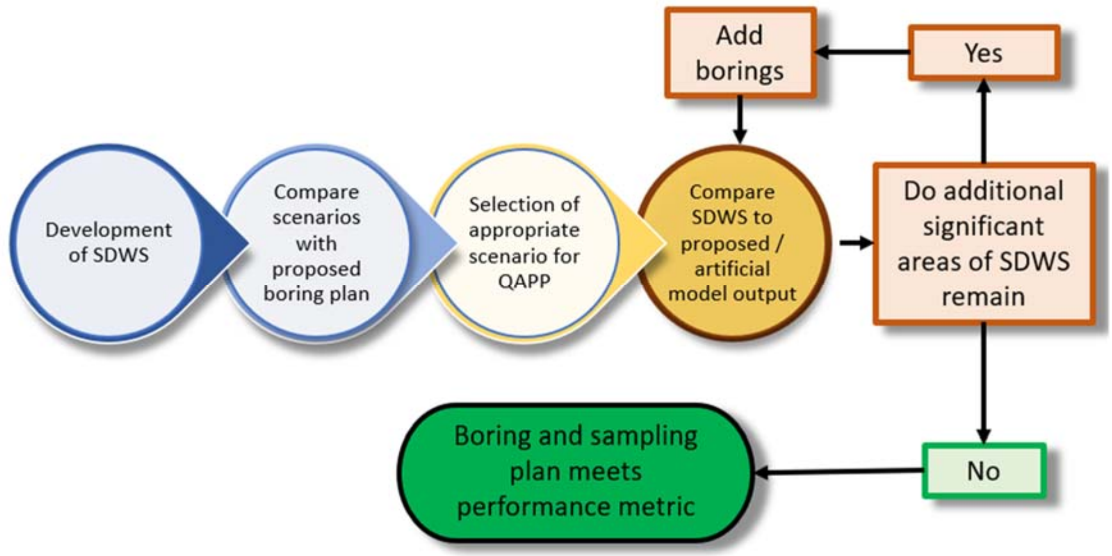
4.2.2 Standard Deviation to Warrant Sampling

A process for highlighting regions to target for sampling based on SD and RIM non-exceedance probability was developed in response to Comment #17 of the USEPA's *Comments on 3/30/2020 Design Investigation Work Plan*. This process statistically combines the SD with IK* indicator values into a metric for determining error rates, such that areas of the model can be queried to demonstrate where additional samples might be useful in reducing model uncertainty. This section describes the development and use of a metric termed SDWS and relates to the Quality Assurance Project Plan (QAPP) Worksheet #11 in terms of evaluating acceptable levels of uncertainty and determining if sufficient samples are being proposed (Step 6 of Worksheet #11 in the QAPP).

Development and site-specific use of SDWS is provided in the flow diagram below and outlined in the following steps:

- Development of SDWS – Neptune (2020) provided proofs and methods for a variety of error rates (see Attachment E-3) at relevant RIM >52.9 pCi/g non-exceedance probabilities and associated SD values.
- Scenario development – scenarios were developed to compare with the proposed boring locations to the SDWS for varying Type I/Type II error rates.
- Areas of SDWS were mapped for graphical comparison with the proposed boring plan. This overlay of SDWS areas and proposed borings assisted in the determination if areas of SWDS existed without proposed boring(s).
- A specific error rate was selected for further modeling in relation to the QAPP Worksheet #11.
- Additional proposed borings were added to the model and it was rerun (see Section 4.2.1).
- If significant SDWS locations were identified then more borings were added until the number of borings and samples was considered appropriate and the level of uncertainty was acceptable, per Step 6 of Worksheet #11.

Workflow Figure: Flow diagram demonstrating development and use of Standard Deviation to Warrant Sampling Metric



Development of SDWS

The two types of error rates were developed based on the null hypothesis (H_0) of the IK* model, where a probability of RIM non-exceedance of < or equal to 0.5 indicates the presence of RIM >52.9 pCi/g, with an alternative hypothesis (H_A) of a RIM non-exceedance probability > 0.5 indicating the material is not RIM (>52.9 pCi/g).

$$H_0: \mu \leq 0.5 \quad Material\ is\ RIM(> 52.9\ pCi/g)$$

$$H_A: \mu > 0.5 \quad Material\ is\ NOT\ RIM(< 52.9\ pCi/g\ )$$

For Type I errors, the null hypothesis is rejected when the null is true. The impact of Type I errors is that RIM >52.9 pCi/g is erroneously classified as NOT >52.9 pCi/g and left in place. In a Type I error, areas of RIM >52.9 pCi/g would not be excavated and would be an act of false compliance. Alternatively, for Type II errors, the null hypothesis is not rejected when the alternative hypothesis is correct, causing material with activity concentrations <52.9 pCi/g to be classified as RIM >52.9 pCi/g. In a Type II error, areas of RIM <52.9 pCi/g would be excavated, resulting in an over-excavation, and would be an act of false exceedance. What this means, relative to the current estimated model, is that Type I errors are potentially present for cells >0.5 non-exceedance probability (not targeted for excavation) and Type II errors are potentially present for cells <0.5 non-exceedance probability (targeted for excavation).

Scenario Development and Comparison to Proposed Plan

As a first step, a range of SDWS scenarios were developed to provide a comparison to the proposed boring plan – in other words, answering the question "are there proposed borings located in areas of SDWS" based on various Type I/Type II scenarios provided by Neptune (2020). If so, from a qualitative perspective, one could ascertain that the proposed sampling plan was, indeed, targeting areas of interest (i.e., SDWS). Table E-3 provides associated RIM non-exceedance probabilities and SDWS for this evaluation.

As shown in the table, several of the RIM non-exceedance probability and SD scenarios were excluded from further analysis (i.e., graphically comparing the SDWS map and current boring locations) due to the SDWS being above the maximum SD value (Figures E-9a through E-9ab). Additionally, for the Type I - 15% / Type II - 25% error scenario, the SDWS criteria for RIM non-exceedance probabilities at 0.4 and 0.6 is an SD of 0.06, which was overly conservative. This low (overly conservative) SDWS resulted in extensive areas requiring sampling. In fact, all areas at 0.4 and 0.6 RIM non-exceedance probabilities were higher than the 0.06 SD value. Due to this overly conservative SD and assumed sample requirement, this scenario was not carried forward in the process, recognizing that it would take an excessive number of samples.

It can be seen in Attachment E-3 that several error percentage scenarios produce the same criteria to warrant sampling (e.g., 40% Type I and II Error is equivalent to 30% False Compliance and 40% False Exceedance criteria). To limit redundancy, Table E-3 provides cases where False Compliance is greater than False Exceedance but recognizes that similar SDWS exists for cases of where Type I and Type II errors are equal.

Figures E-11a through E-11c, respectively, were developed from the Warrant to Sample Scenarios A, B, C (Table E-3) and include model outputs illustrating areas above a particular SDWS (inherently at a specific RIM probability). Additionally, these figures contain proposed boring locations that were developed through other evaluations. The position of SDWS areas and proposed borings demonstrate that a significant number of SDWS areas have intersecting/nearby proposed borings. It should be noted that due to the high volume of samples collected in Area 1 and in turn, low SD in Area 1, this analysis only applies to Area 2.

TABLE E-3 STANDARD DEVIATION TO WARRANT SAMPLING SCENARIOS

Scenario	Type I Error Rate (%)	Type II Error Rate (%)	Confidence Level (%) NEP > 0.5	Confidence Level (%) NEP < 0.5	Error Type Considered	RIM non-exceedance probability	SDWS	Analyzed/Not Analyzed (NA)
A	30	35	70	65	Type I (outside RIM)	0.6	0.11	Analyzed (see Figure E-11a)
						0.7	0.22	NA - Above Max Standard Deviation
						0.8	0.33	NA - Above Max Standard Deviation
						0.9	0.44	NA - Above Max Standard Deviation
					Type II (inside RIM)	0.4	0.11	Analyzed (see Figure E-11a)
						0.3	0.22	NA - Above Max Standard Deviation
						0.2	0.33	NA - Above Max Standard Deviation
						0.1	0.44	NA - Above Max Standard Deviation
B	30	40	70	60	Type I (outside RIM)	0.6	0.13	Analyzed (see Figure E-11b)
						0.7	0.26	NA - Above Max Standard Deviation
						0.8	0.39	NA - Above Max Standard Deviation
						0.9	0.51	NA - Above Max Standard Deviation
					Type II (inside RIM)	0.4	0.13	Analyzed (see Figure E-11b)
						0.3	0.26	NA - Above Max Standard Deviation
						0.2	0.39	NA - Above Max Standard Deviation
						0.1	0.51	NA - Above Max Standard Deviation
C	15	25	85	75	Type I (outside RIM)	0.6	0.06	NA - Entire Area Above SDWS
						0.7	0.12	Analyzed (see Figure E-11c)
						0.8	0.17	Analyzed - For Th (see Figure E-11c), NA for Ra - Ra does not exceed SDWS for specified indicator value
						0.9	0.23	NA - Above Max Standard Deviation
					Type II (inside RIM)	0.4	0.06	NA - Entire Area Above SDWS
						0.3	0.12	Analyzed (see Figure E-11c)
						0.2	0.17	NA - Does not exceed SDWS for specified indicator value
						0.1	0.23	NA - Above Max Standard Deviation

NEP = Non-exceedance probabil ty (RIM >52.9 pCi/g)

<u>Selection of Confidence Levels of Interest for Progression to QAPP</u>

The SDWS error rates can also be used as Confidence Level (CL) in the estimated RIM >52.9 pCi/g extent because they are related through hypothesis testing and the differentiation between decision-making and estimation. Based on the information and analyses provided in this DIWP, an acceptable confidence interval of 70% for Type I errors and 60% for Type II errors was selected for further evaluation and modeling. These confidence levels are considered acceptable because:

- When Type I error is less than Type II error, there is more emphasis towards over-excavation rather than under-excavation (when outside the RIM >52.9 pCi/g), yet there is recognition that because the RODA requires optimizing the excavation, limiting over excavation is important.
- This project is a subsurface investigation of a landfill which therefore includes a level of uncertainty that cannot be overcome by excessive sampling (USNRC 2012).
- Confirmation sampling will verify or refine the excavation limits.

Based on these error rates, the next step is to determine if the inclusion of the additional DI data in the model lowers the SD below the SDWS. Seventy percent CL is applicable to areas outside the RIM > 52.9 pCi/g, and 60% CL areas are applicable to areas inside RIM > 52.9 pCi/g. This metric has been put forth as part of the QAPP as a performance metric and to provide an acceptable level of uncertainty (Worksheet #11 Principle Study Question- [PSQ]-1).

<u>Comparisons, Model Update and Additional Borings</u>

As part of the process above, the 70/60% Type I and Type II CLs SDWS regions were graphically compared to existing boring locations (**Figures E-11a** through **E-11c**). The results indicate that areas with significant spatial extent of SDWS (at a variety of error rates) have proposed borings located in these polygons and/or directly adjacent to these polygons. This graphical comparison provides credibility that the proposed boring plan is adequate for meeting the objectives of lowering model uncertainty.

Using the 70% CL and 60% CL, as described above, the model was re-run with the proposed boring plan, and SDWS fields were re-processed with new model output. Figure **E-11d insets A and B** provide the maps of spatial extent of SDWS in the existing model and an updated model using the proposed borings as artificial data (see above). In **Figure E-11d inset B** it can be observed that, with the proposed boring plan, there is one area of significant SDWS in the middle of Area 2 southwest of proposed borings A2-SB001 and A2-SB016. As a following step (outlined in the workflow above) two additional borings were added to the model with artificial data to determine if the SDWS is sufficiently lowered. **Figure E-11d inset C** provides the model output SDWS after the inclusion of the additional borings and after all remaining SDWS areas (with the exception of a few minor polygons) have been removed. Therefore, this analysis indicated that the previously proposed borings, with two additional borings focused on remaining SDWS areas, are sufficient to meet SDWS at the 70% Type I and 60% Type II CL. These analysis and results provide quantifiable, statistical support of Step 6 of Worksheet #11 in the QAPP.

4.2.3 Indicator Variability Metric

In addition to considering the uncertainty regarding the non-exceedance probability threshold criteria, the kriging SD can also be considered when determining boring locations. Specifically, areas that display both relatively higher SD and are also near the decision criteria cutoff (0.5) are subject to greater uncertainty relative to decisions regarding the need for excavation. In order to easily identify both areas with high relative SD, and areas approaching the decision criteria, Parsons developed an IVM tool for determining areas near RIM decision criteria cutoff that also possess high SD. IVM was developed as an exploratory analysis or tool to ensure borings that were proposed to satisfy other DI goals also generally aligned with the goal of confirming the current estimated RIM >52.9 pCi/g shell, and was not necessarily designed to be used for determining where borings should be located. It is recognized that other areas of the model should be explored and that is why a variety of tools were used / developed in this DIWP process.

The IVM was designed to highlight regions within the area boundary that are both near the decision criteria (0.5) and have higher relative SD values. IVM involves first weighting the probabilities of non-exceedance near 0.5 within the grid space. In order to perform this weighting, the following function was used:

Equation 4.3.1:

$$W(x_i) = \begin{cases} x_i \leq 0.5 & {x_i}^2 \\ x_i > 0.5 & (1 - x_i)^2 \end{cases}$$

For *i* = 1 to *n* where *n* is the total number of nodes in the grid space and x_i is the indicator value for node *i*

Equation 4.3.1 results in larger numbers near 0.5. For example, for a resulting grid node with a non-exceedance probability of 0.90, using **Equation 4.3.1** results in a final weighted value of 0.01, where as a grid node with a non-exceedance probability of 0.45 results in a final weighted value of 0.20. The grid cell with the non-exceedance probability of 0.45 receives a greater value than the grid cell with non-exceedance probability 0.90.

After the non-exceedance probabilities are weighted near 0.5, they are then combined with the SD values using the following function:

Equation 4.3.2

$$\text{IVM}\big(W(x_i)\big) = W(x_i) \cdot sd_i$$

For *i* = 1 to *n* where *n* is the total number of nodes in the grid space and sd_i is the kriging SD for node *i.*

Equation 4.3.2 allows for SD to be included in the final metric, which results in areas with both higher SD and non-exceedance probabilities near 0.5 to have larger final grid space values.

The IVM was developed for specifically determining areas for DI boring placement; however, the kriged grid space is three-dimensional. The depth of high IVM is not as consequential as the horizontal location for boring placement since sampling will be performed at certain depths based on field screening.

Following the data reduction, the final X-Y grid space of IVM values was contoured to show regions of highest IVM. The IVM results for both Areas 1 and 2, radium and thorium are presented in Figure 6D and 6E of the DIWP. As demonstrated on these maps, the regions of high IVM are being addressed by the proposed boring program.

4.3 Thorium Quantification Limit Analysis

To understand the uncertainty in the ability to predict thorium >52.9 pCi/g using gamma counts, an evaluation was completed to support a more quantified understanding of the reliability of thorium at these lower levels. It is recognized that while thorium-230 is not a gamma emitter at these concentrations, there is a correlation between radium and thorium for both Areas 1 and 2. Using this correlation between radium and thorium, and understanding the known detection limit for a typical 2-inch x 2-inch sodium iodide (NaI) detector for radium-226, an approximate detection limit for thorium from gamma counts can be estimated.

Using published data and site empirical data the following approach was taken:

- According to specifications in NUREG-1507 *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions* (NRC 1998), the detection limit of radium-226 for a 2-inch-by-2-inch sodium iodide (NaI) gamma detector is 2.8 pCi/g. This is the starting point for estimating a reasonable detection limit for thorium, recognizing the relationship between thorium and radium.
- Existing samples of hard data of thorium and radium were analyzed for correlations beyond those done previously (SSP&A 2017). **Figure E-12** demonstrates this relationship. Several regressions were developed to determine the correlation co-efficient. The data is displayed as the logarithm of the combined Ra and Th values offset by one in order to remove negative values from the regression. One regression is a quadratic fit to all of the combined Ra and combined Th data. Two other quadratic fit regressions are displayed on subsets of the entire data set.

The correlation coefficient (R^2) for the quadratic fit to all the data was 0.81, demonstrating that the relationship of radium to thorium represents a good correlation. When data for Ra below 2.8 pCi/g is removed from the regression, the R^2 improves slightly to 0.82, indicating the data are more strongly correlated above this concentration. This could potentially be due to the influence of occurrences of background Ra and Th concentrations within Areas 1 and 2. The final regression, in which both data for Ra below 2.8 pCi/g and data points that exhibit a higher Ra concentration than that of Th are removed, exhibits an R^2 of 0.90, indicating a better correlation of the data.

Additional regressions were similarly created for combined thorium to gamma and combined radium to gamma (provided as **Figures E-13** and **E-14**, respectively). These regressions suggest previous data have a correlation coefficient (R^2) above 0.67 for the entire span of combined Th and Ra concentrations observed.

Based on the correlation between combined Ra and combined Th (**Figure E-12**), Th generally exists in higher concentrations than Ra at the Site. Within the region of Ra concentrations between 2.8 and 10 pCi/g, Th concentrations are occasionally observed above the threshold of 52.9 pCi/g, indicating that lower Ra concentrations could indicate the presence RIM >52.9 pCi/g for Th.

While the relationship between combined Th and combined Ra is not intended to be used quantitatively in the geostatistical model, it does inform the sample selection process within the DI. This relationship will be explored further with the collection of additional data by sampling in regions where radium has been estimated between 7.9 pCi/g and 52.9 pCi/g. (**Figure E-15**). **Figure E-15** shows the radium >7.9 pCi/g extent compared to the current RIM >52.9 pCi/g extent. The proposed borings generally intersect or are proximal to regions in which the radium >7.9 pCi/g boundary extends beyond the current defined RIM >52.9 pCi/g boundary. The data collected from these borings will be used to further this analysis on combined radium vs combined thorium.

From Figures E-13 and E-14, a relationship between gamma and both combined Th and combined Ra is presented. While it is recognized that gamma could potentially be an indicator for both Ra and Th based on the presented regressions, it is acknowledged that the absence of gamma does not necessarily indicate the absence of RIM >52.9 pCi/g. In order to improve the regressions, the sampling program will prioritize gamma range targets, as described in Section 1.3. Beyond the target gamma ranges, gamma will not inform sample selection, which will instead be randomized within four-foot intervals. By randomizing the sample depth selection, the reliance on gamma is lessened within the DI, and potential impacts of biased sampling will be reduced.

5.0 EXCAVATION OPTIMIZATION

Evaluations are ongoing to optimize the excavation of RIM in Areas 1 and 2. The RODA specifies that a limited number of isolated pockets of RIM located between 8 and 12 feet B2005GS can remain in place as long as the activity left behind is offset by removal of RIM, with preference to areas of higher activity (e.g., 1000 pCi/g) at depths of 12 to 20 feet B2005GS within Area 1 and/or 2. Each isolated pocket identified to remain in place is subject to USEPA approval. In addition, the overall activity removed must equal the total activity between 0 and 16 feet B200GS. Those areas which are potentially >1,000 pCi/g and associated areas for activity off-set (areas less than 1,000 pCi/g but advantageously positioned for removal due to proximity to proposed excavation extents), will be tentatively identified as part of the 30% design using the methods described in the PEP (Parsons 2020) and elaborated on in this appendix. This is a preliminary optimization because substantial new data will be obtained in the DI.

5.1 Total Activity and Impacted Soil Volume in 4-foot Sub-intervals Between 0 and 20 feet B2005GS

Developing an increased understanding of total activity at a higher resolution by depth is an initial step in excavation optimization. Building from the total activities by depth presented in the PEP (Parsons 2020), further depth discretization was performed to explore total activity and associated soil volumes in 4-foot intervals between the 2005 ground surface and 20 feet B2005GS. Examining these sub-intervals allows for better understanding of distribution of activity from 0 to 20 feet B2005GS and allows for identification of any clear pattern of total activity values. For example, high total activity in 0 to 4 feet B2005GS may indicate a bias due to surface sampling results. Presented below are refinements of the activity calculation equations from Appendix B of the PEP (Parsons 2020).

As discussed in the PEP (Parsons 2020), the RIM activity calculation can be defined as Equation 5.1.1, below. Equation 5.1.1 has been modified from the version presented in the PEP to acknowledge that the model gridding is developed in a uniform rectilinear structure, or of equal cell size throughout the gridded model space. Further consideration will be given to using or including an alternative equation to the activity balance provided here (and the PEP), one which eliminates the redundant density parameter in accordance with USEPA's comments.

The equation presented in the PEP (Parsons 2020) had a general form that included a subscript for grid cell volume, indicating that cell volumes may differ on a cell-by-cell basis, which is not the case for the current rectilinear grid. The subscript for cell volume has been removed in the simplified Equation 5.1.1 (below), because the model gridding is developed in a uniform rectilinear structure, or of equal cell size throughout the gridded model space. Grid cells in Area 1 and Area 2 models are 15-meter by 15-meter by 0.5-foot (vertical).

Equation 5.1.1, simplified from Appendix B of PEP (Parsons 2020):

$$TAct = Act_{z_1-z_2} = \sum_{i=1}^{n}(va_i)\rho_B$$

Where:

$TAct$	= Total activity
$Act_{z_1-z_2}$	= Activity over the depth interval z_1 to z_2
a_i	= Activity concentration at grid cell i
v	= Soil volume of grid cell (15 meters x 15 meters x 0.5 foot)
n	= Number of grid cells where RIM is > 52.9 pCi/g over depth interval z_1 to z_2
ρ_B	= Soil bulk density (weight of the dry soil/total soil volume)

Since the total activity to be removed is the equivalent of total activity between 0 and 16 feet B2005GS in areas > 52.9 pCi/g, **Equation 5.1.1** can then be depth-limited where z_1 = 0 and z_2 = 16 feet B2005GS (Equation 2).

As with **Equation 5.1.1**, **Equation 5.1.2** from the PEP (Parsons 2020) has been simplified below to remove the subscript for cell volume, as the cell sizes are constant and the use of a subscript is unnecessary.

Equation 5.1.2, as simplified from Appendix B of PEP (Parsons 2020):

$$TAct_{0-16} = \sum_{i=1}^{n}(v_{\,0-16}a_{i\,0-16})\rho_B$$

Where:

$TAct_{0-16}$	= Total activity over the depth interval 0 to 16 feet B2005GS
$a_{i\,0-16}$	= Activity concentration at grid cell i over depth interval 0 to 16 feet B2005GS
v_{0-16}	= Soil volume of grid cell (15 meters x 15 meters x 0.5 ft) over depth interval 0 to 16 feet
n	= Number of grid cells where RIM is greater than 52.9 pCi/g over depth interval z_1 to z_2
ρ_B	= Soil bulk density (weight of the dry soil/total soil volume)

For the calculation of total activity, the bulk density of the material is assumed to be a constant fixed soil density value of 1.85 g/cm^3. In the PEP (Parsons 2020), the relationship described between bulk density and total activity used the term "relative." The term "relative" was intended to indicate that, during activity balancing, the same bulk density value will be applied to both the isolated pockets and the off-set excavation areas.

Because both calculations assume the same value for bulk density, the total activity calculation in the activity-balancing becomes a function of soil volume and activity concentration between soil left in place and soil used for off-set. We note that the material density will vary randomly within a small range (likely to be < 25%), whereas cell-based activity can vary by orders of magnitude. Thus, a cell's total activity is driven predominantly by the activity concentration value.

It is recognized that a different equation can be used, as suggested by the USEPA, where density is eliminated from these equations as discussed above. Future calculations will consider the ratio as presented in the USEPA comments on the PEP.

Employing the modified **Equations 5.1.1** and **5.1.2**, above, and incorporating additional depth-discretization of total activity into separate 4-foot intervals, total activity can be mathematically defined by **Equation 5.1.3**, below:

Equation 5.1.3, as modified from Appendix B of PEP (Parsons 2020):

$$TAct = TAct_{0-16} = A_{0-4} + A_{4-8} + A_{8-12} + A_{12-16}$$

Where:

$\boldsymbol{TAct}$ = Total activity
$\boldsymbol{TAct_{0-16}}$ = Total activity over the depth interval 0 to 16 feet B2005GS
$\boldsymbol{A_{z1-z2}}$ = Activity within the interval of z1 to z2 feet B2005GS

The resulting total activity and associated soil volumes for the 4-foot intervals are presented below in **Table E-2.** Total activity and volume for 16-20 feet B2005GS is provided to assist in identifying the availability of possible off-set locations for total activity balancing.

TABLE E-2 TOTAL ACTIVITY AND ASSOCIATED VOLUME IN 4-FOOT LAYERS: 0 TO 20 FEET B2005GS

Depth Interval (feet B2005GS)	Area 1		Area 2	
	Volume (CY)	*Activity (Ci)*	*Volume (CY)*	*Activity (Ci)*
0-4	1,977	6.7	27,035	104.1
4-8	2,751	9.9	19,687	43.0
8-12	4,077	12.1	17,267	33.1
12-16	2,708	13.4	9,338	10.2
0-16	**11,512**	**42.1**	**73,323**	**190.4**
16-20	2,306	2.2	9,921	30.4

Note: Ci – Curies

In reviewing the distribution of RIM > 52.9 pCi/g presented in **Table E-2**, it appears Area 1 has total activity distributed throughout the 0 to 16 feet B2005GS interval, with slightly more activity present from 8 to 16 feet B2005GS and minimal activity present at 16 to 20 feet B2005GS. Based on the total activity distribution by depth in Area 1, it appears that the activities are not overly biased by surface samples. The activity model for Area 1 can be further refined by additional data collection within, and surrounding, the RIM boundary. The DI field investigation data collection will assist in data resolution in the Area 1, which will refine the activity model.

There is less data density in Area 2, especially data at depth, which can be seen in the total activity distribution among the 4-foot intervals. Most of the activity within 0 to 16 feet B2005GS interval is present in the 0 to 4 feet B2005GS interval. Additionally, the model identified more total activity from 16 to 20 feet B2005GS than in 12 to 16 feet B2005GS interval. While it is understood that the material in Areas 1 and 2 are heterogeneous, the variance in total activities between 4-foot intervals is likely due to lower data density at depth. This region of lower data density is an area identified for improvement to underpin the updated geostatistical model for the RD, and data collected during the DI will be incorporated in the model to increase vertical and horizontal resolution of activity concentration data, and thus total activity values.

This analysis of total activity by depth can be further discretized, as needed, to further refinement of the excavation extent in the 30% design. These discretization methods will be paramount to developing an optimized excavation extent during the 90% design following incorporation of data collected during the DI.

5.2 Activity Balancing Improvement for Design

Parsons acknowledges that the total activity calculations and discretization analysis, identification of isolated pockets of RIM between 8 and 12 feet B2005GS, identification of areas relative to the 1,000 pCi/g criteria between 12 and 20 feet B2005GS, and analysis of overburden removal relative to RIM are areas for improvement in the development of an optimized excavation plan. Evaluation of these areas is underway, and further conceptualization discussion is provided in the 30% design document and will be fully developed for the final excavation plan.

As mentioned previously, the RODA specifies that isolated areas of RIM between 8 and 12 feet B2005GS that has activity concentrations > 52.9 pCi/g can remain in place as long as the activity left behind is off-set by removal of RIM between 12 and 20 feet B2005GS within Areas 1 and/or 2. Those areas within 8 and 12 feet that are proposed to be left in place, and associated areas for activity off-set, will be identified with the inclusion of new sample data after the DI is completed using the methods described in the PEP (Parsons 2020) and the depth discretization and activity balancing discussed in this appendix.

A necessary aspect of the RD will include excavation efficiency; thus, the ratio of RIM (total activity and volume) to volume of overburden removal required to access RIM will be reviewed. By reviewing the ratio of RIM removal to overburden disturbance, it can be evaluated if excavation efforts are better allocated in an alternative location within Areas 1 and/or 2 with a more advantageous ratio of RIM (total activity and volume) to volume of overburden removal. The RIM (total activity and volume) versus overburden disturbance ratio for determining whether it is advantageous to excavate is in development.

Based on the optimized excavation approach that allows areas of RIM > 52.9 pCi/g from 8 to 12 feet B2005GS to be left in place, the Equation 4 of Appendix B of the PEP (Parsons 2020) is modified as shown below.

Equation 5.2.1, as modified from Appendix B of PEP (Parsons 2020):

$$TAct = TAct_{0-16} = A_{0-8} + (A_{8-12} - A_{IP\ 8-12}) + A_{>1000@12-16} + HSA_{>1000@16-z3}$$

Where:

$A_{IP\ z_1-z_2}$ = Activity of isolated pockets of RIM (>52.9 pCi/g) over the depth interval z_1 to z_2

$A_{>1000@\ 12-16}$ = Activity of RIM >1000 pCi/g between 12-16 feet B2005GS, Areas <1000 pCi/g may be removed based on excavation efficiency (i.e., near a proposed excavation extent)

$HSA_{>1000@16-z3}$= Hot Spot Activity in the excavation required below 16 feet B2005GS, where z3≤20 feet B2005GS, to balance A_{IP} and $A_{<1000@12\text{-}16}$ with preference given to areas >1000 pCi/g to make up the activity balance. Areas <1000 pCi/g may be removed based on excavation efficiency (i.e., near or within a proposed excavation extent).

Given Equation 4 and the remedial objective, when the sum of the RIM activities from the proposed isolated pockets and RIM < 1000 pCi/g between 12 and 16 feet B2005GS that will remain in place is less than or equal to the activity of the RIM between 12 and 20 feet B2005GS that will be excavated, the total activity 0 to 16 feet B2005GS goal is met. Mathematically this is explained in **Equation 5.2.2:**

Equation 5.2.2, modified from previously unnumbered equation in Appendix B of PEP (Parsons 2020):

$$A_{IP\ 8-12} + A_{<1000@12-16} \le A_{>1000@12-16} + HSA_{>1000@16-z_3}$$

then

$$TAct(removed) \ge TAct_{0-16}$$

6.0 SPATIAL AND DEPTH UNCERTAINTY OF CURRENT DATA

There are unaccounted changes or inaccuracies in the current elevation data on which the model is based that add to general depth uncertainty, including the gamma collection methods and their association with laboratory samples and the elevation standardization as it relates to landfill subsidence and additional fill deposits.

6.1 Gamma Collection Methods

An area of uncertainty in historical gamma data involves core retrieval techniques that have made the quantification of a relationship between core-scanned data and downhole data not always straight-forward, as discussed further in **Section 6.2**. Increasing core recovery and/or process development for handling poor recovery data will help support an improved relationship between downhole gamma and core-scanned gamma, if possible.

6.2 Elevation Standardization

Improving the spatial accuracy of the data to be collected as part of the DI has been identified as a key element in model development. The existing geostatistical model is currently based on 2005 ground surfaces. The 2005 ground surface elevation used in the model and as shown in Figure 5B from the DIWP was determined through aerial photogrammetry. After 2005, fill material was placed over top portions of Areas 1 and 2. Further, due to the fact that Areas 1 and 2 are landfills, there is a greater possibility that subsidence has occurred. Although, due to the age of these landfills, natural subsidence since the borings were installed is expected to be minimal. These two mechanisms, placement of fill and natural subsidence, resulted in changes to the current surface of Areas 1 and 2 making the 2005 ground surface uncertain. Because a ground survey was not performed in 2005, further uncertainty is introduced.

In addition to the uncertainty in the estimate of the 2005 ground surface, the potential for natural subsidence to have occurred since the time of sample collection adds a level of uncertainty to the measured sample depth. This uncertainty is greater for the oldest samples, such as those collected during the original RI (1993-1997).

Another source of error identified during review of historical data is uncertainty in the relationship between the length of core retrieved and how core scans relate to the below-ground depth. Error is inherent when interpreting borehole depths versus lengths of recovered core, as core expansion or loss in recovery during extraction introduces uncertainty of true below-ground-surface depths observed in the core. This uncertainty directly affects the model regressions in terms of the relationship between depth of hard data and gamma scans collected from core, and downhole gamma scans.

A multipronged approach will be undertaken to improve the elevation data for use in the geostatistical model:

- Perform a sitewide ground surface topographic survey in Areas 1 and 2 to document the current (2020) ground surface topography.
- Correct historical hard and soft data from the 2005 ground surface elevations to the 2020 surveyed elevations.
- Perform short (approximately 4-foot) core runs during DI drilling to limit the amount of expansion or loss during extraction of core from the borehole, reducing the possibility for translation error between interpreted core depths as compared to typical core runs > 10 feet. The use of short-core runs will provide more accurate elevation relationship between downhole and core scan data. The 4-foot run lengths are also designed to match the decision-making depth intervals that are in multiples of 4 feet as identified in the RODA. This means that materials collected in each core run should fall within a decision-making interval, even if there is poor recovery.
- Develop correlations on a boring-by-boring basis between downhole responses and core-scan responses to improve the elevation resolution between data collection tools.

Following the DI, the geostatistical model will be updated to include the 2020 surveyed ground surface, elevation-corrected historical hard and soft data, and incorporation of DI data based on the 2020 surveyed ground surface. Details of the sitewide survey are discussed in Section 3 of the DIWP.

7 REFERENCES

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FIGURES

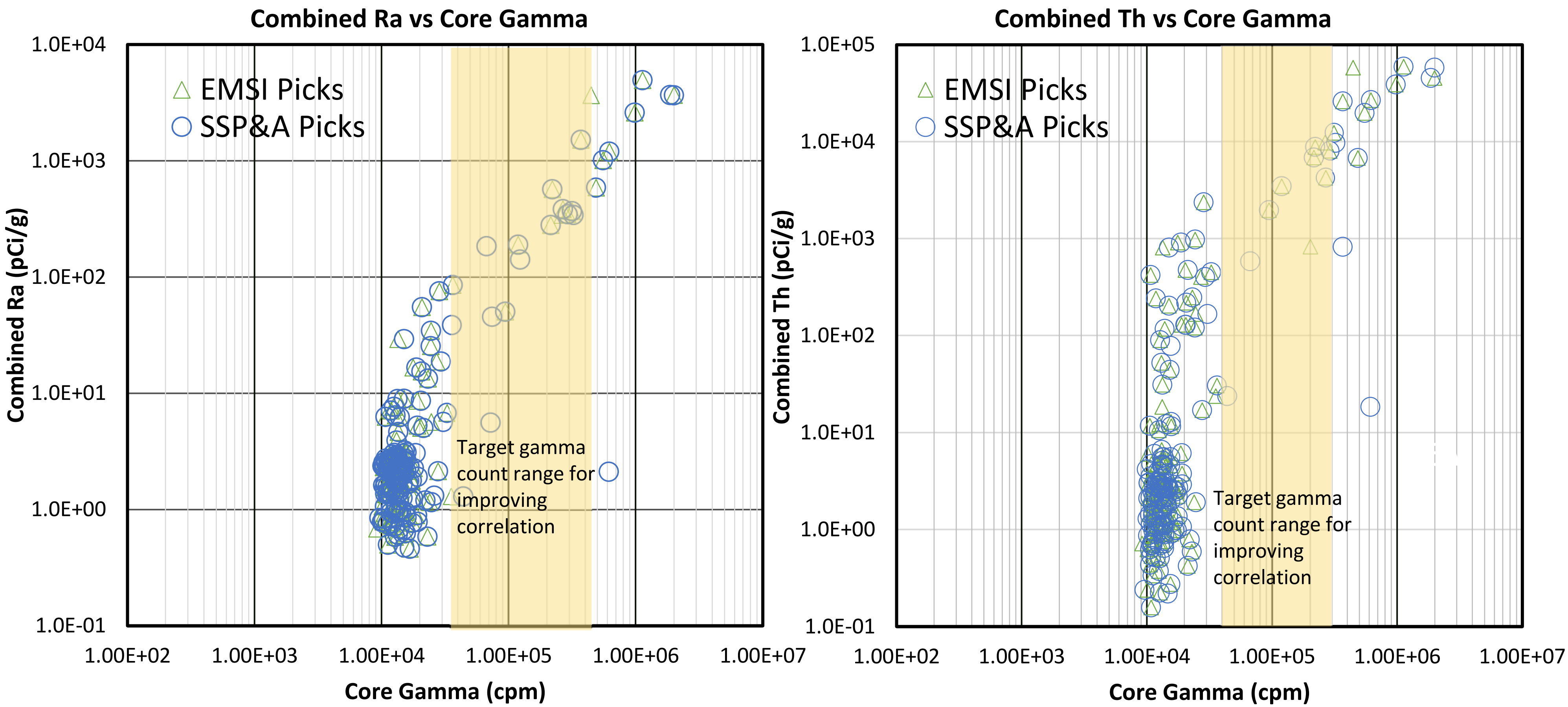


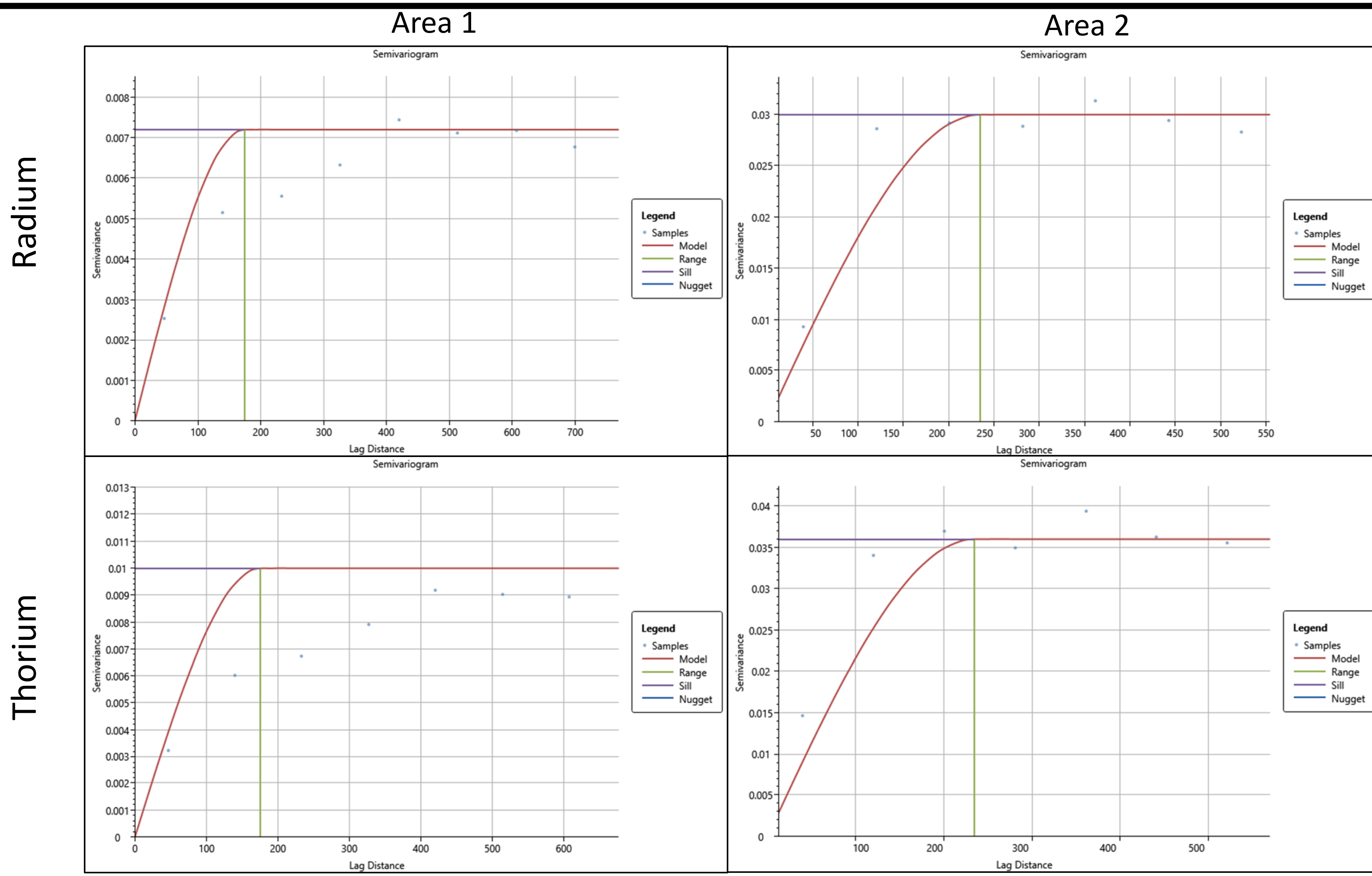
FIGURE E-1

Target Gamma Count Ranges

West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Note: The variogram viewing module does not allow for interactive adjusting of X-axis and Y-axis. The model appears to intersect at a non-zero nugget, however this is not the case and only an effect of zooming in in the plots

FIGURE E-2

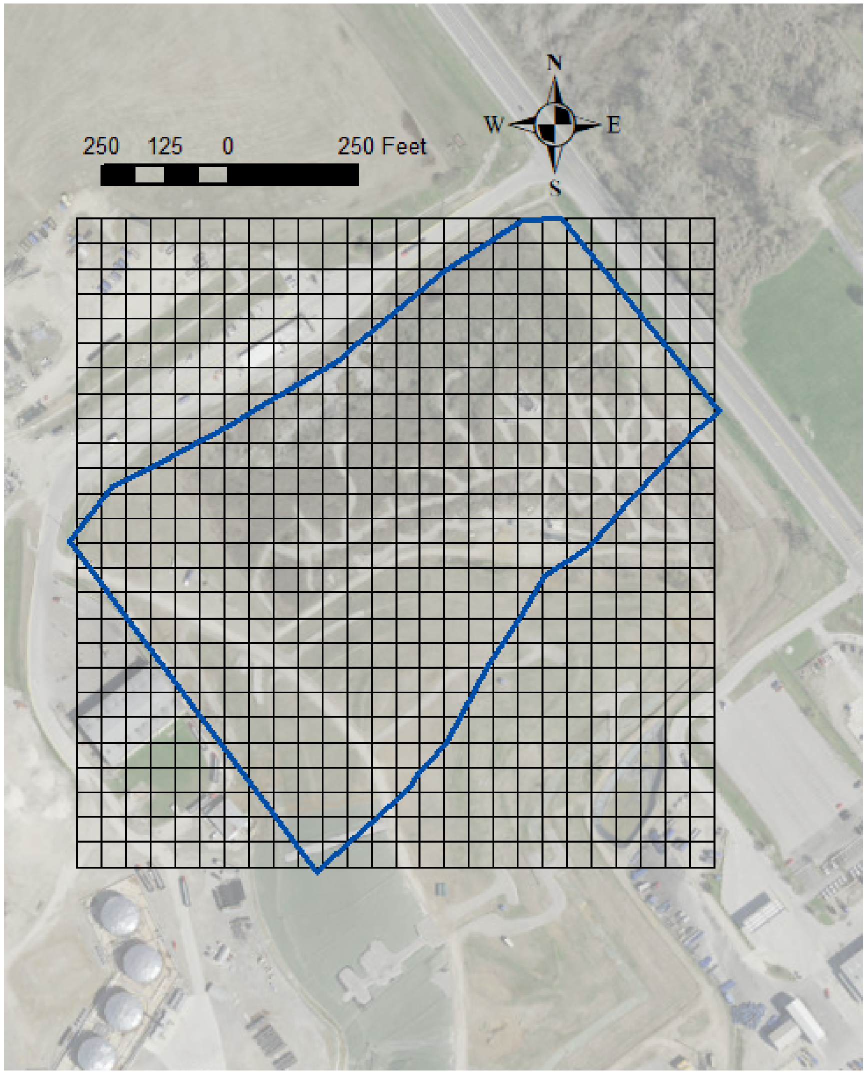
Updated Variograms

West Lake Landfill Operable Unit 1, Bridgeton, Missouri

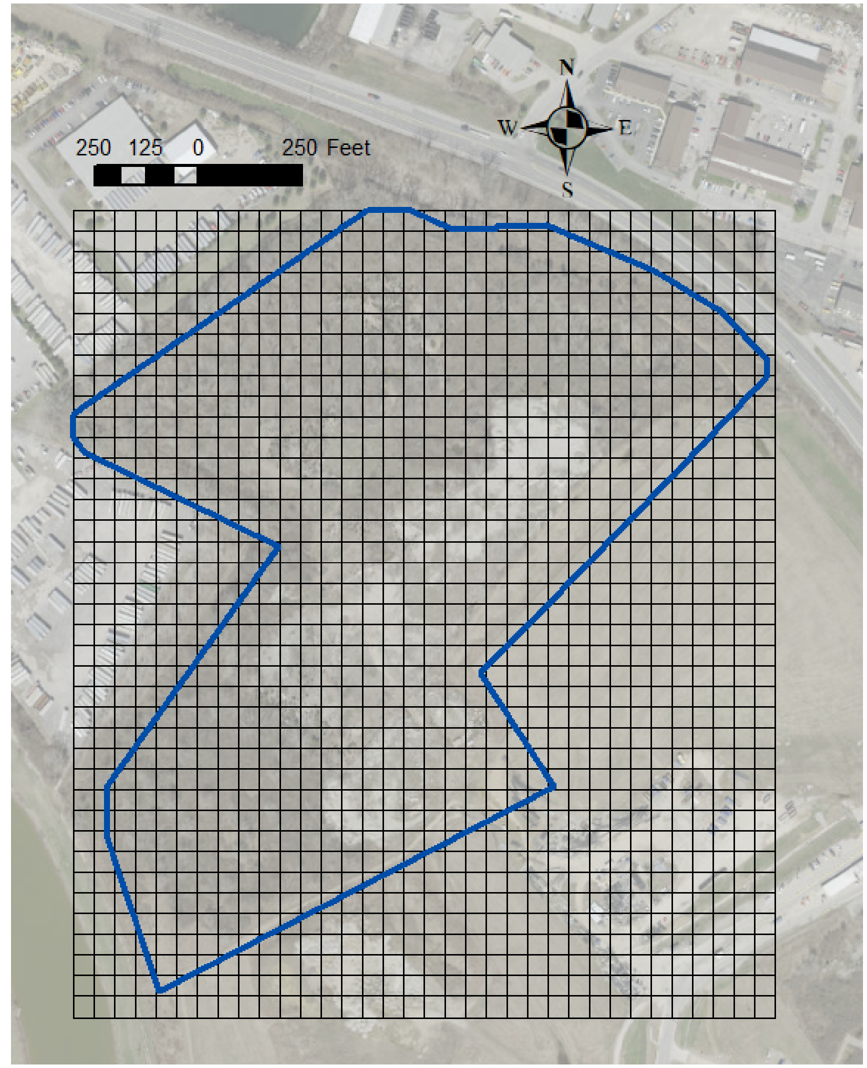
PARSONS

Syracuse, NY

Area 1



Area 2



Legend

Area Boundary

Kriging Grid

FIGURE E-3

225 Square Meter Kriging Grid
Areas 1 and 2

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY

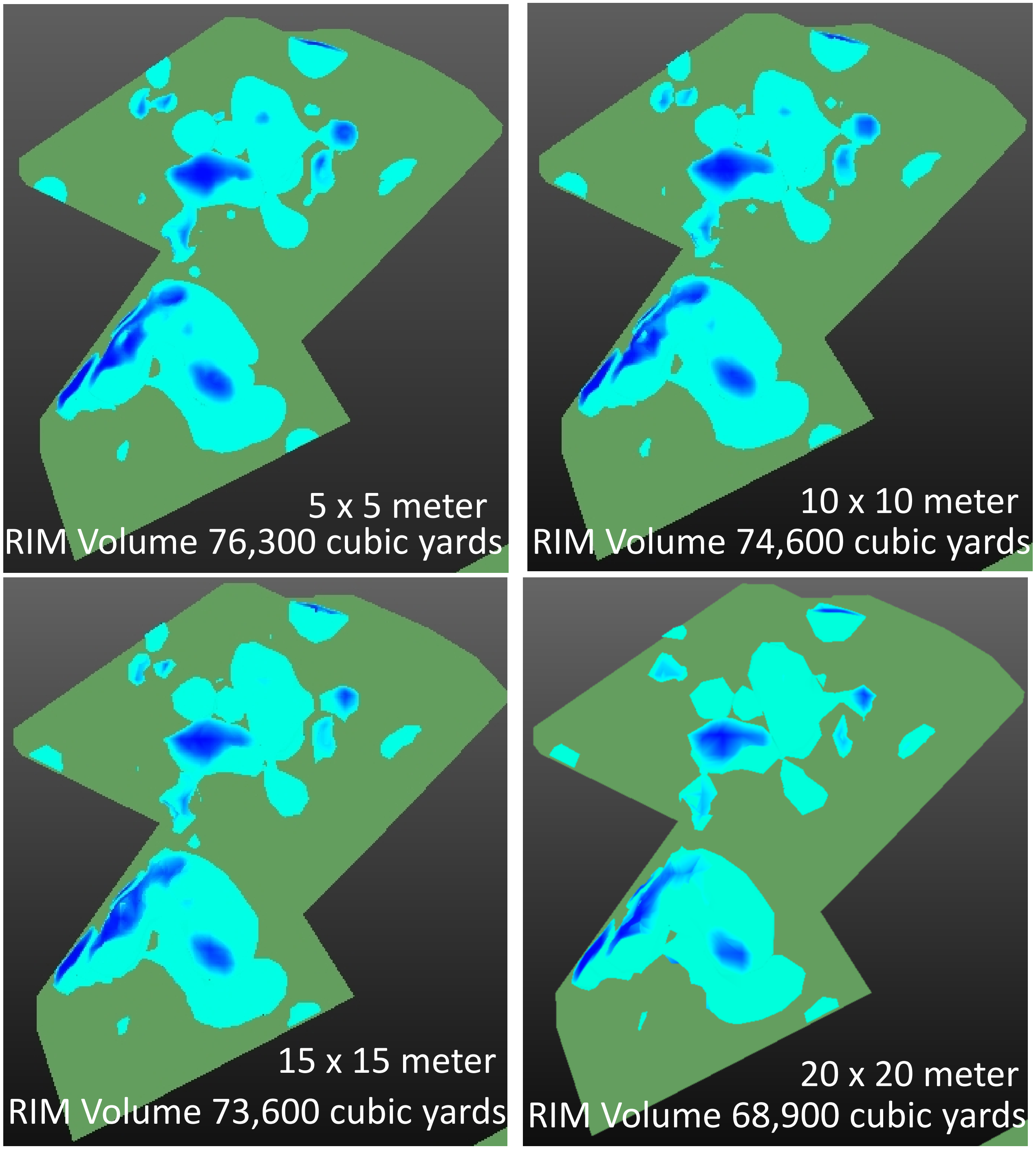


FIGURE E-4

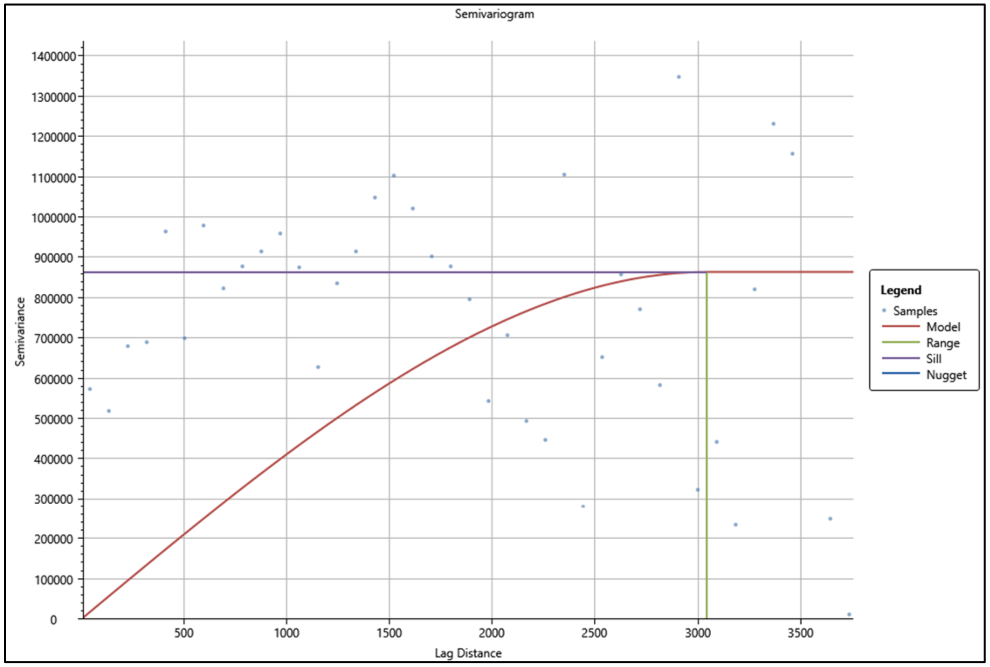
Grid Size Sensitivity
Area 2

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY

Area 1



Area 2

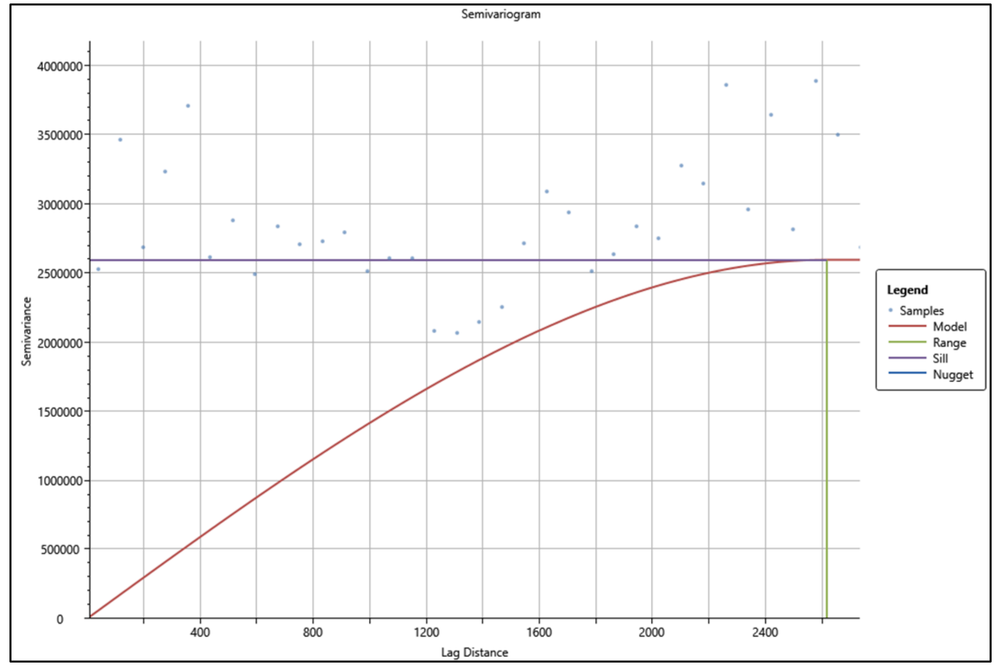


FIGURE E-5

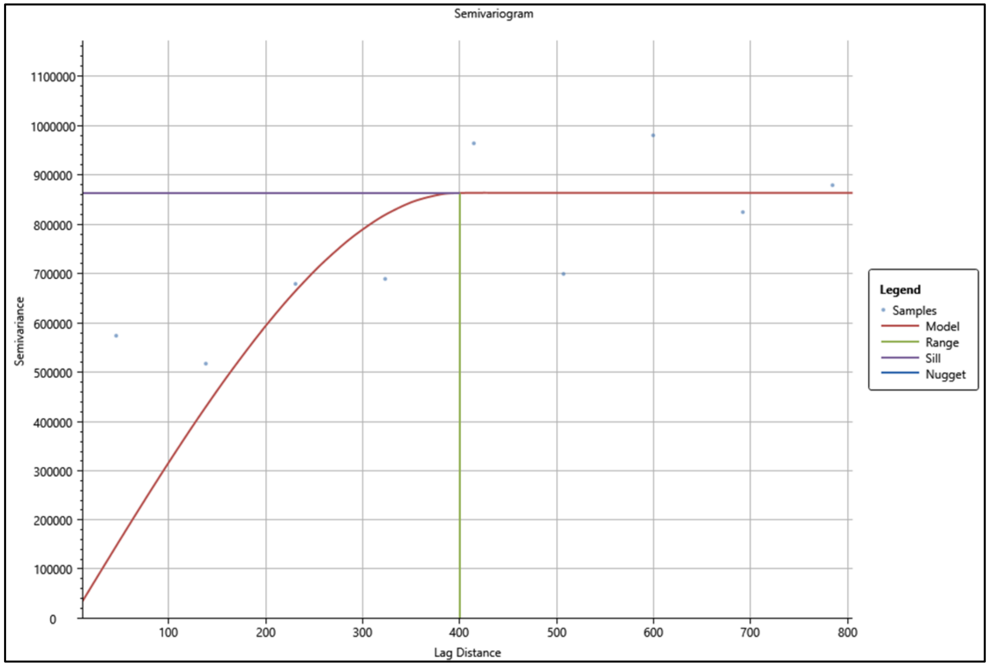
Activity Model Variograms
Autofit

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY

Area 1



Area 2

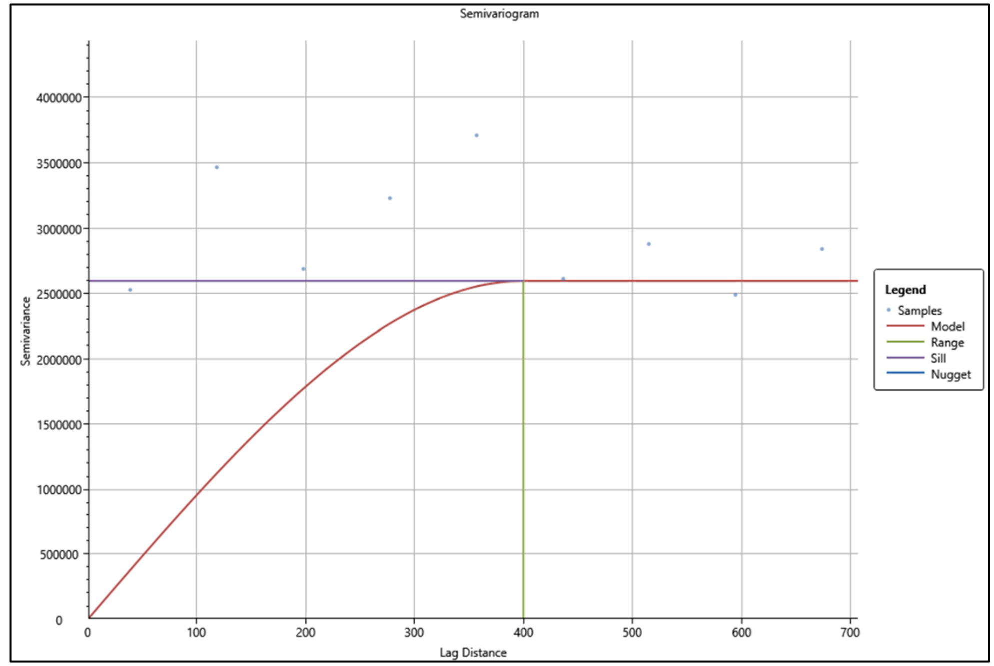


FIGURE E-6

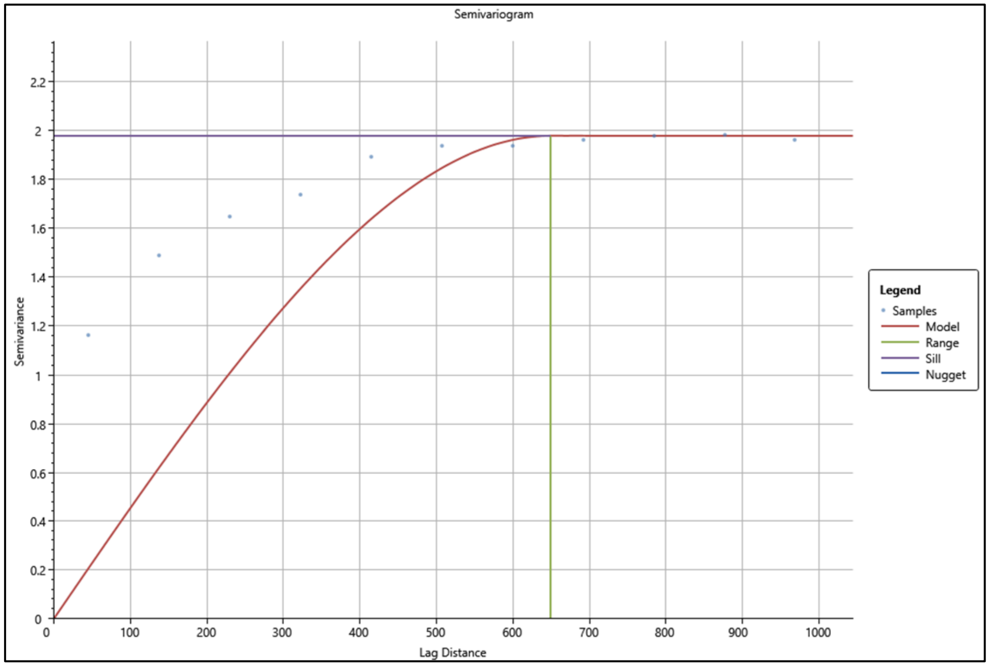
Activity Model Variograms
Alternative Range Analysis

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY

Area 1



Area 2

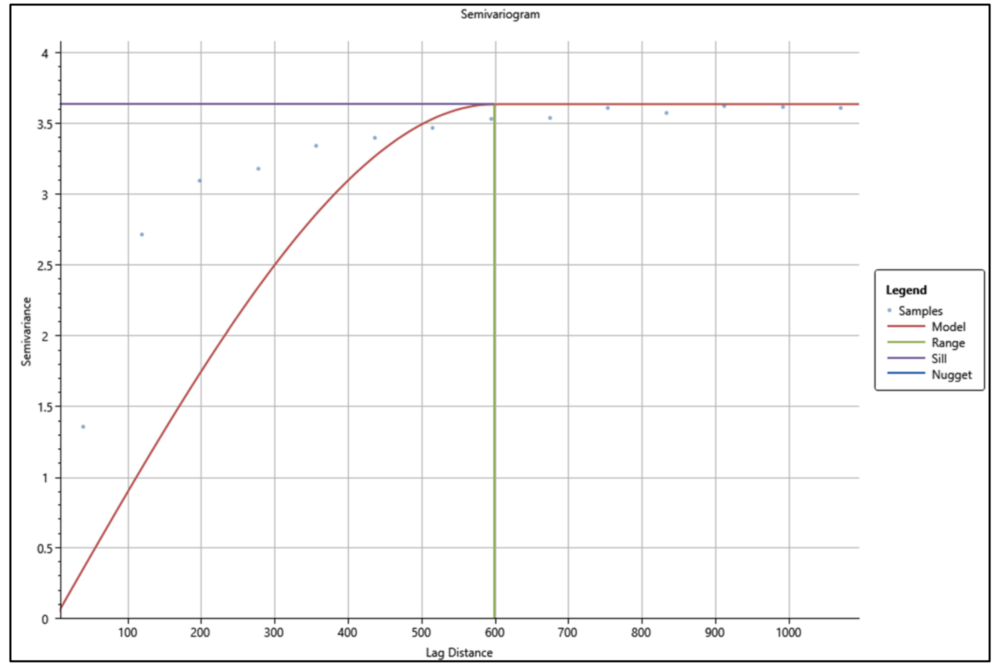


FIGURE E-7

Activity Model Variograms
Example Log Transformed Variograms

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY

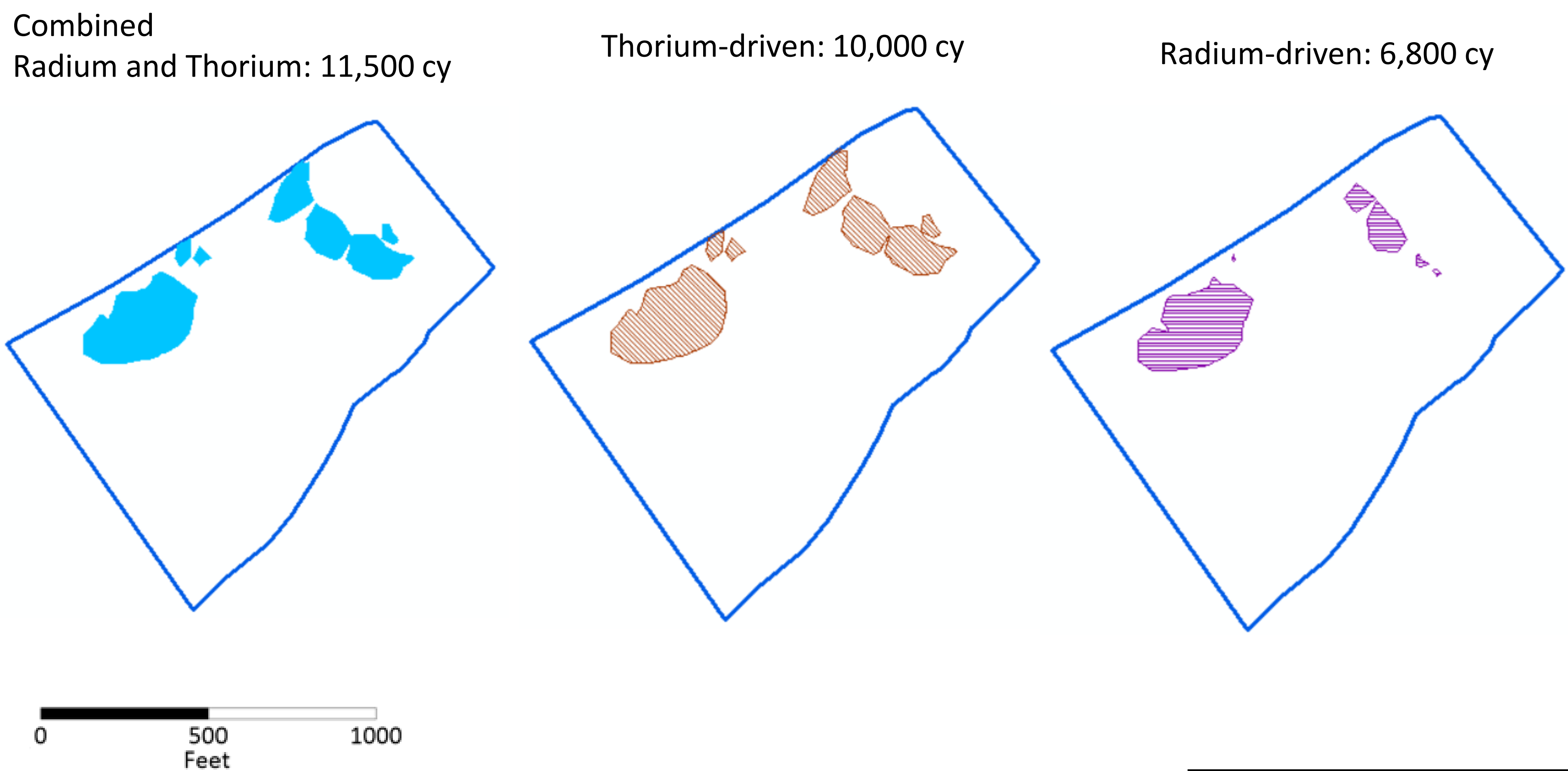


FIGURE E-8a

Radium- and Thorium-Driven Locations
Area 1

West Lake Landfill Operable Unit 1,

PARSONS

Syracuse, NY

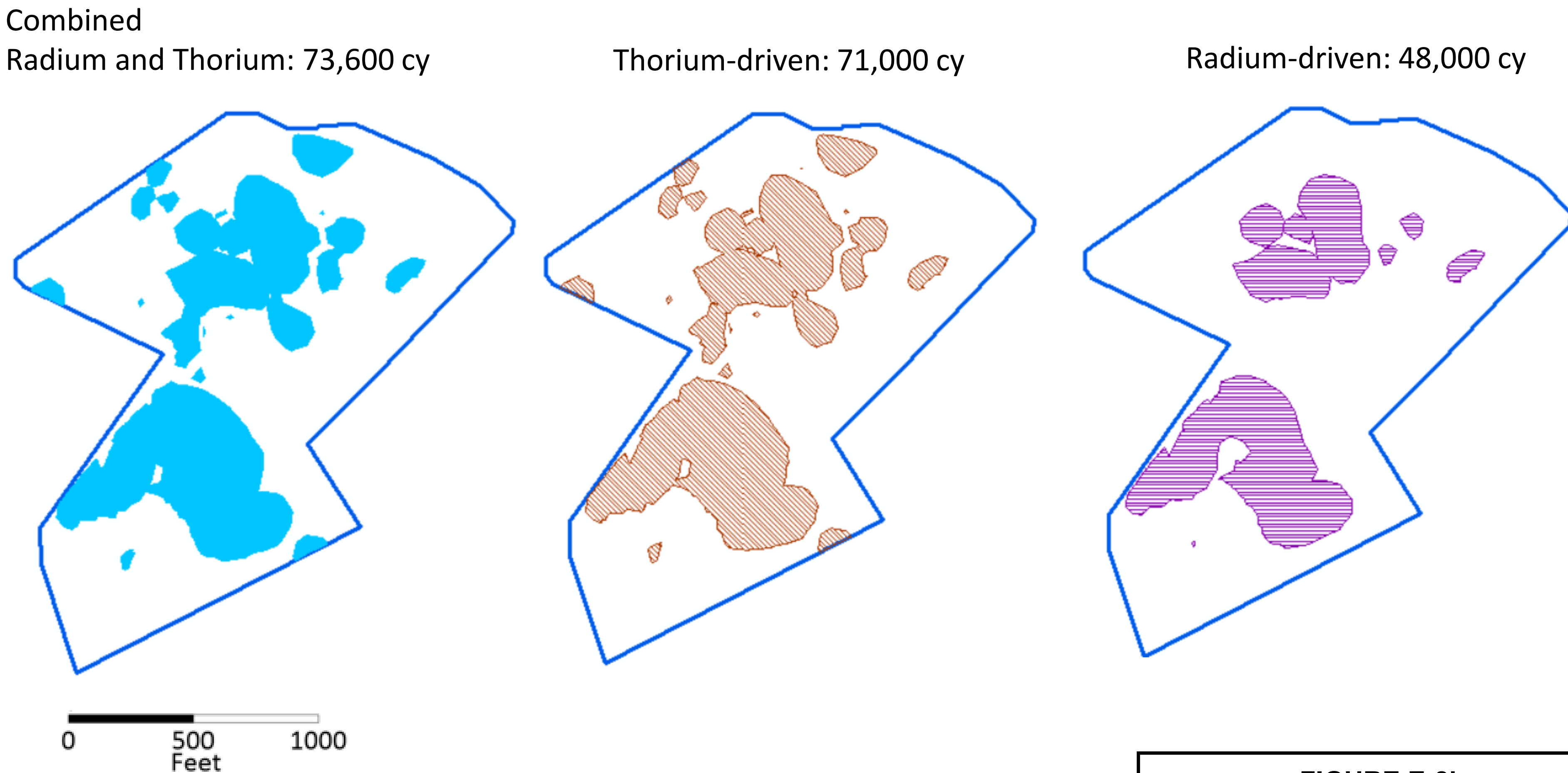


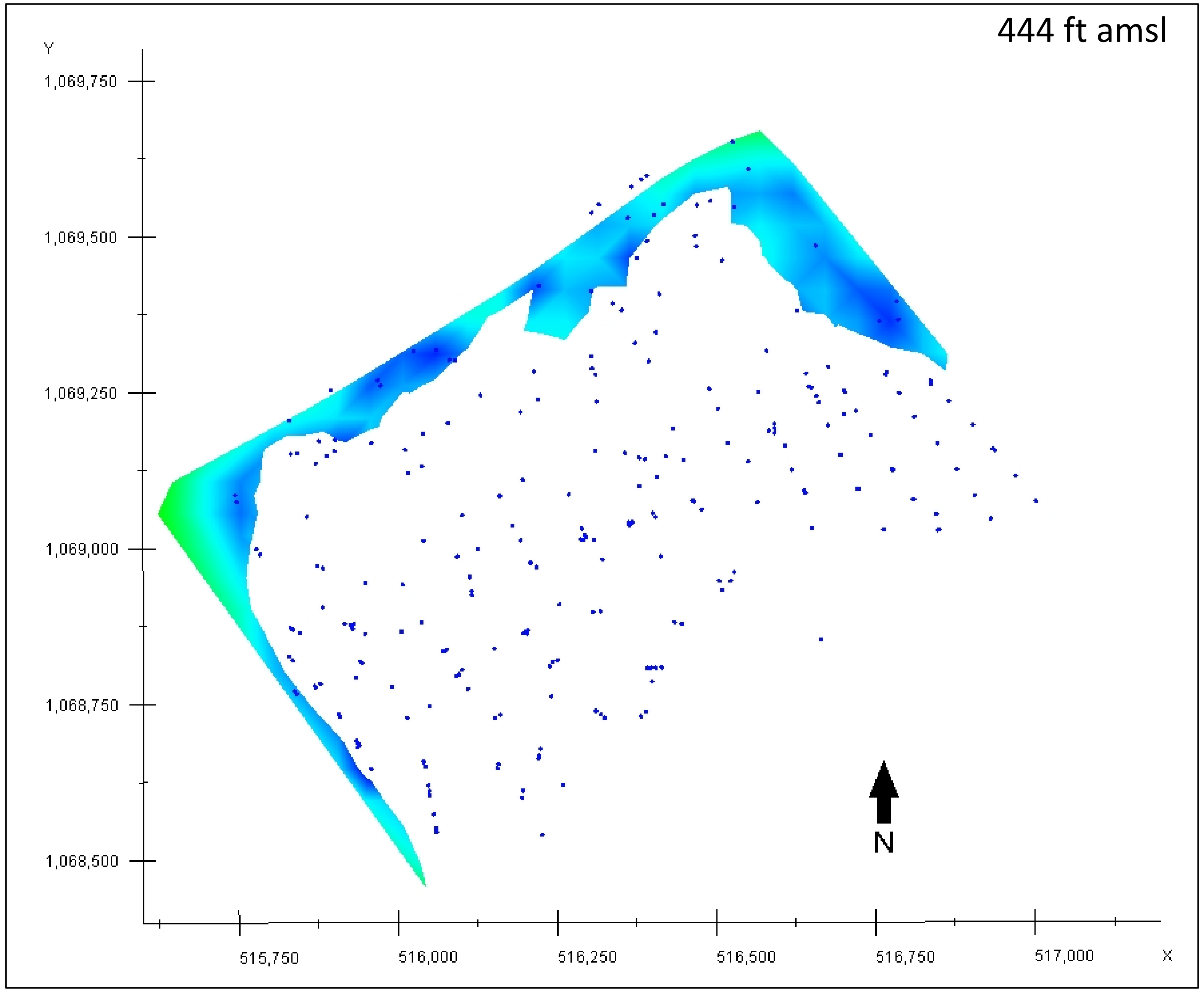
FIGURE E-8b

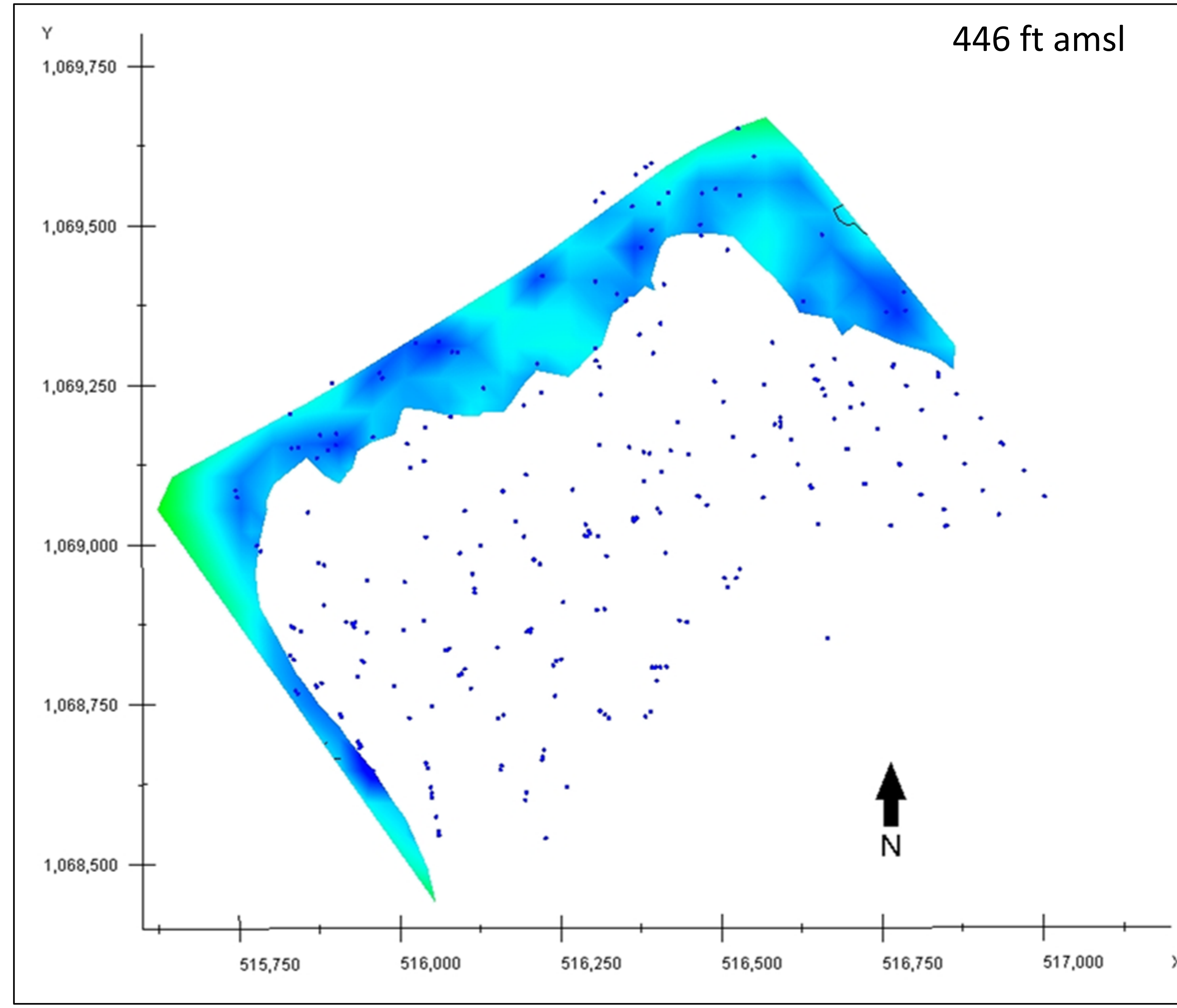
Radium- and Thorium-Driven
Locations
Area 2

West Lake Landfill Operable Unit 1,

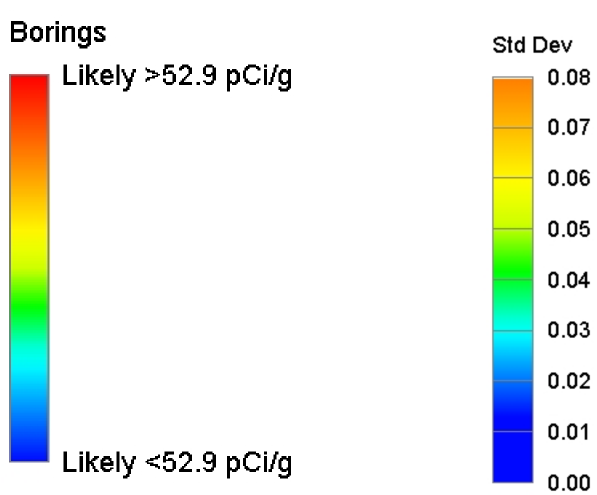
PARSONS

Syracuse, NY





Legend



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

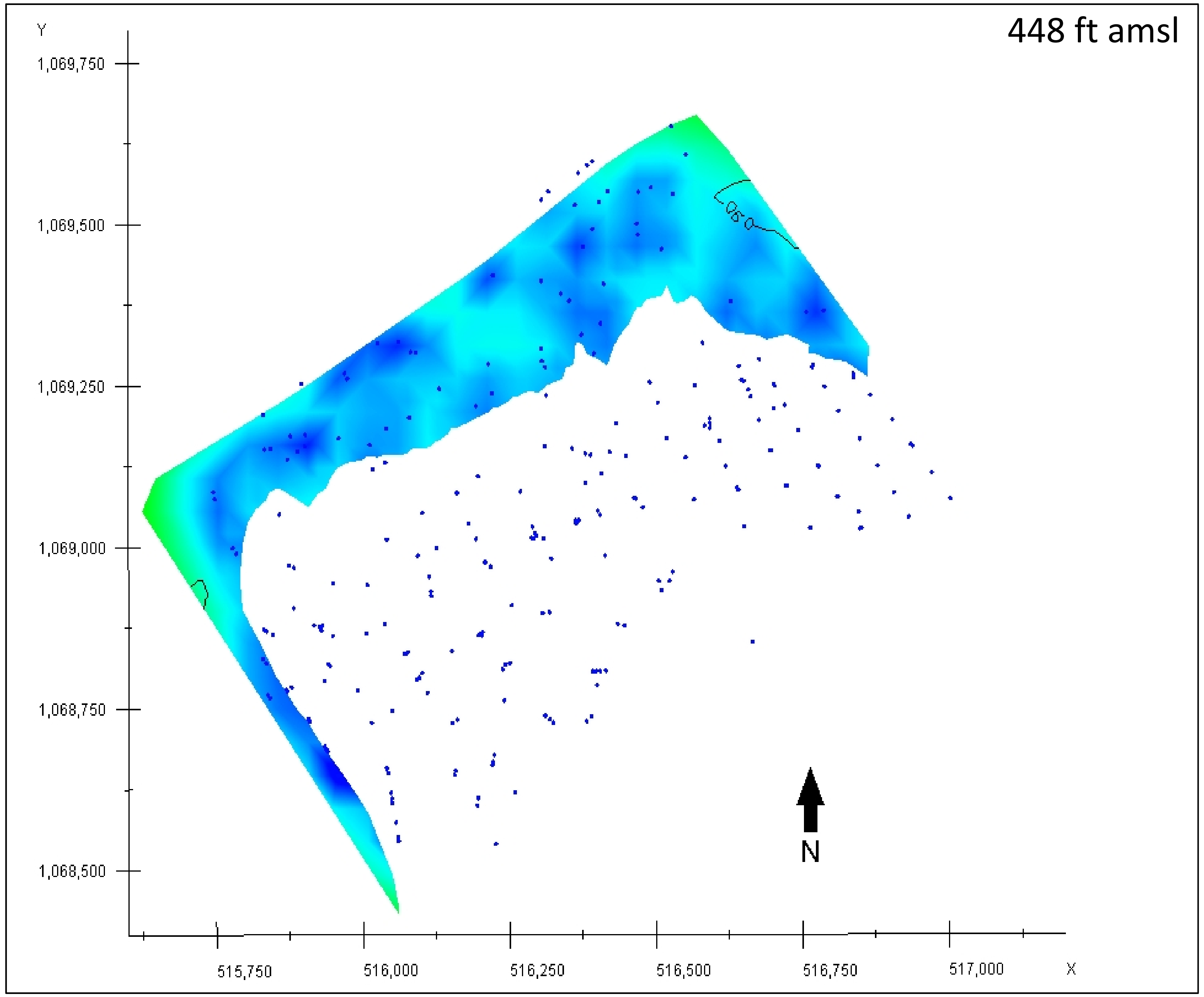
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

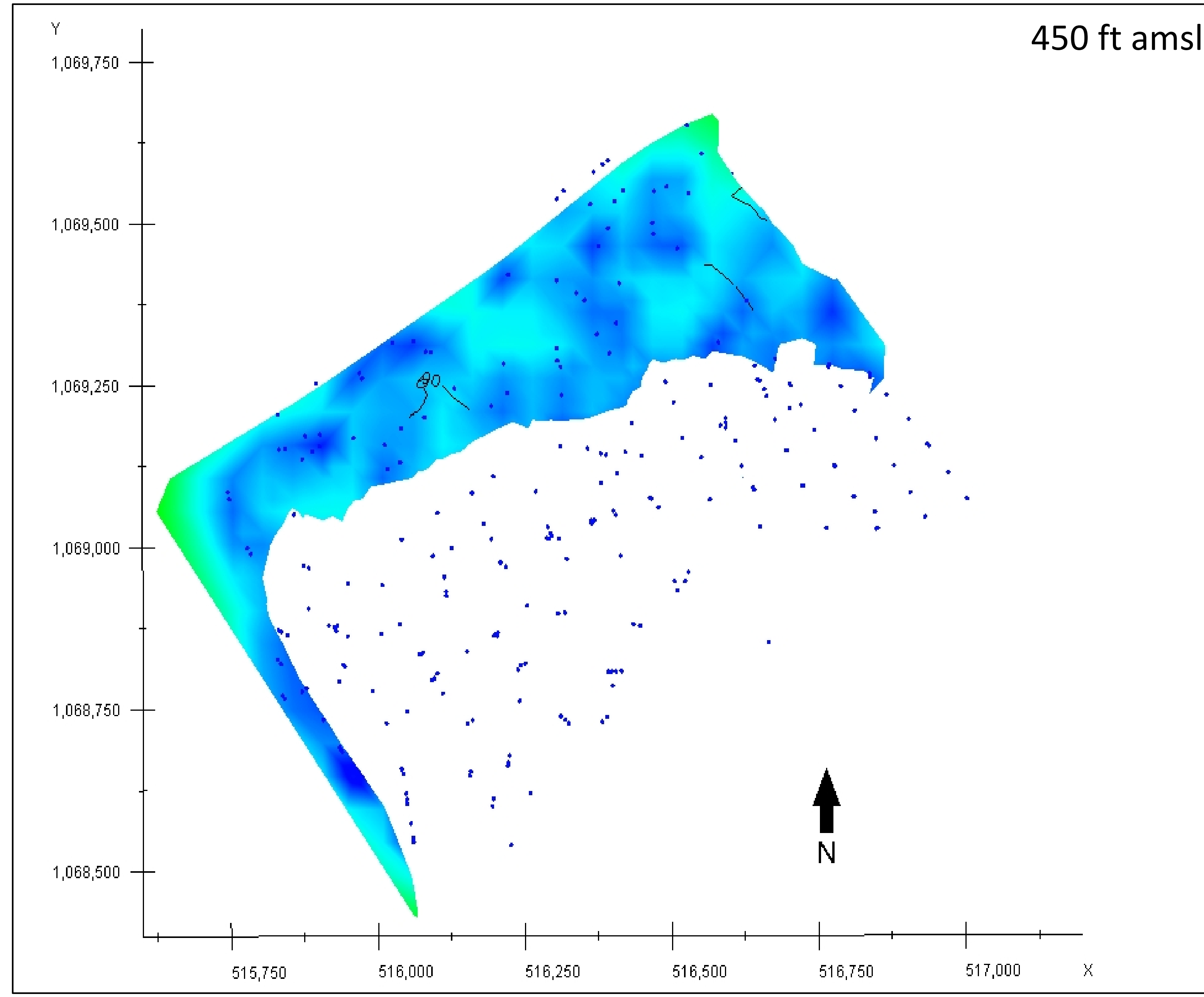
FIGURE E-9a

Area 1
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

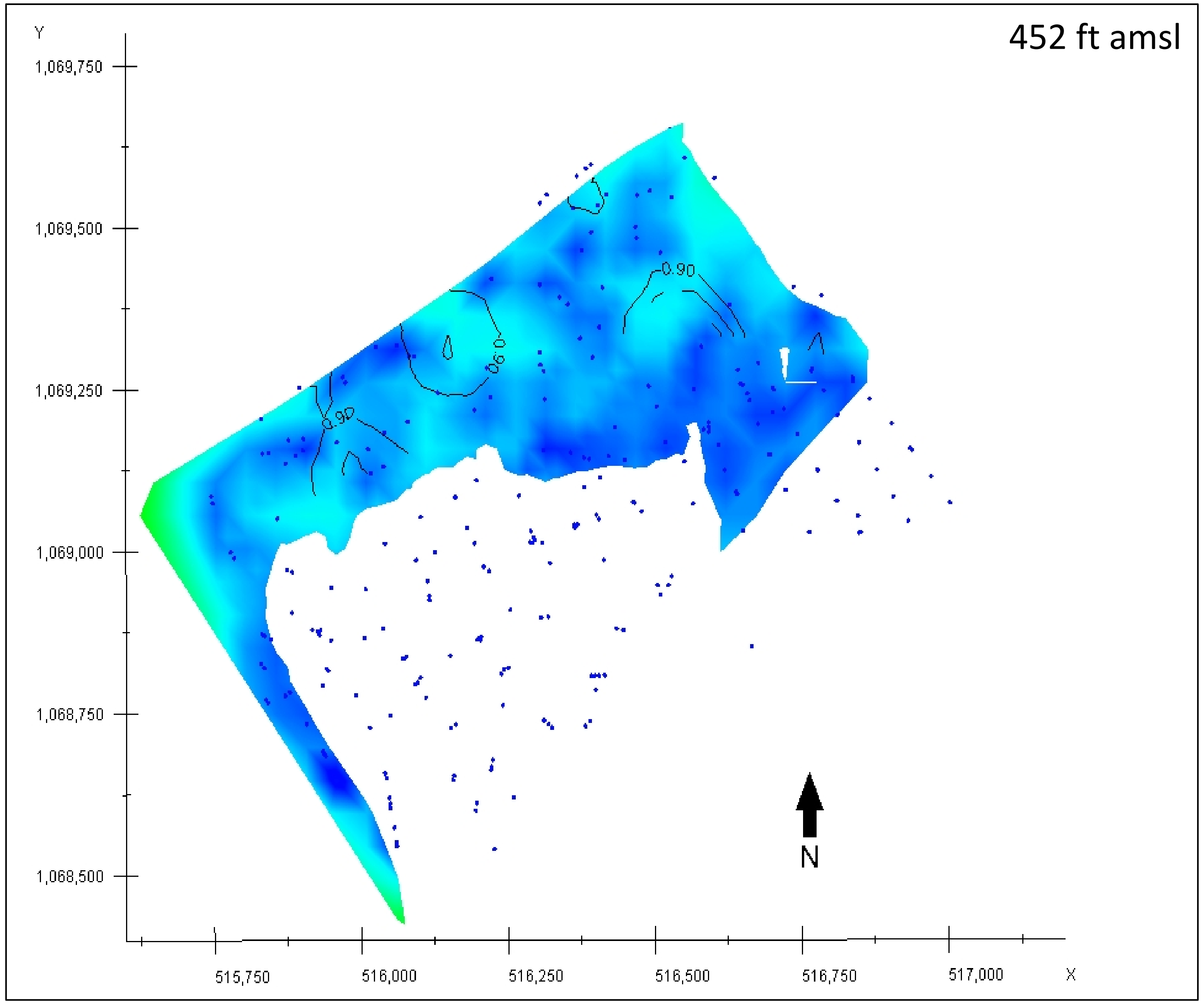
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

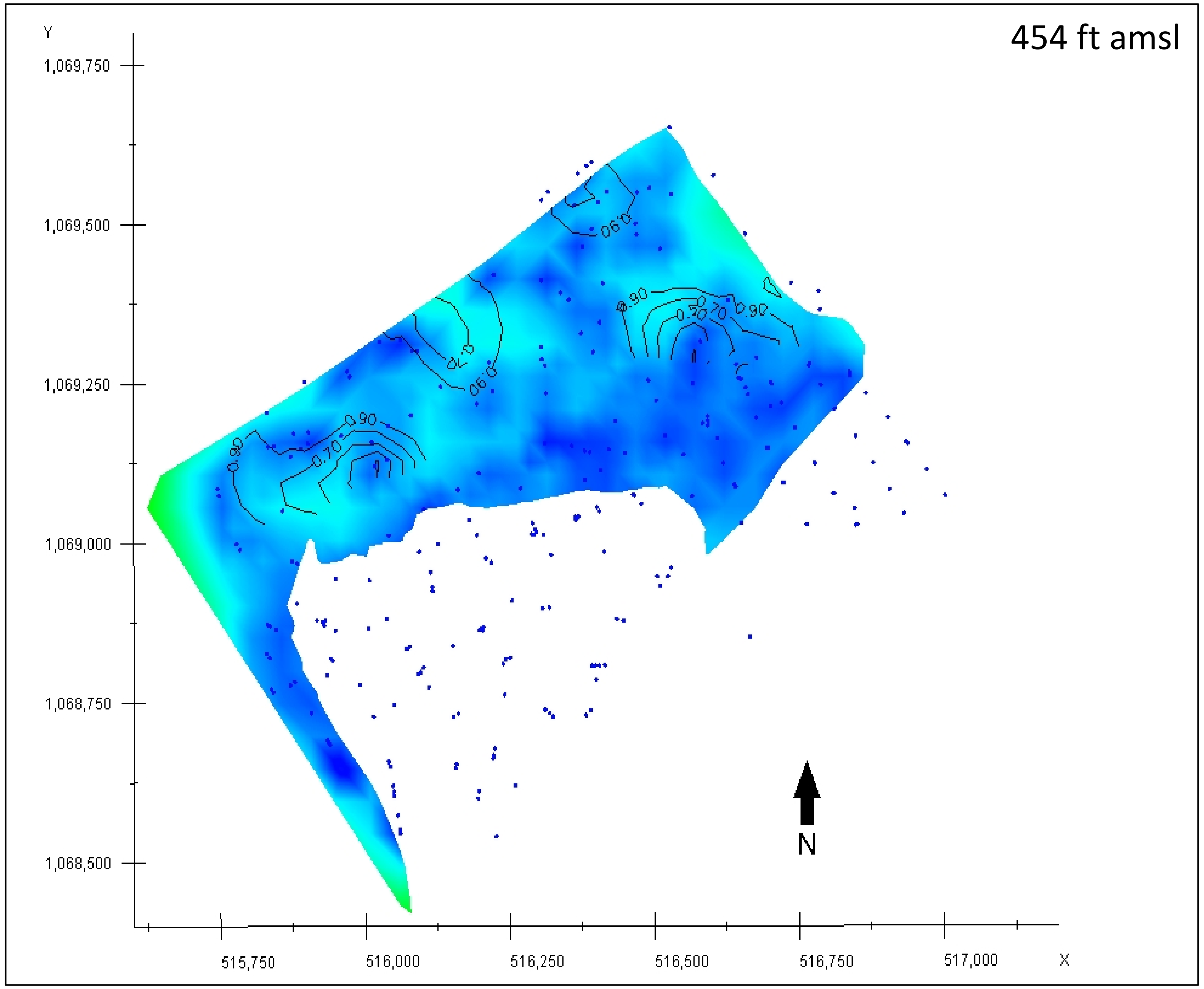
FIGURE E-9b

Area 1
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

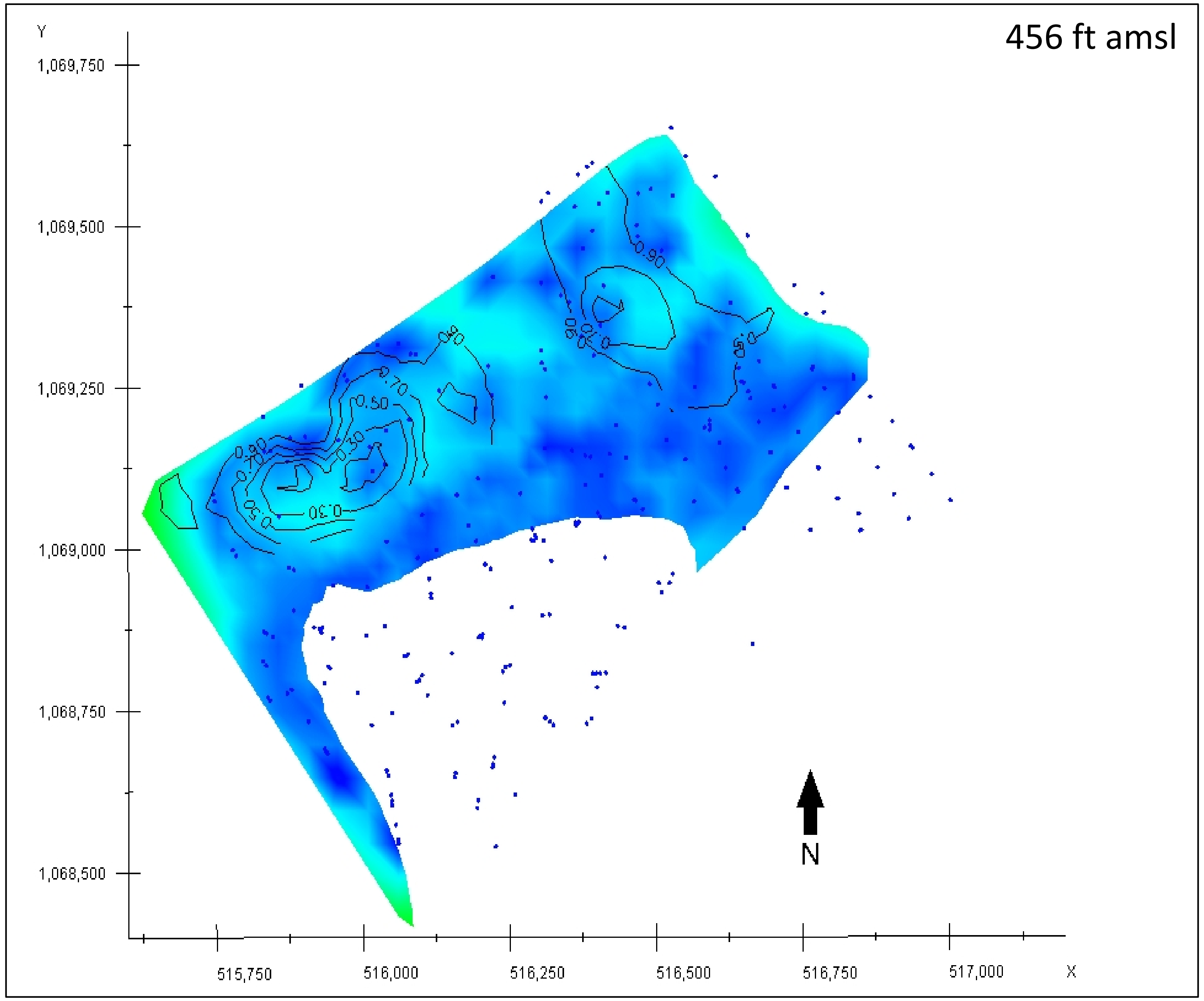
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

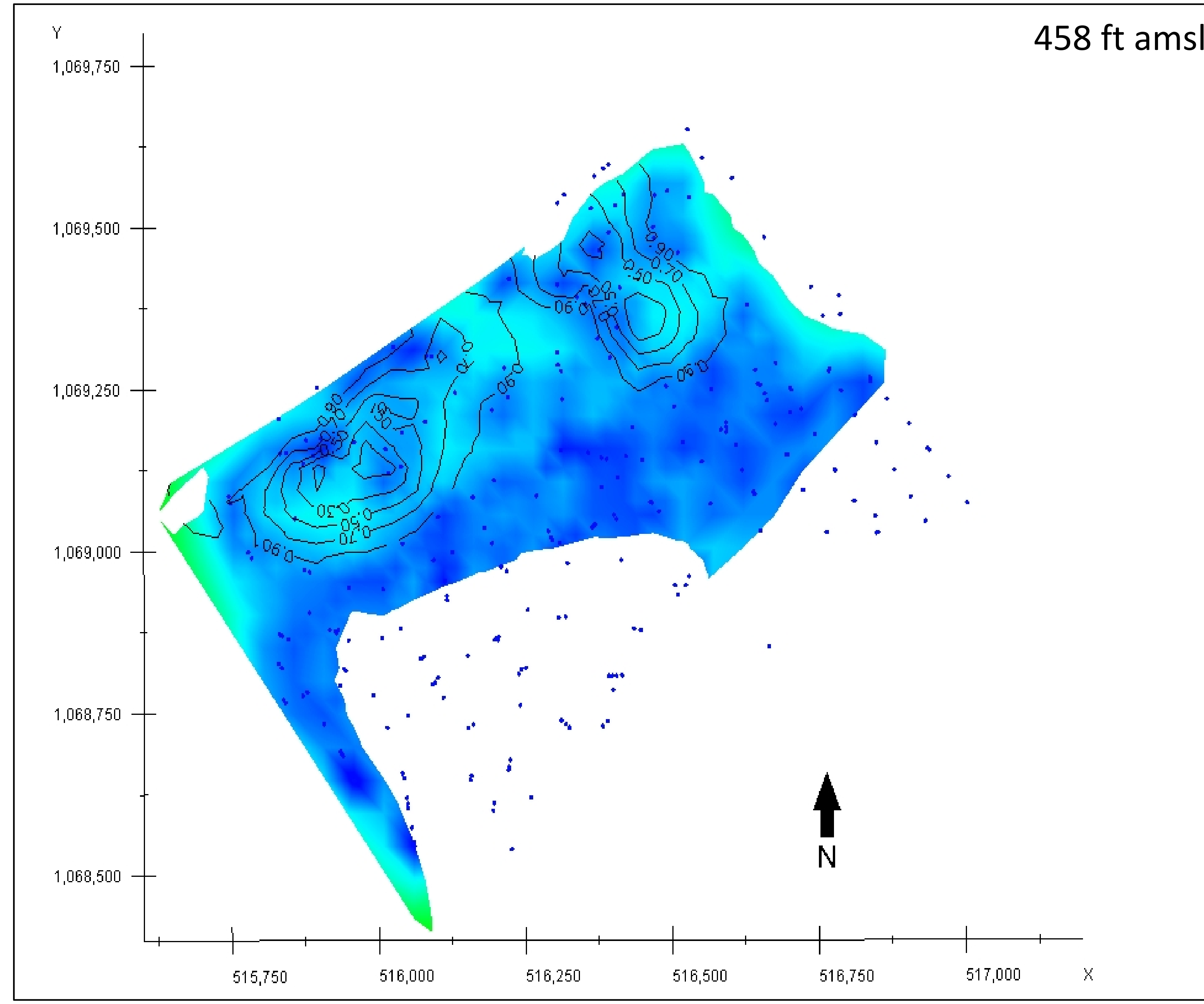
FIGURE E-9c

Area 1
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

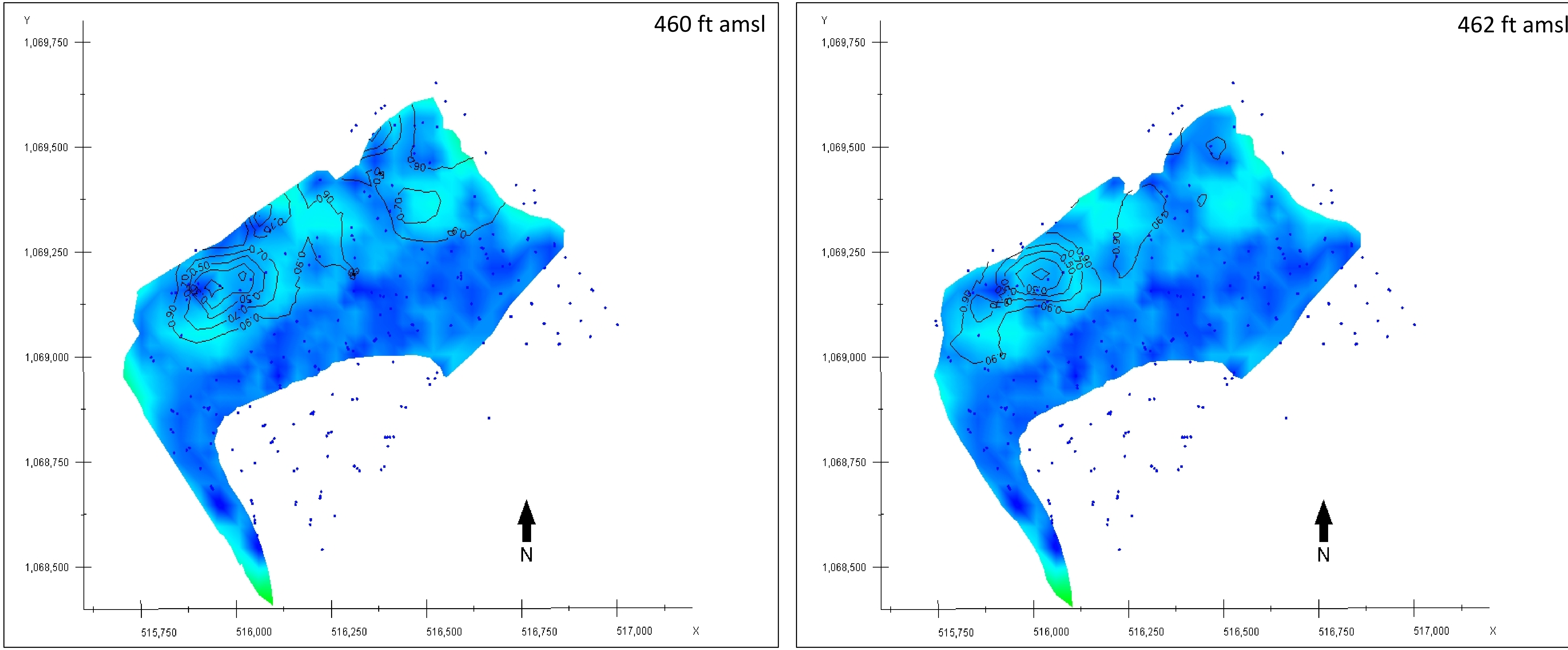
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

FIGURE E-9d

Area 1
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

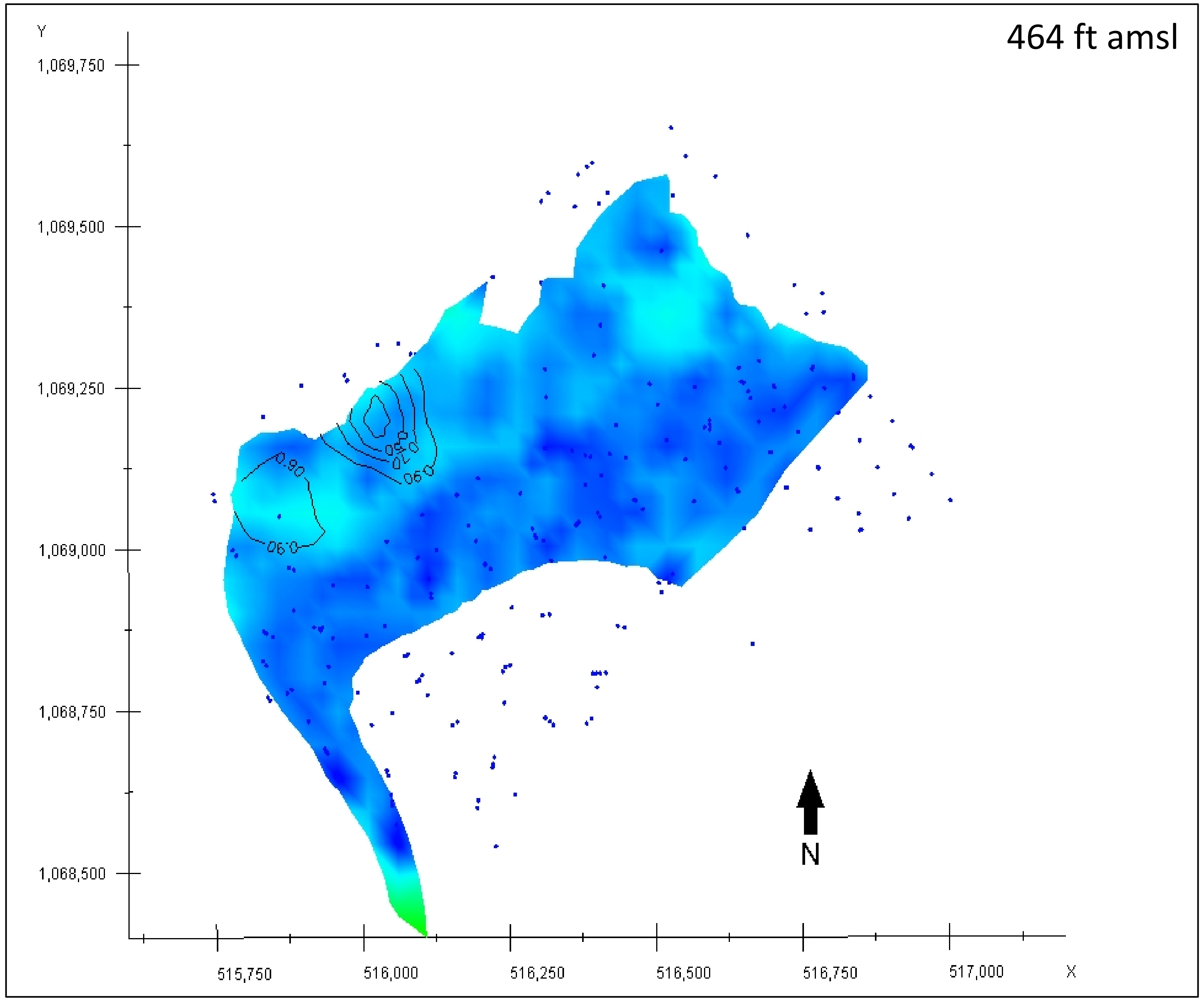
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

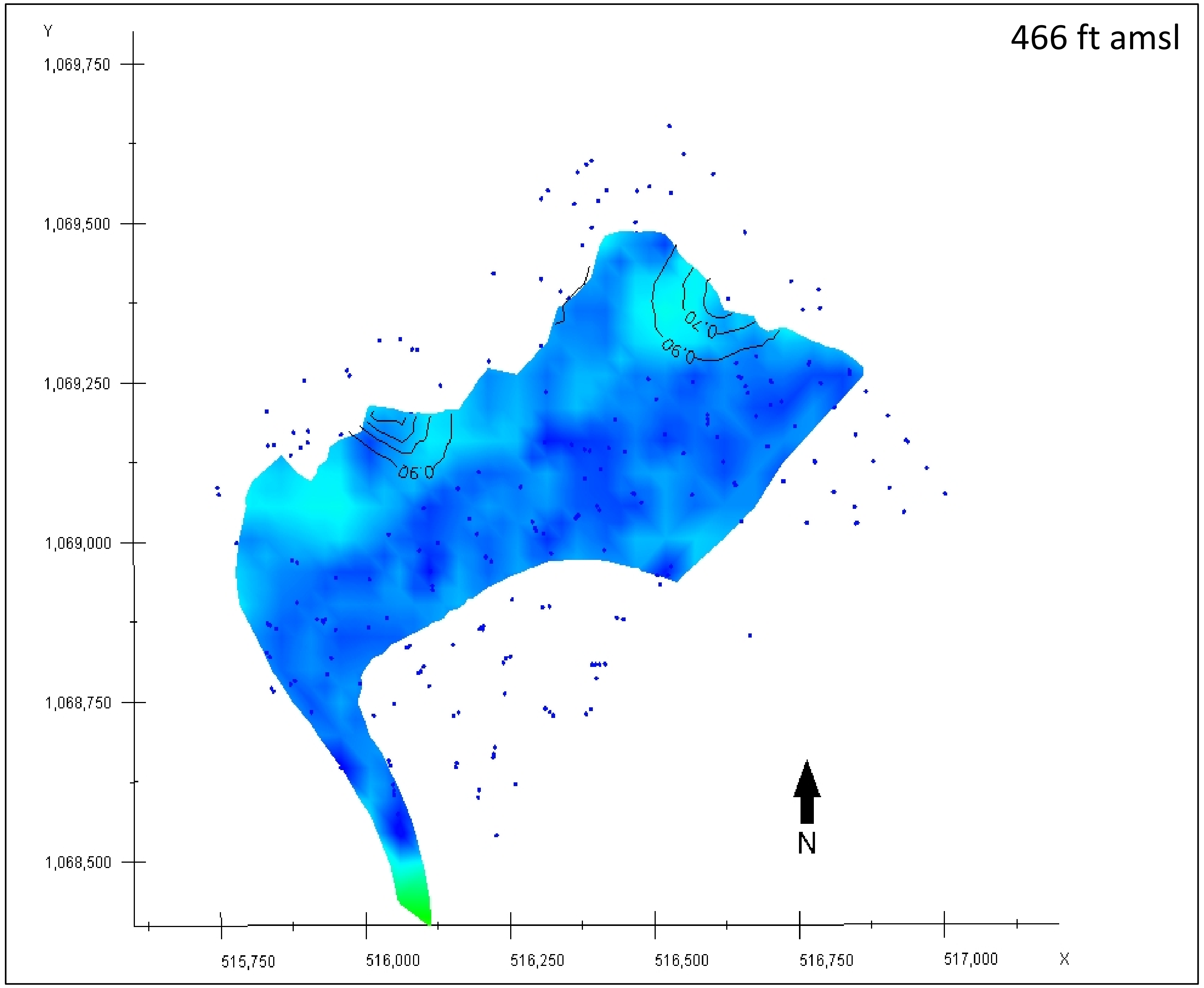
FIGURE E-9e

Area 1
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

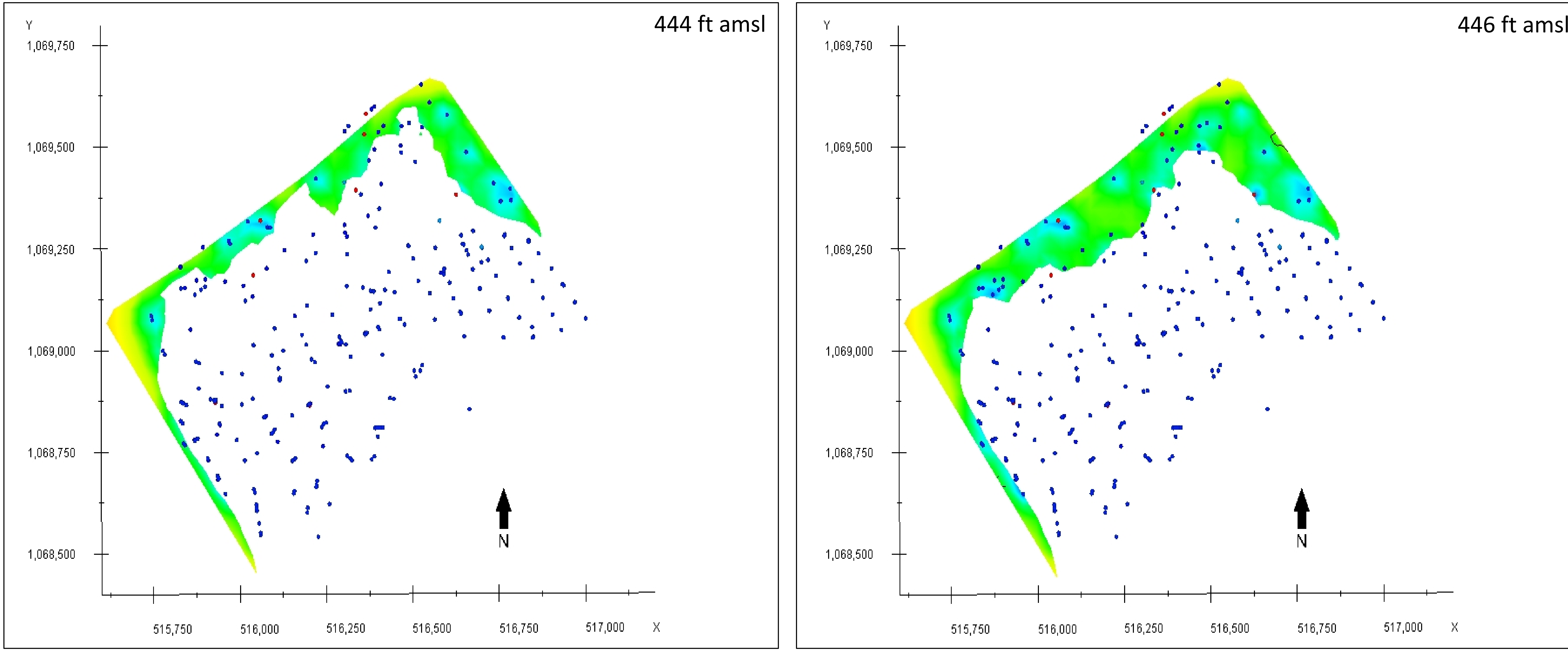
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

FIGURE E-9f

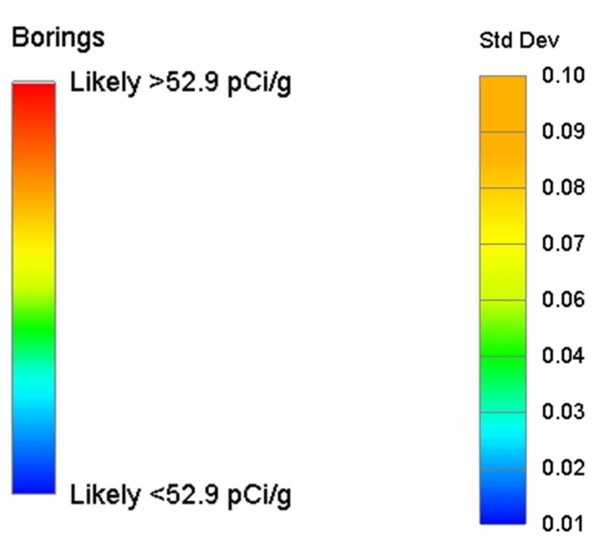
Area 1
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Legend



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

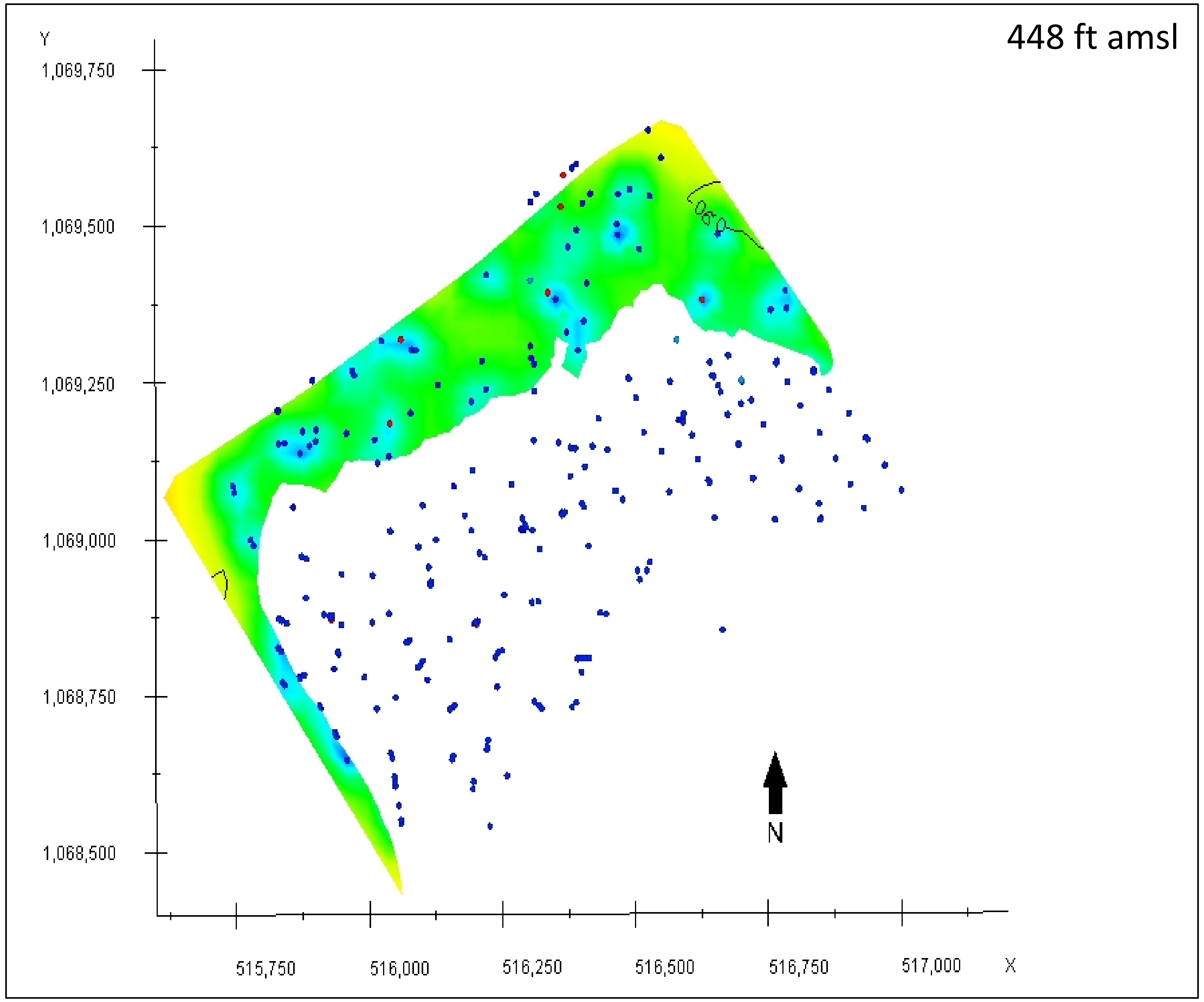
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

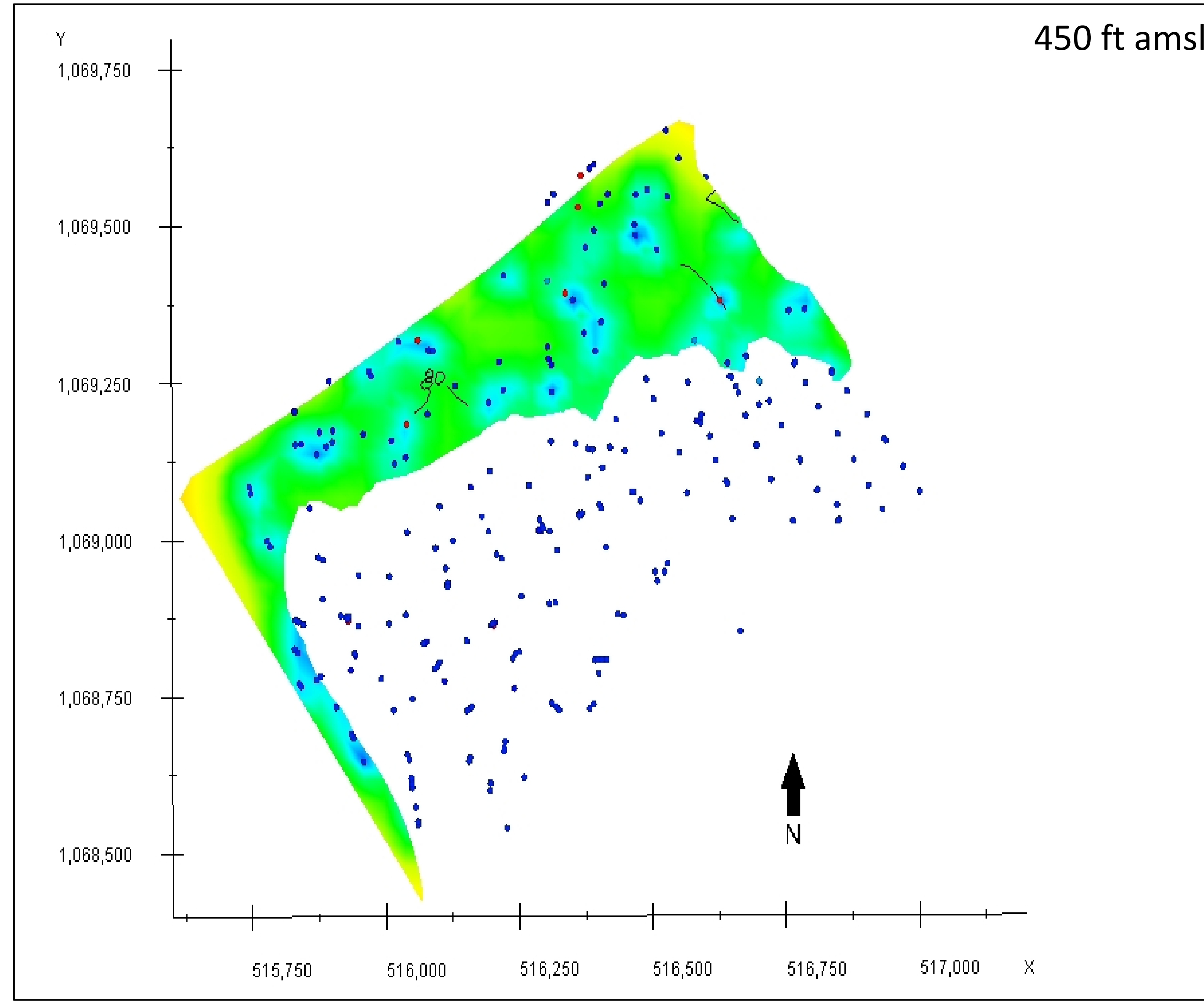
FIGURE E-9g

Area 1
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.10
0.09
0.08
0.07
0.06
0.04
0.03
0.02
0.01

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

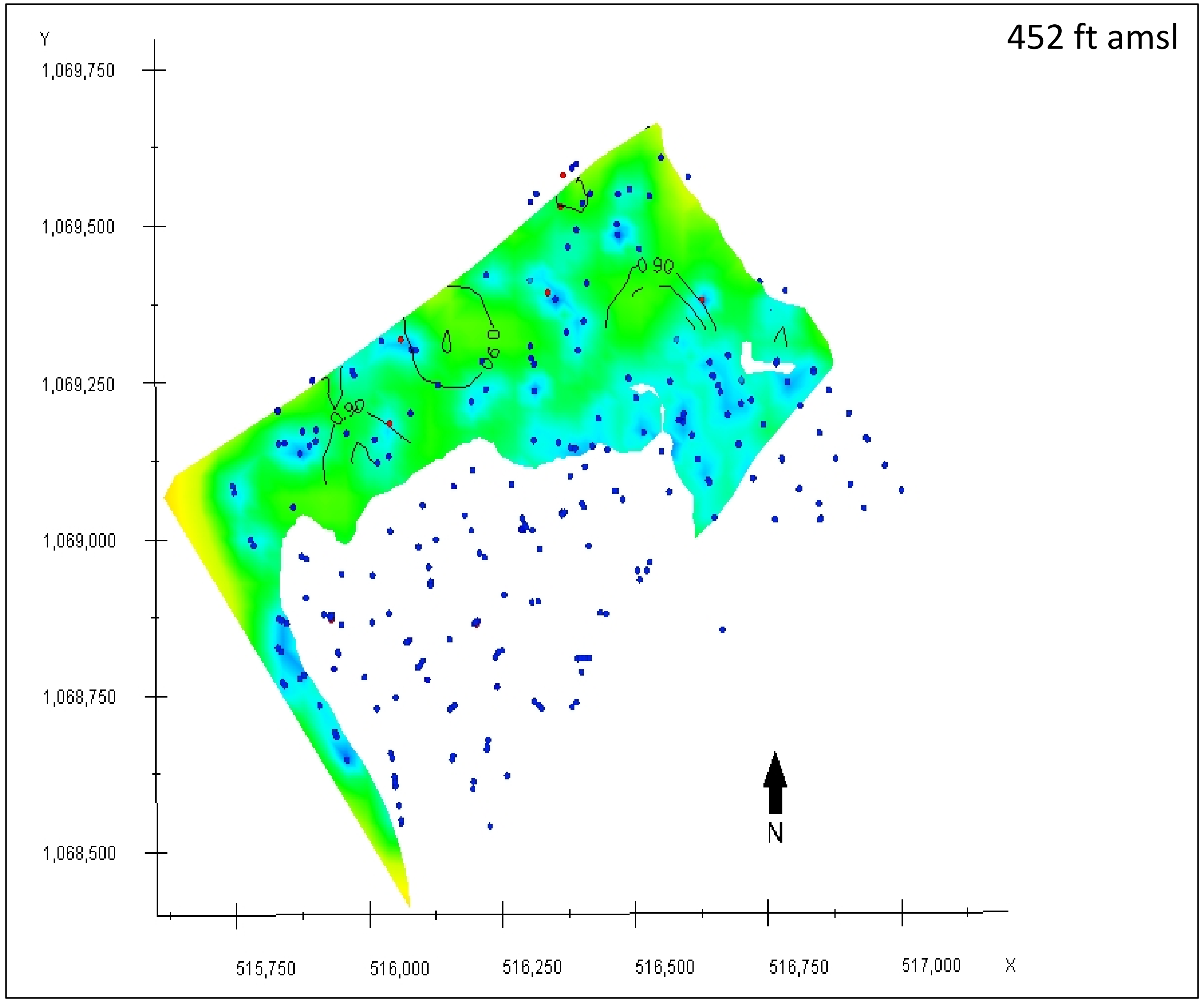
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

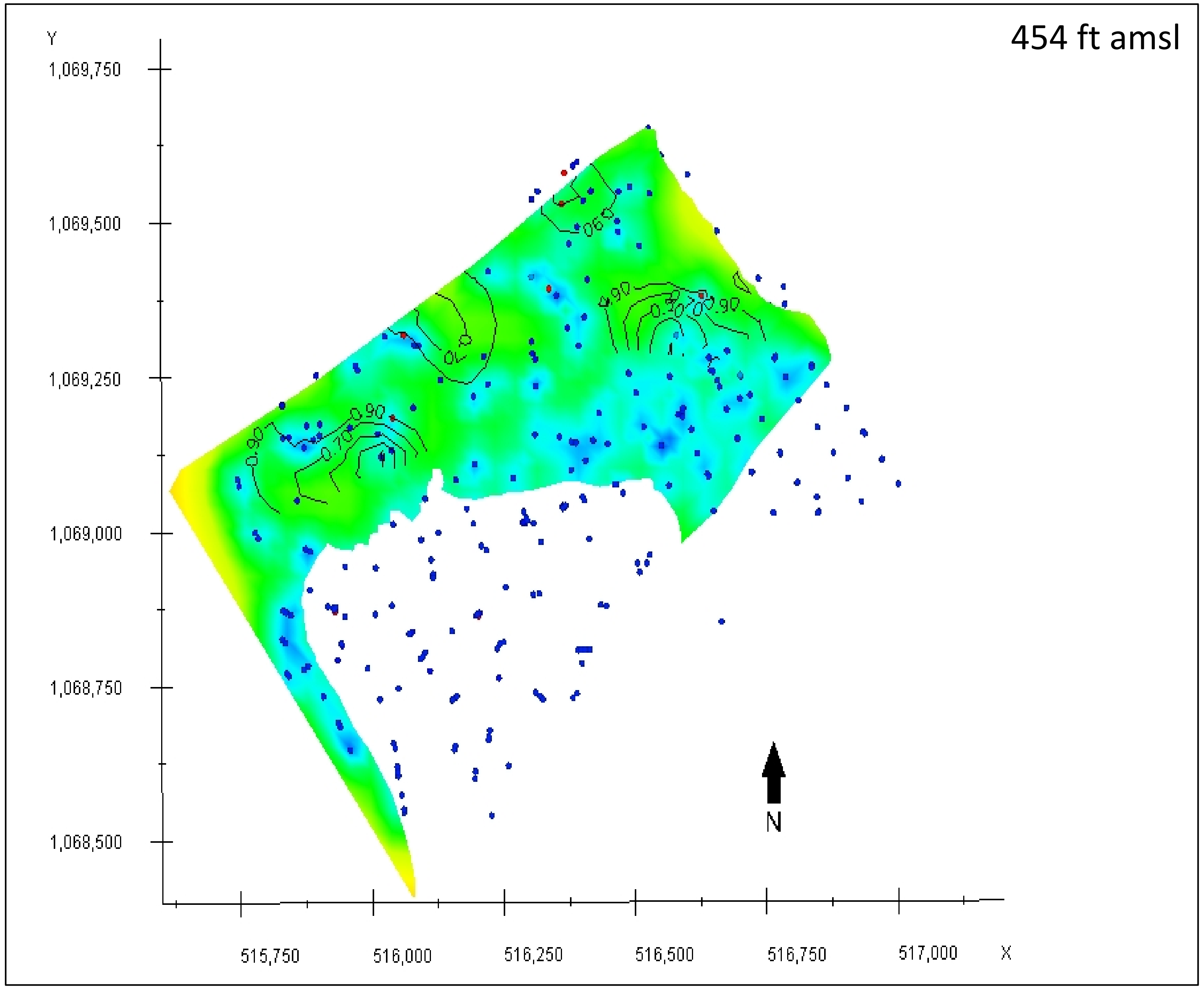
FIGURE E-9h

Area 1
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

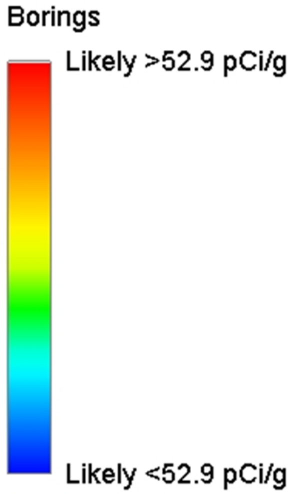
PARSONS

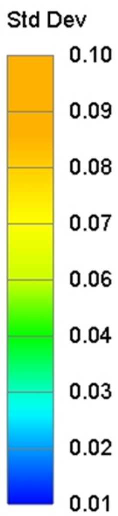
Syracuse, NY





Legend





Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

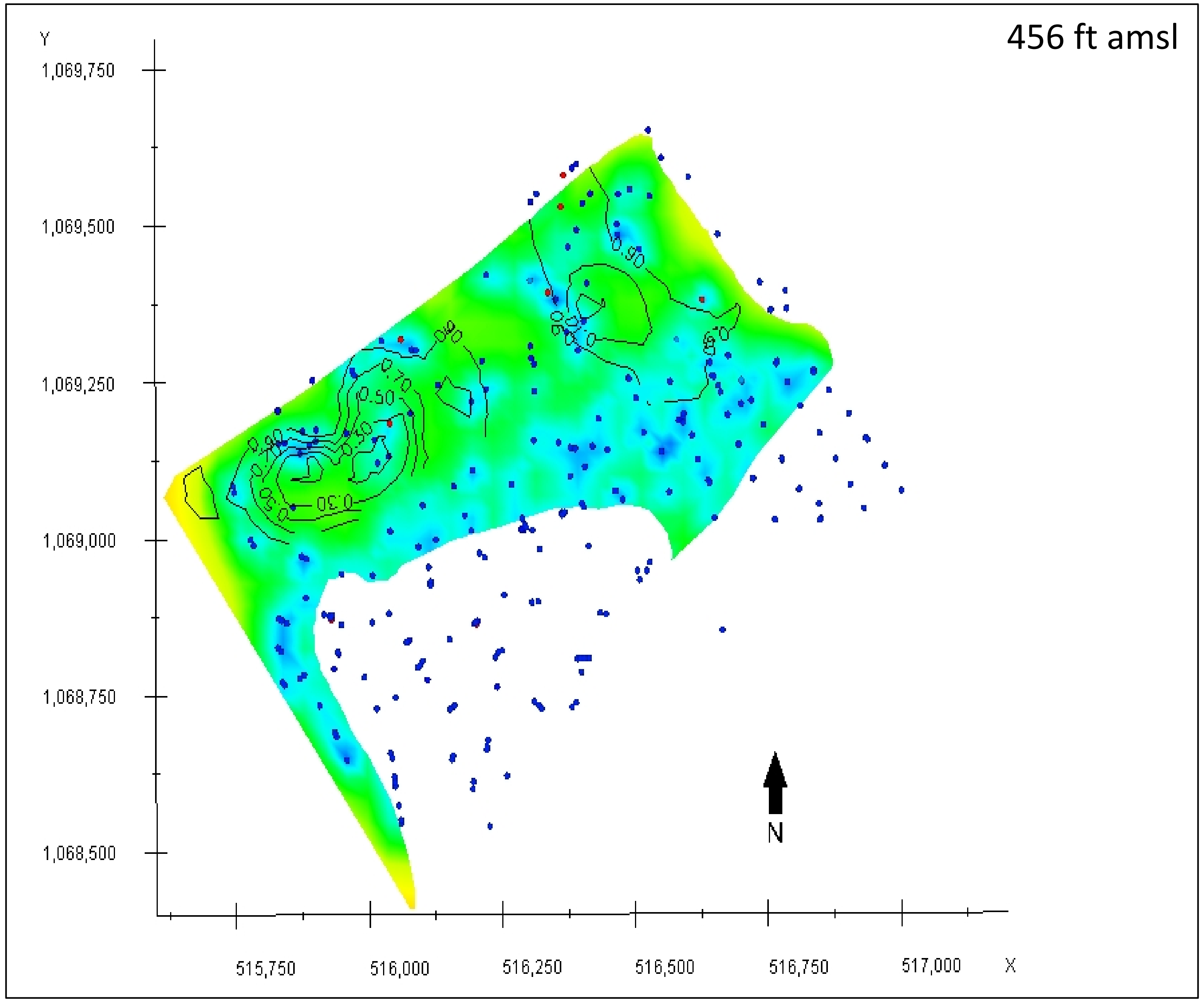
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

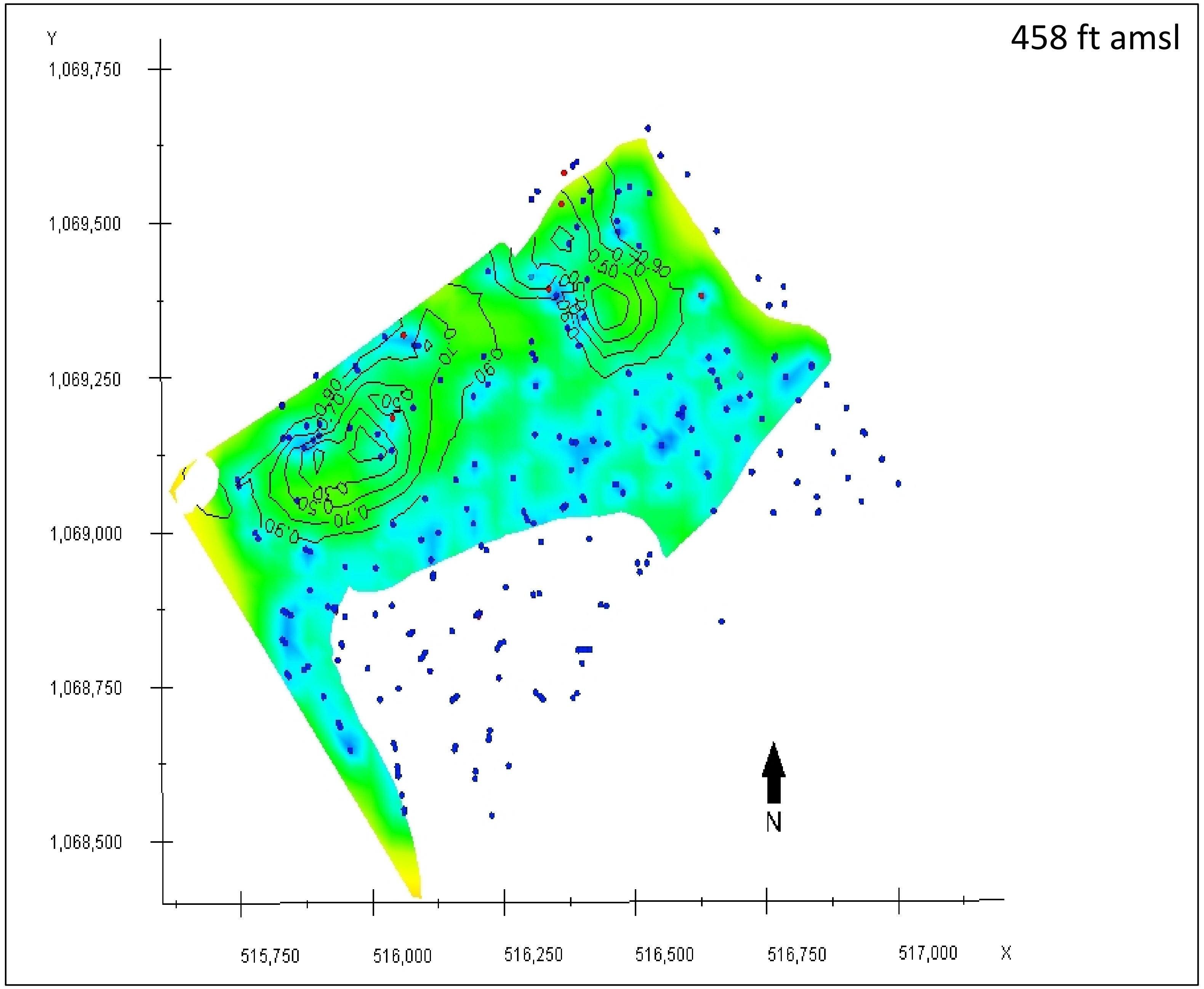
FIGURE E-9i

Area 1
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

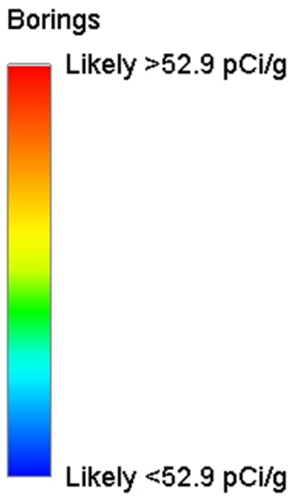
PARSONS

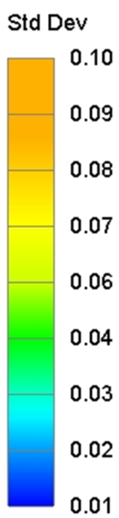
Syracuse, NY





Legend





Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

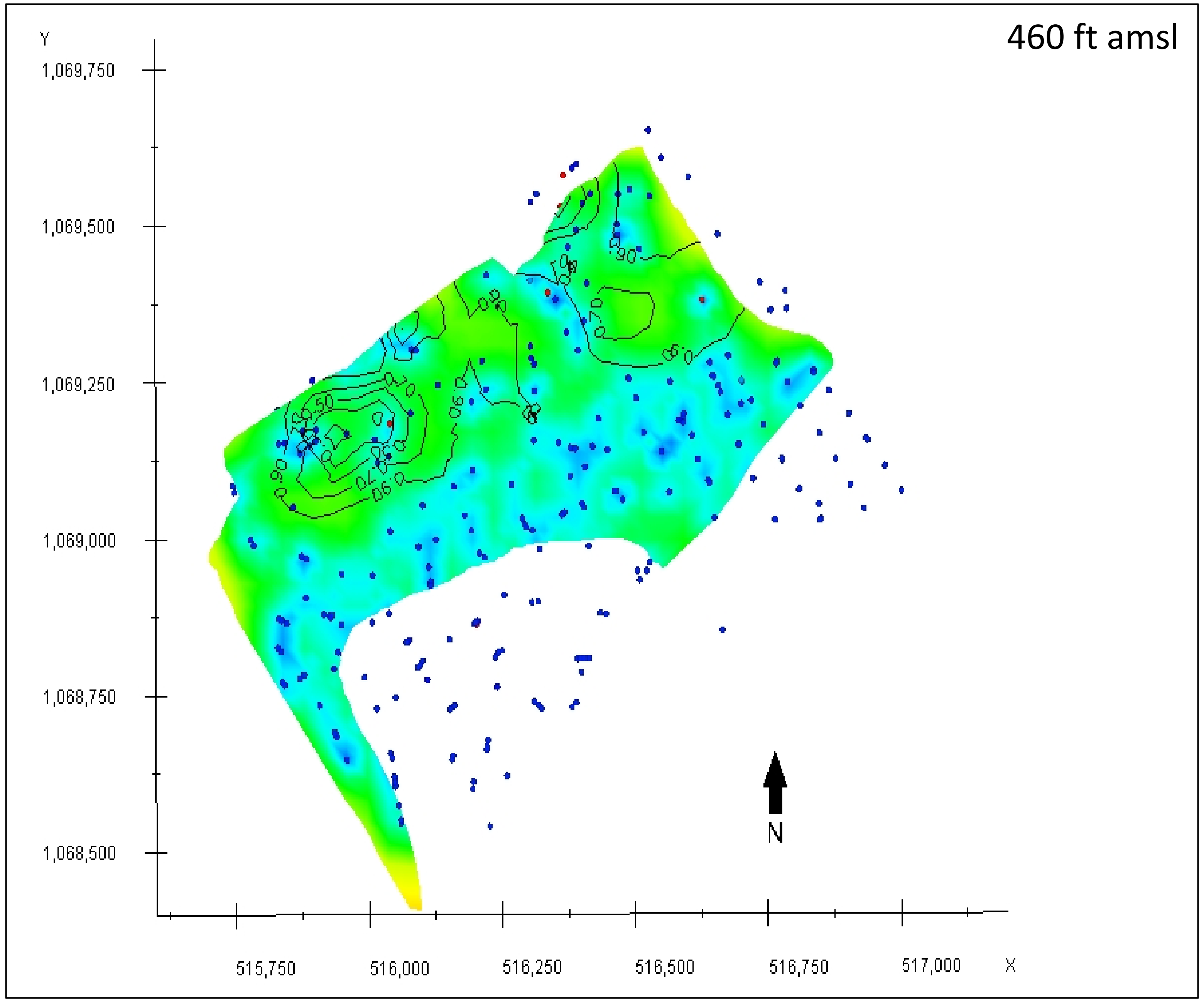
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

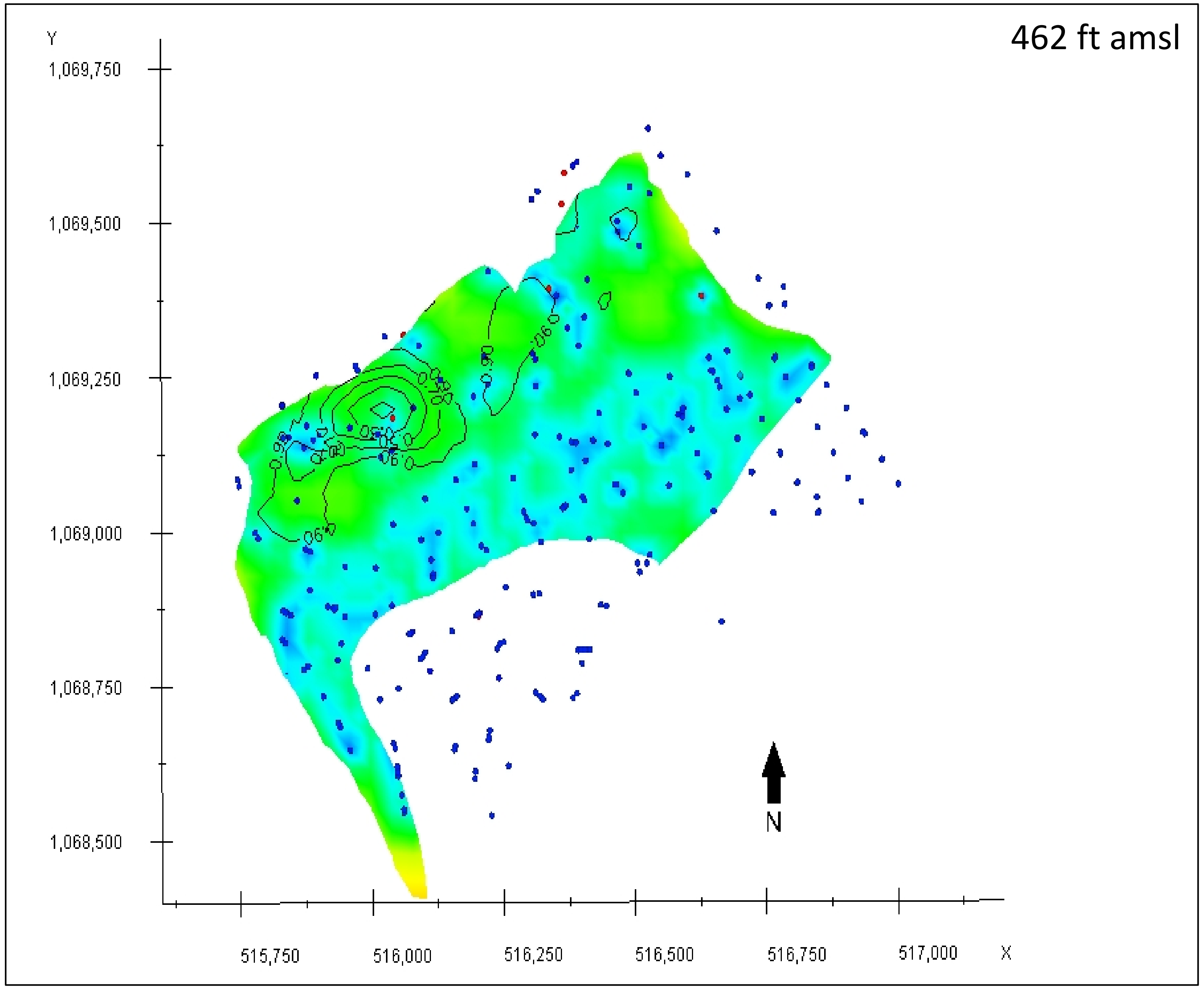
FIGURE E-9j

Area 1
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

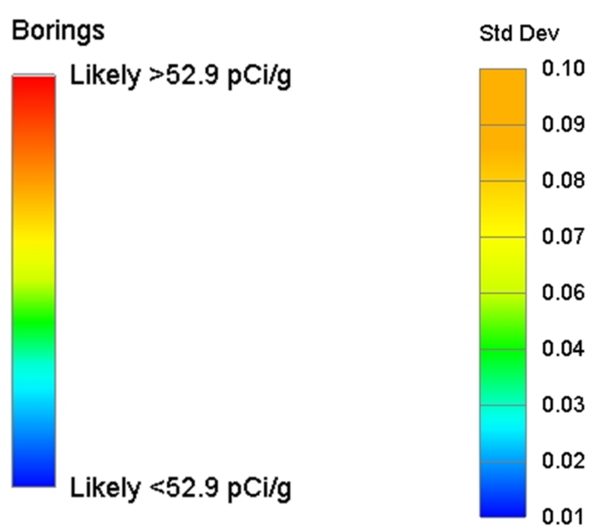
PARSONS

Syracuse, NY





Legend



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

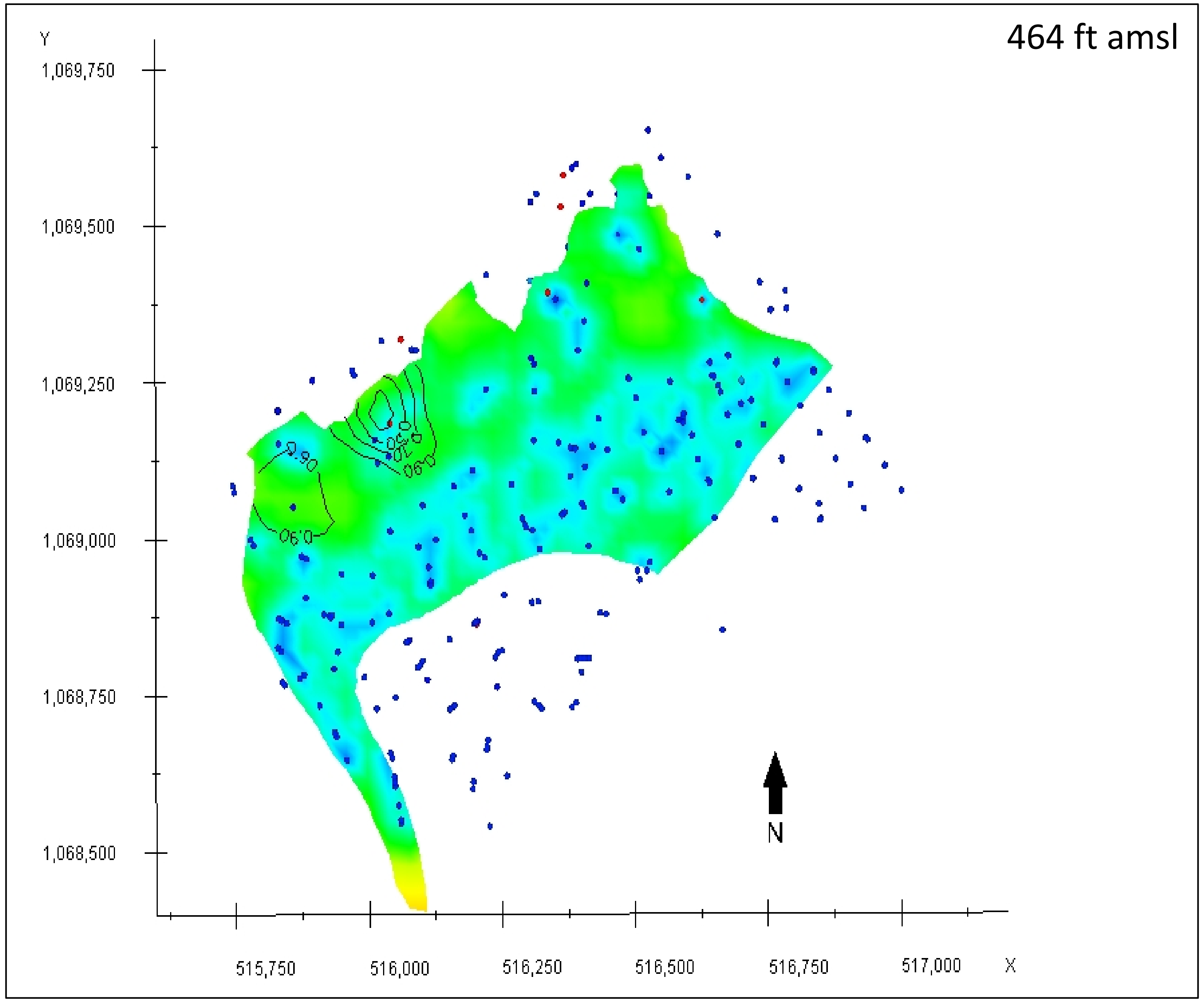
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

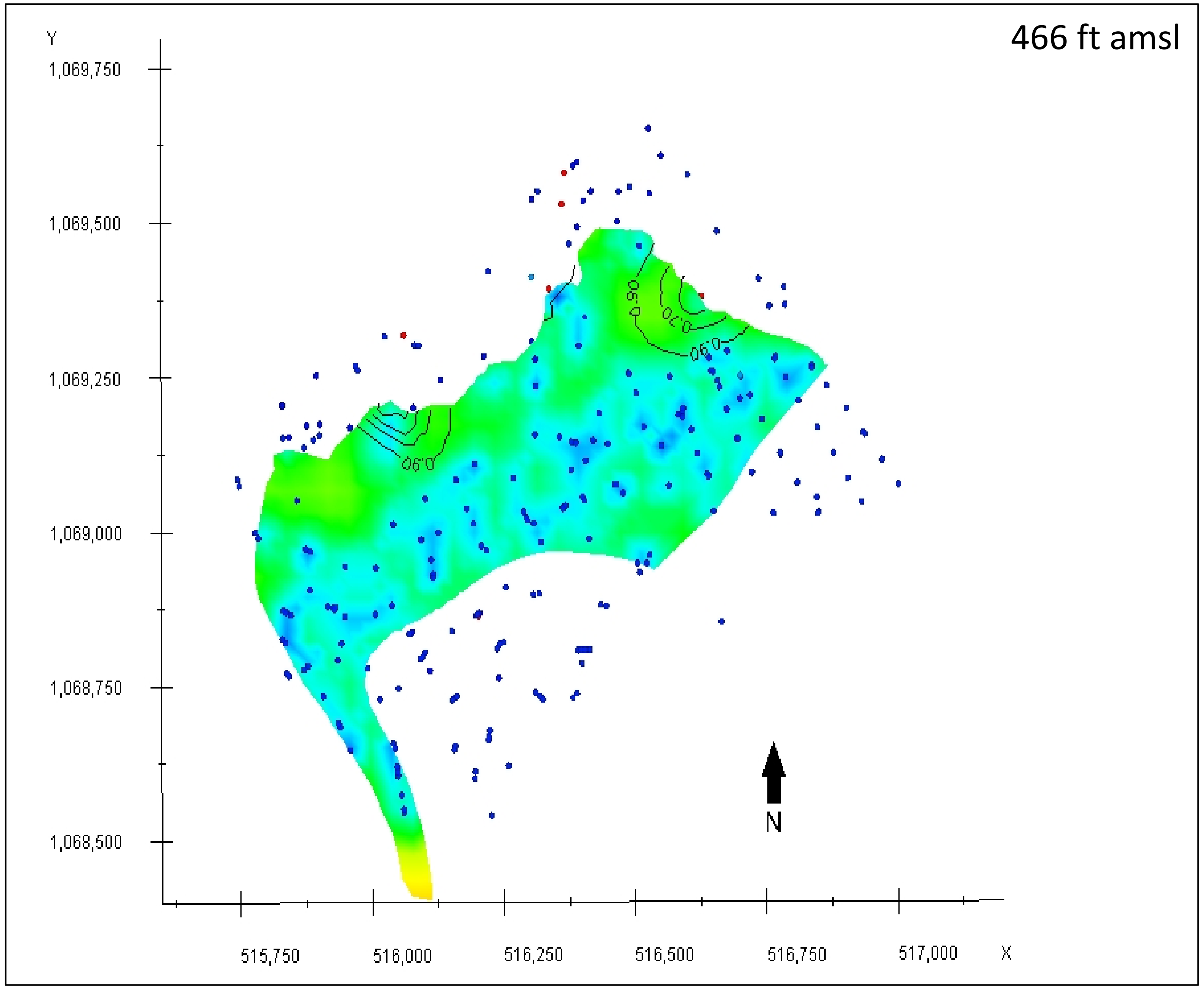
FIGURE E-9k

Area 1
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

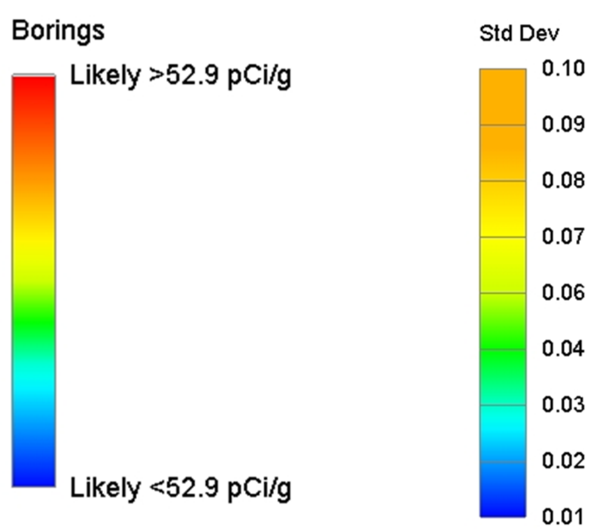
PARSONS

Syracuse, NY





Legend



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

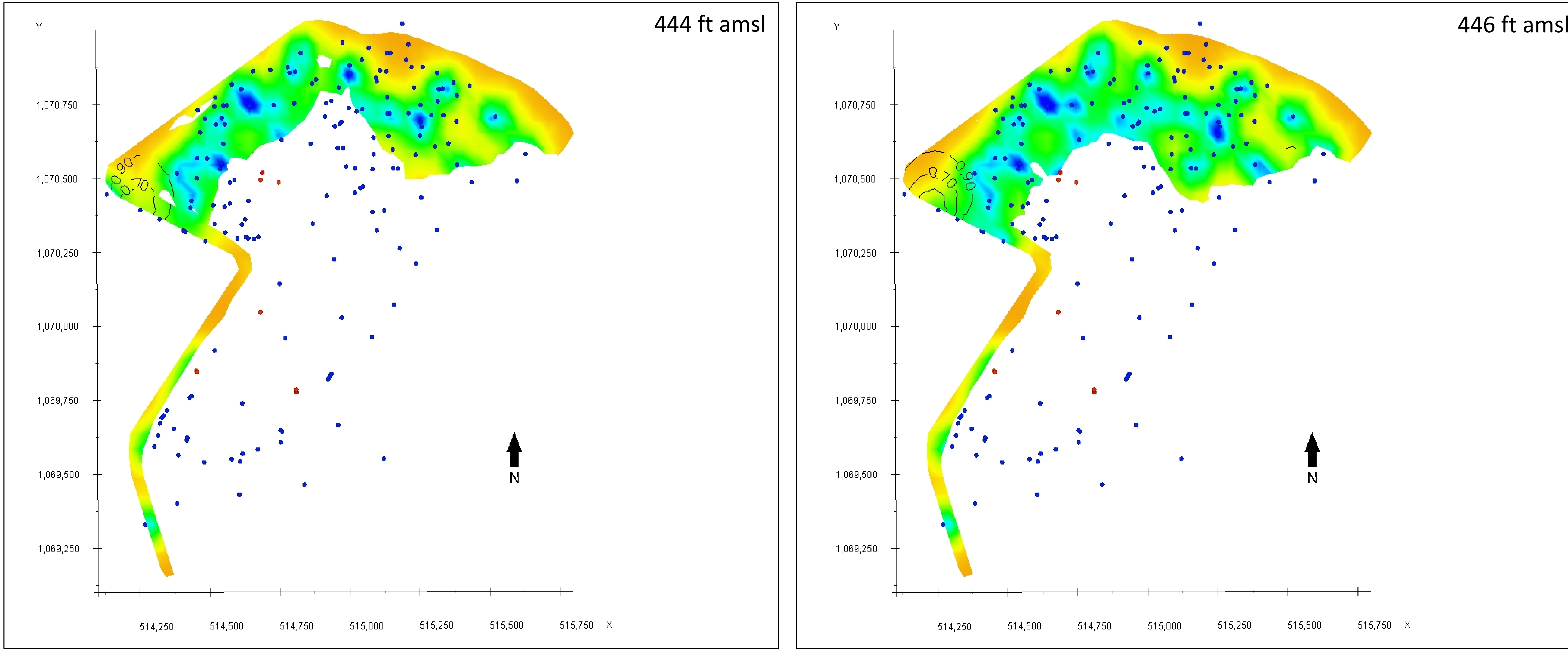
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

FIGURE E-9I

Area 1
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.17
0.16
0.14
0.12
0.10
0.08
0.07
0.05
0.03

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

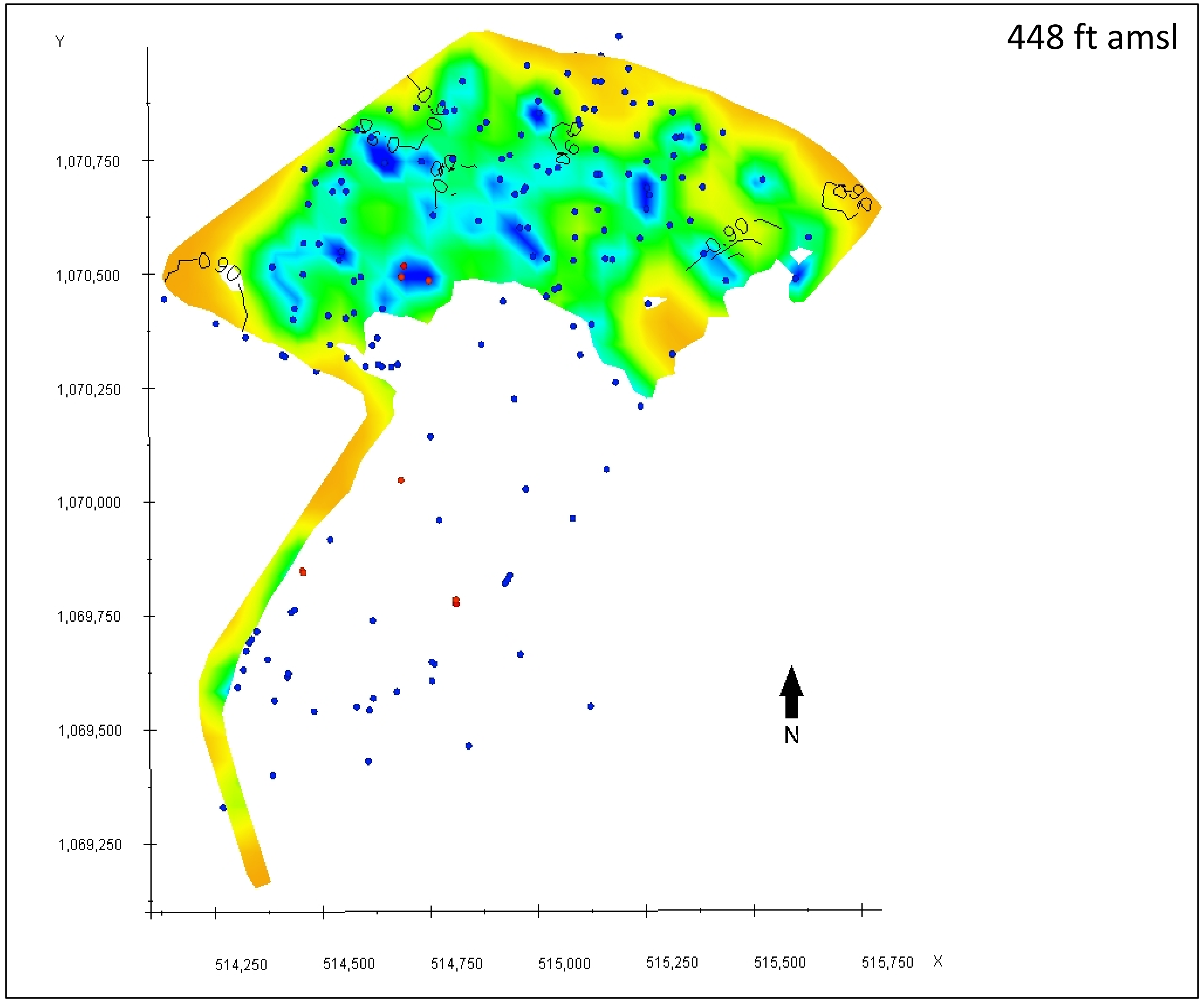
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

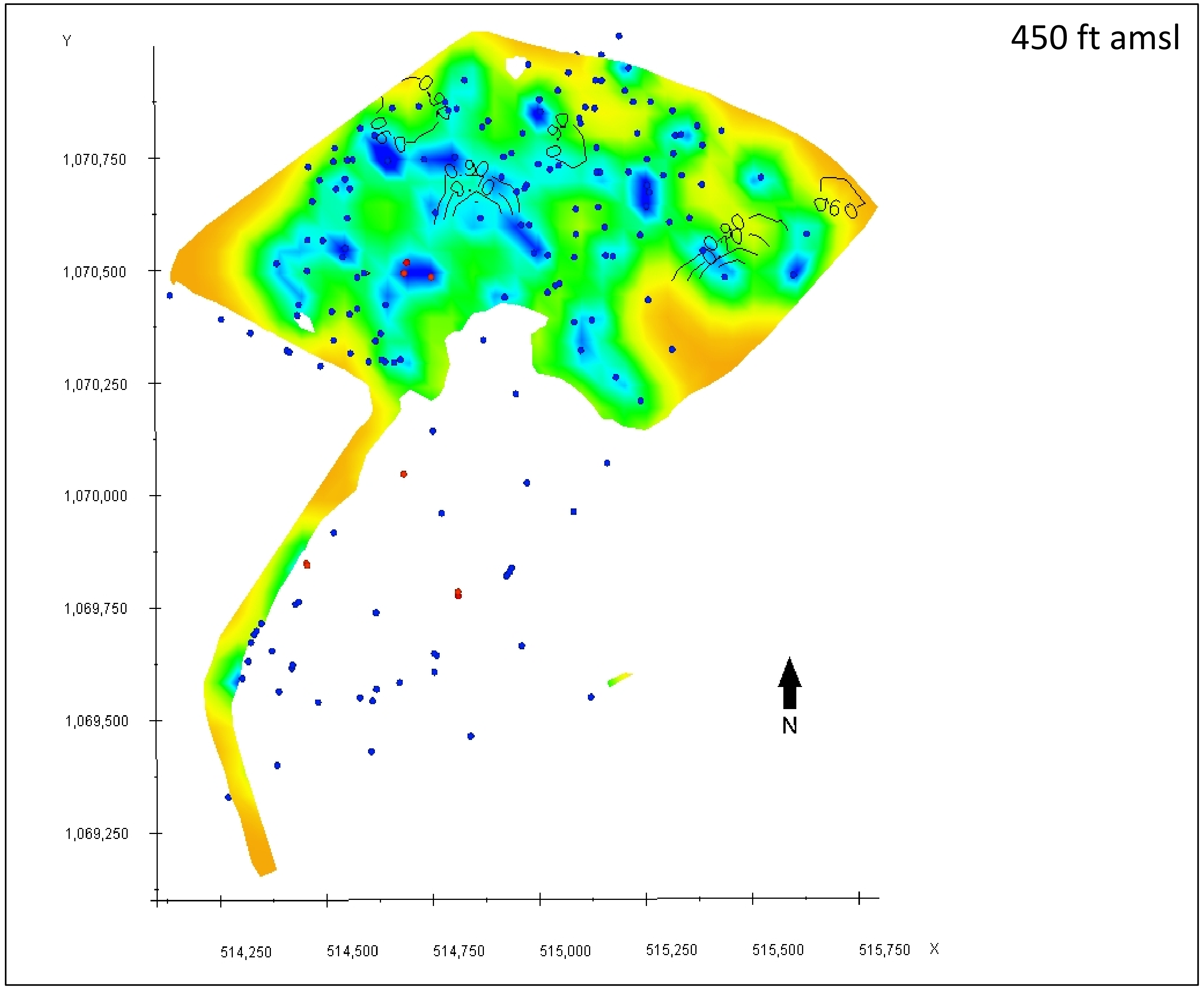
FIGURE E-9m

Area 2
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.17
0.16
0.14
0.12
0.10
0.08
0.07
0.05
0.03

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

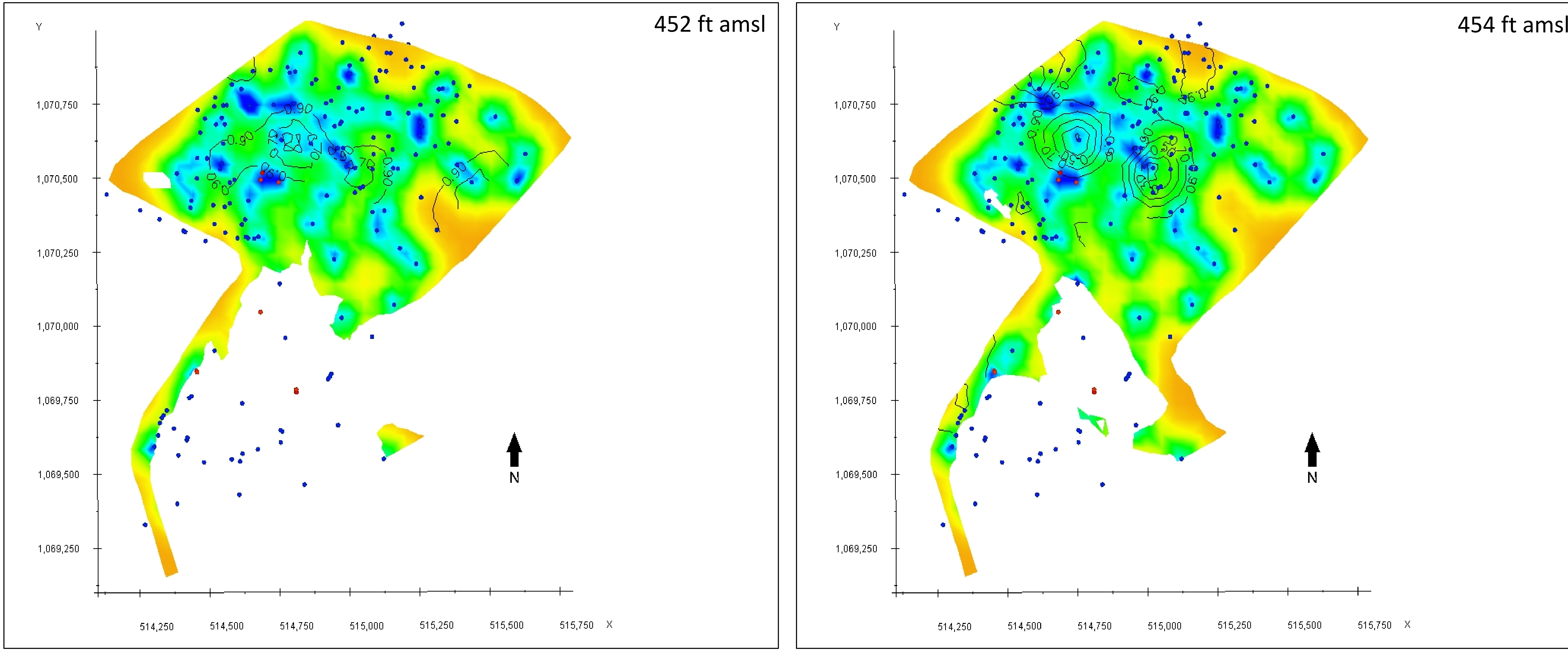
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

FIGURE E-9n

Area 2
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.17
0.16
0.14
0.12
0.10
0.08
0.07
0.05
0.03

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

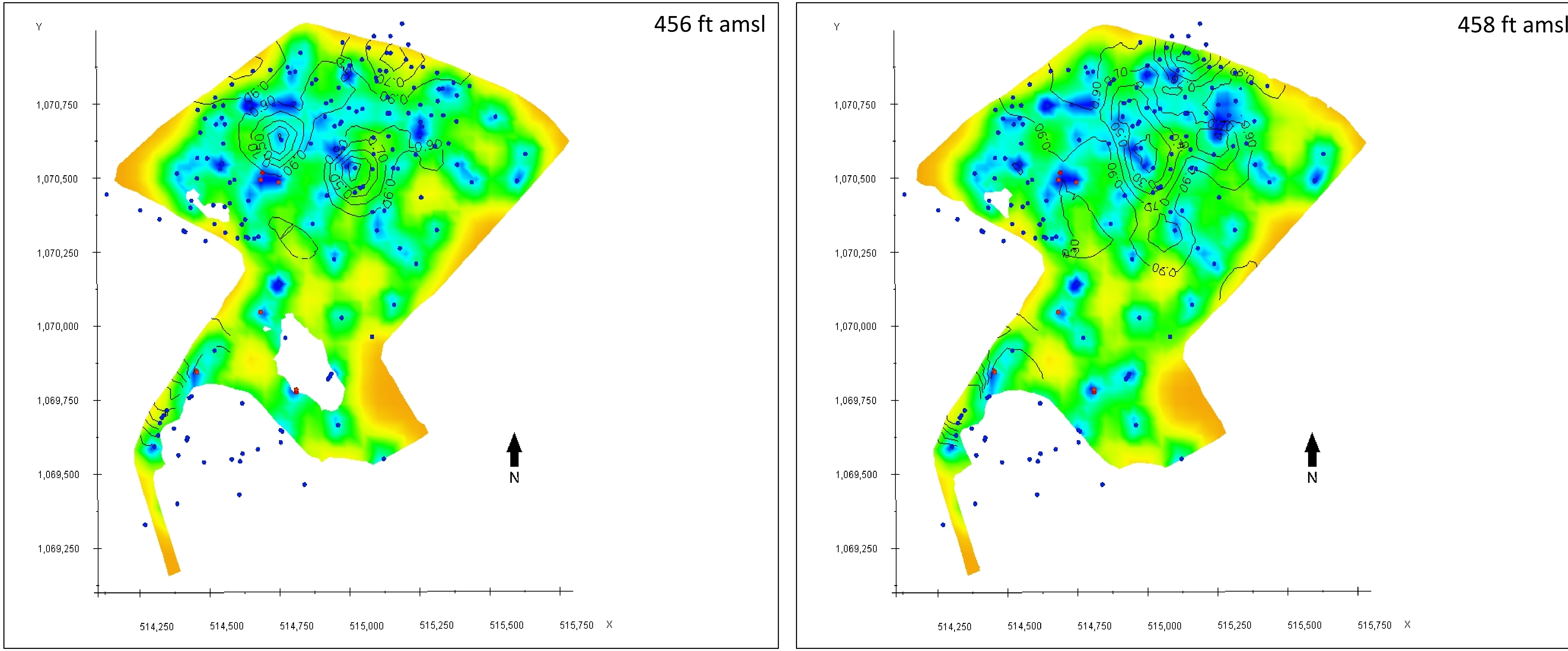
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

FIGURE E-9o

Area 2
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.17
0.16
0.14
0.12
0.10
0.08
0.07
0.05
0.03

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

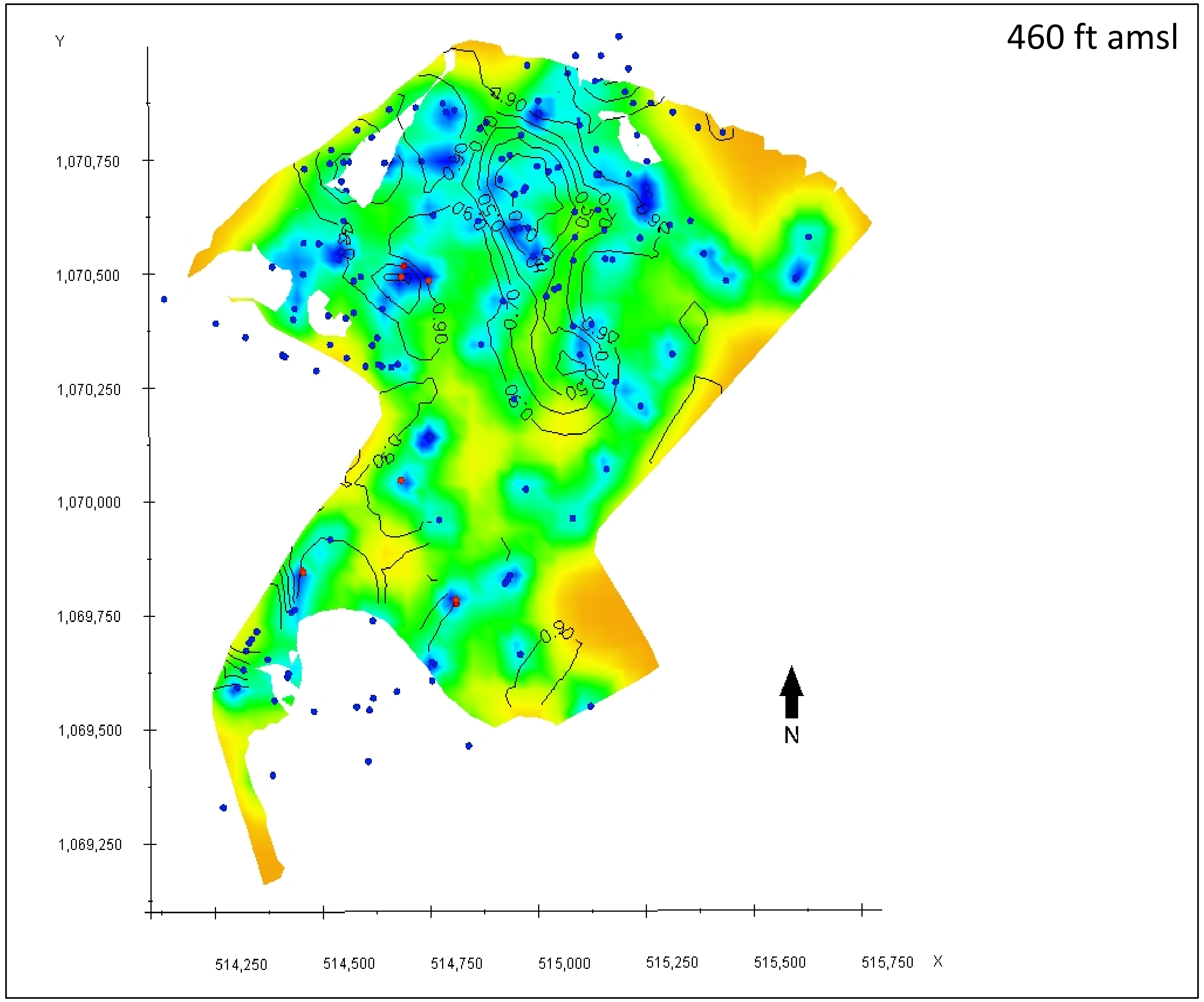
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

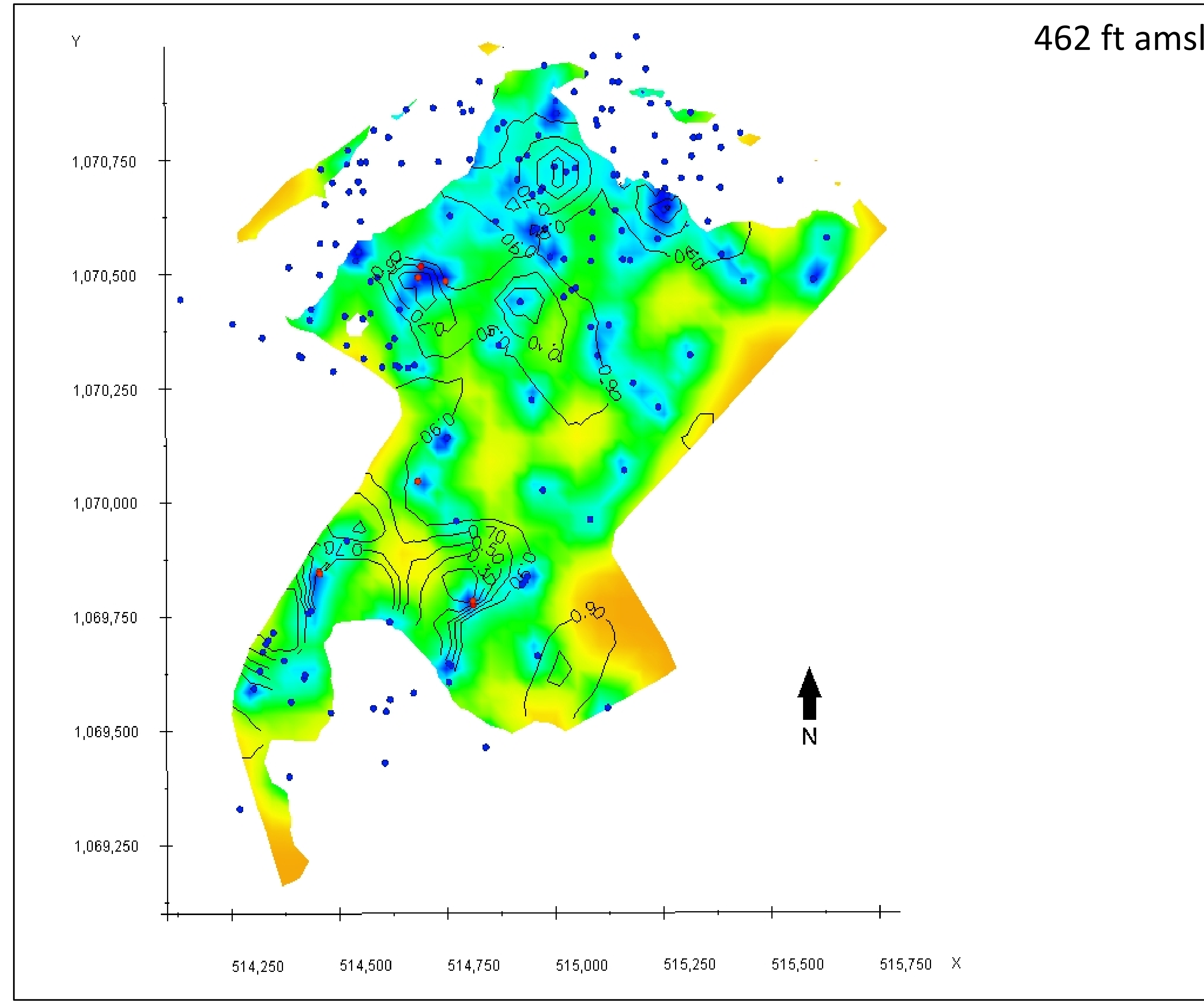
FIGURE E-9p

Area 2
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

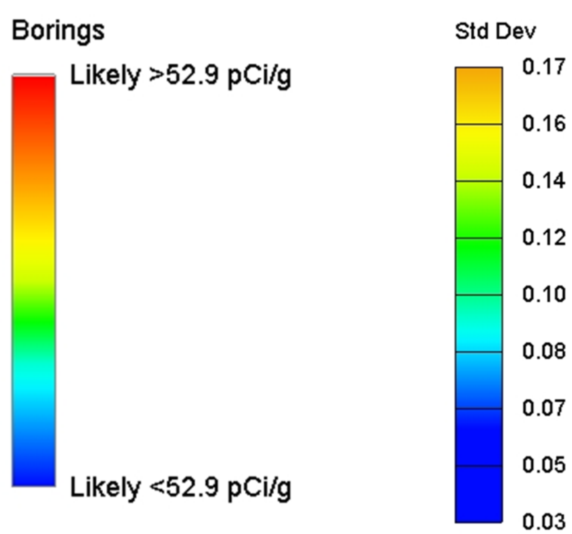
PARSONS

Syracuse, NY





Legend



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

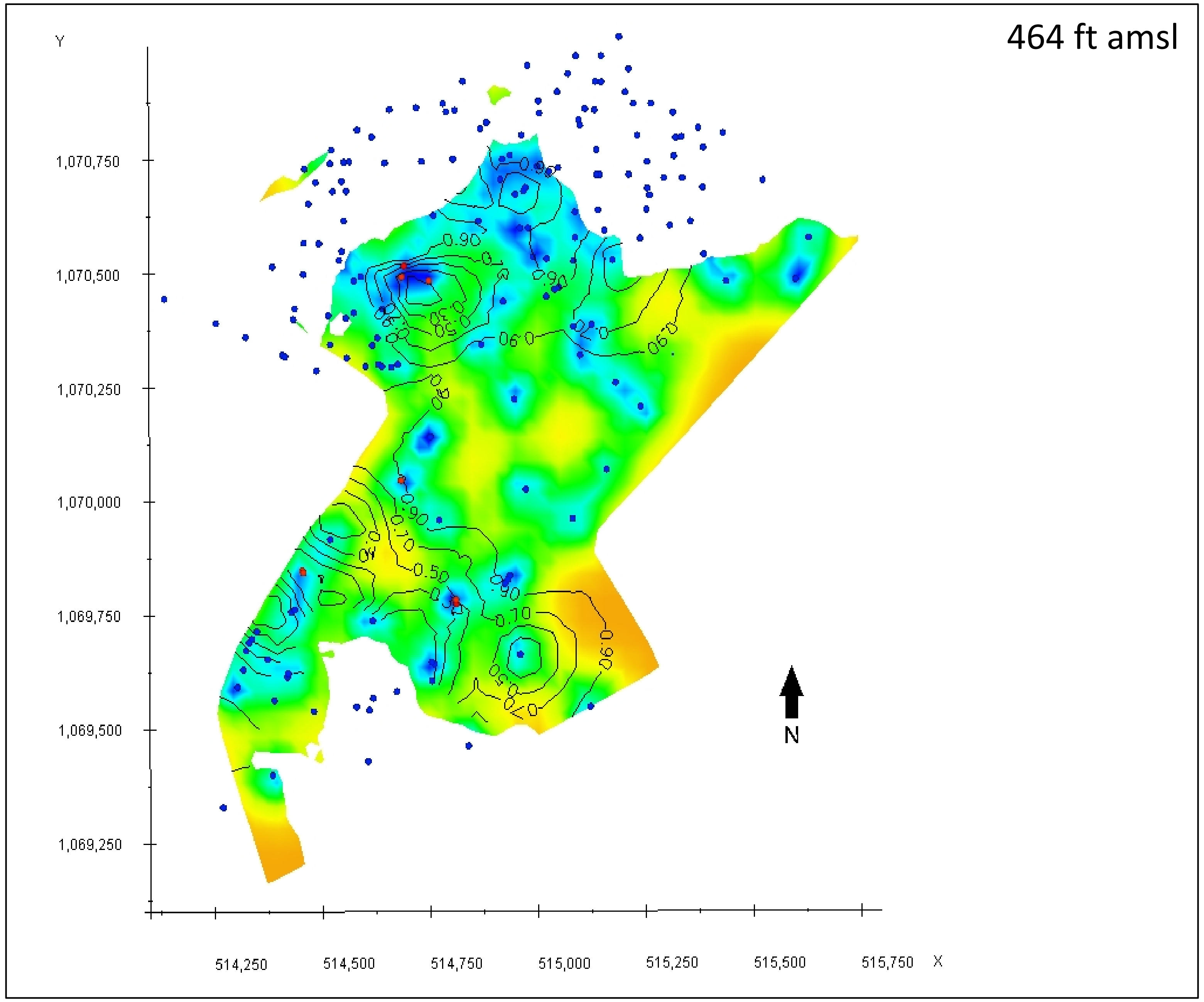
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

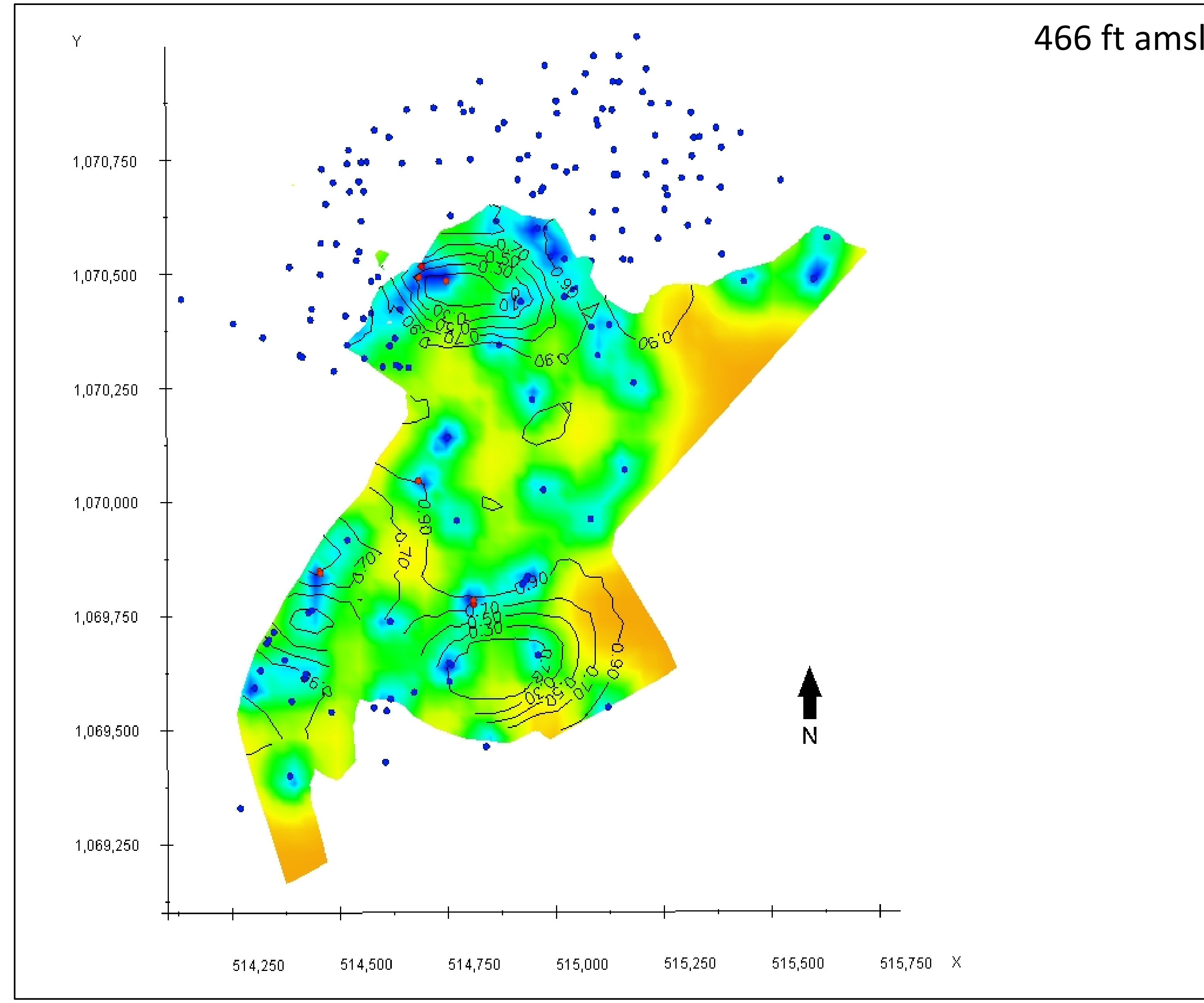
FIGURE E-9q

Area 2
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.17
0.16
0.14
0.12
0.10
0.08
0.07
0.05
0.03

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

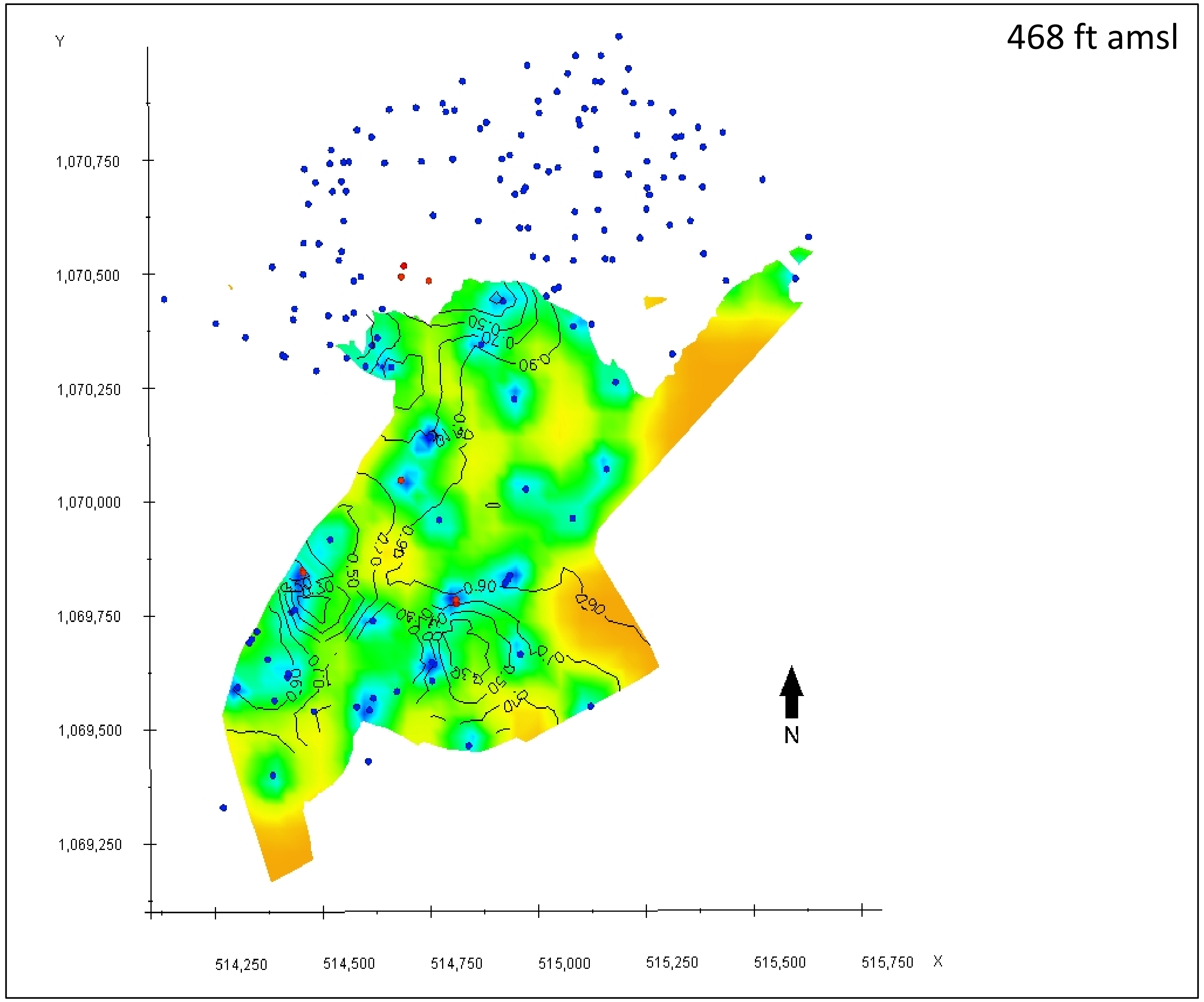
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

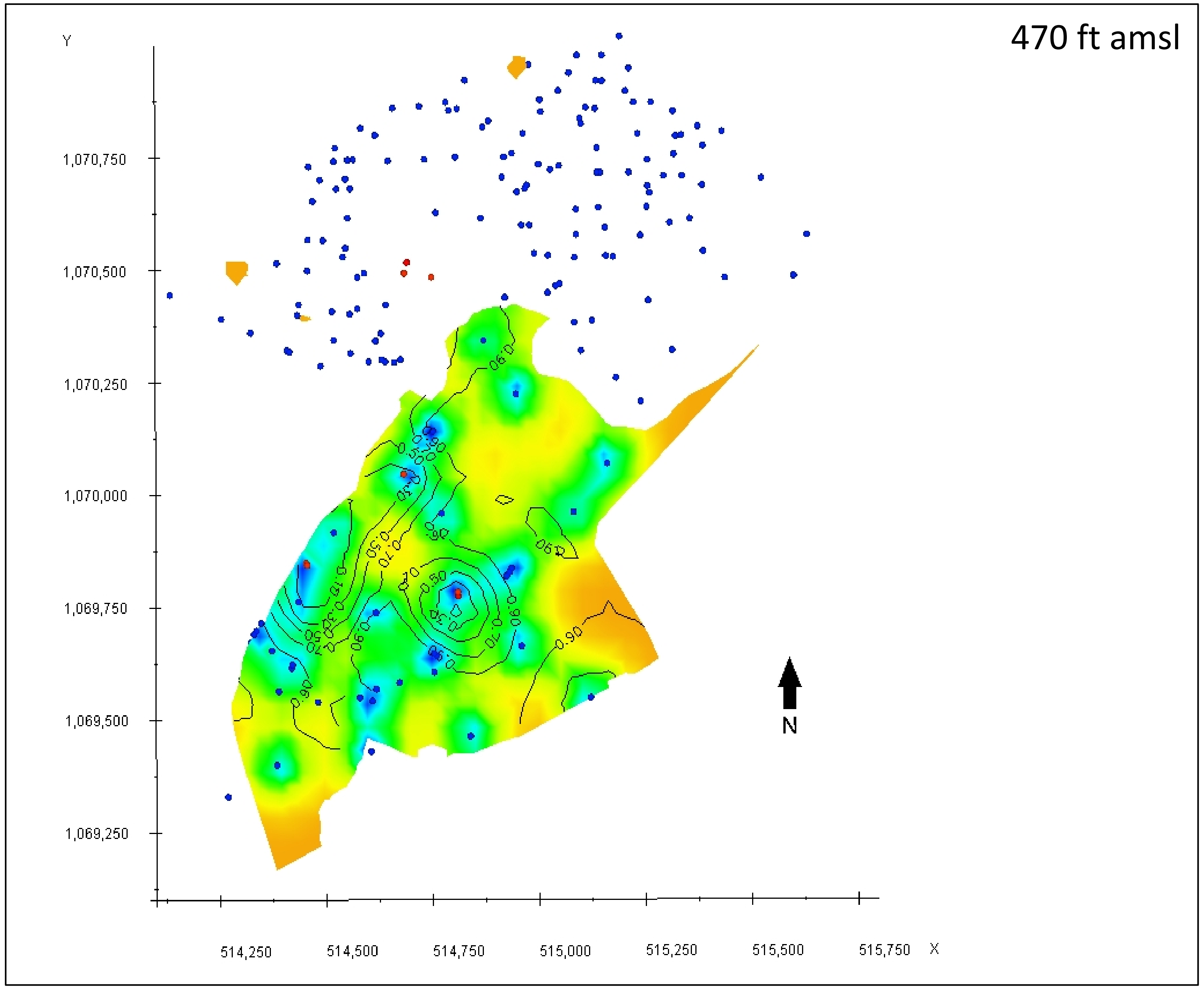
FIGURE E-9r

Area 2
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.17
0.16
0.14
0.12
0.10
0.08
0.07
0.05
0.03

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

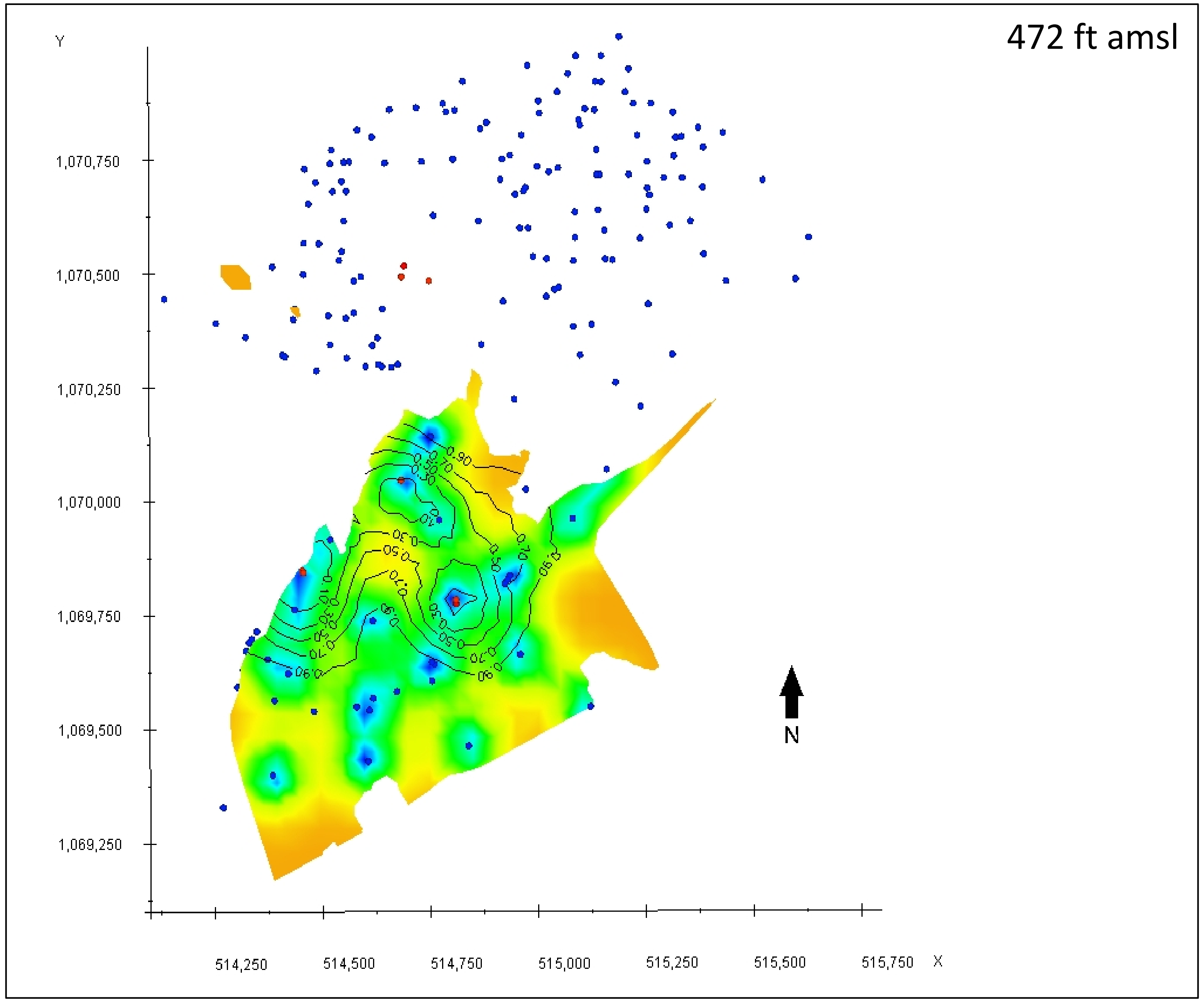
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

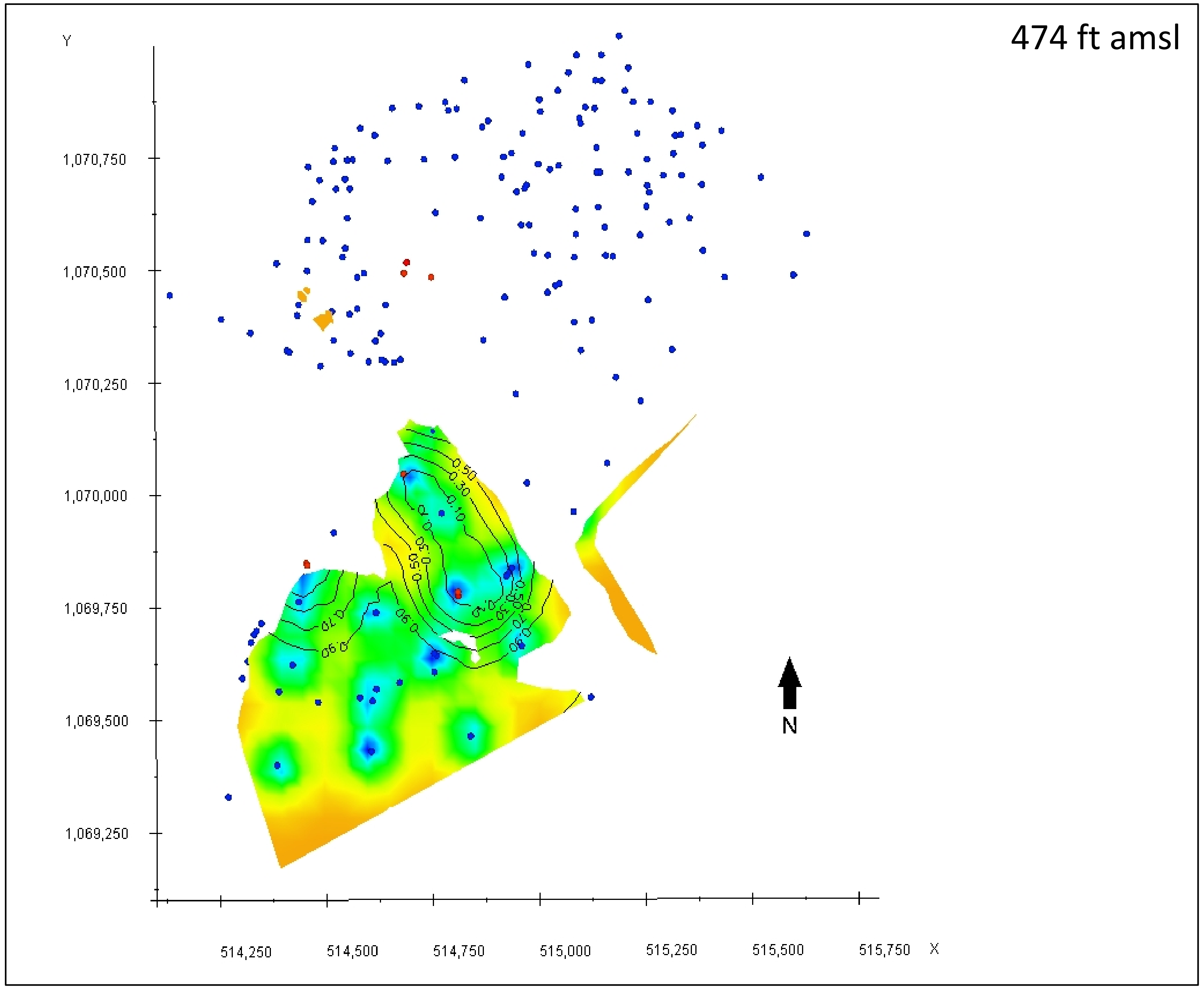
FIGURE E-9s

Area 2
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.17
0.16
0.14
0.12
0.10
0.08
0.07
0.05
0.03

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

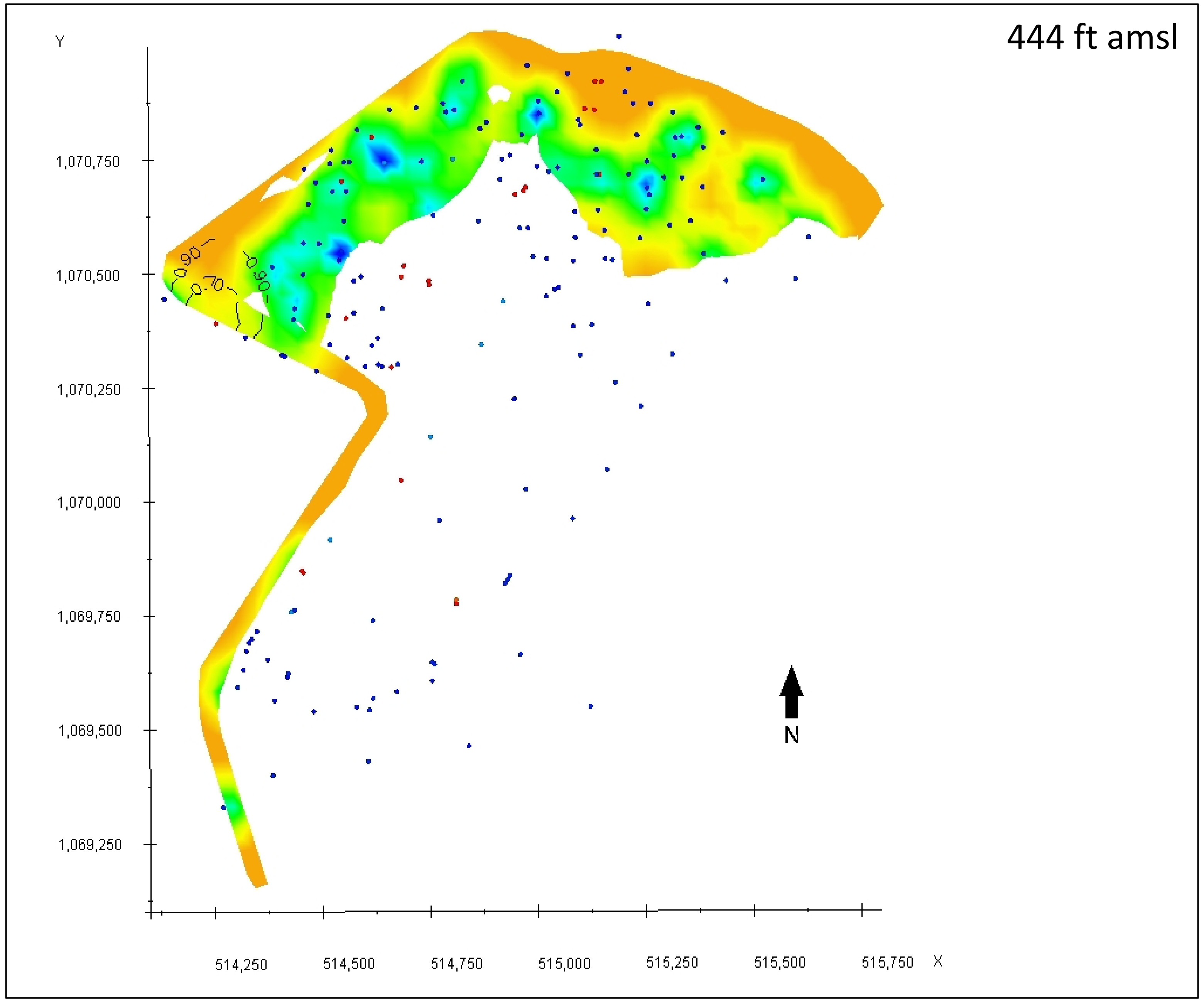
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

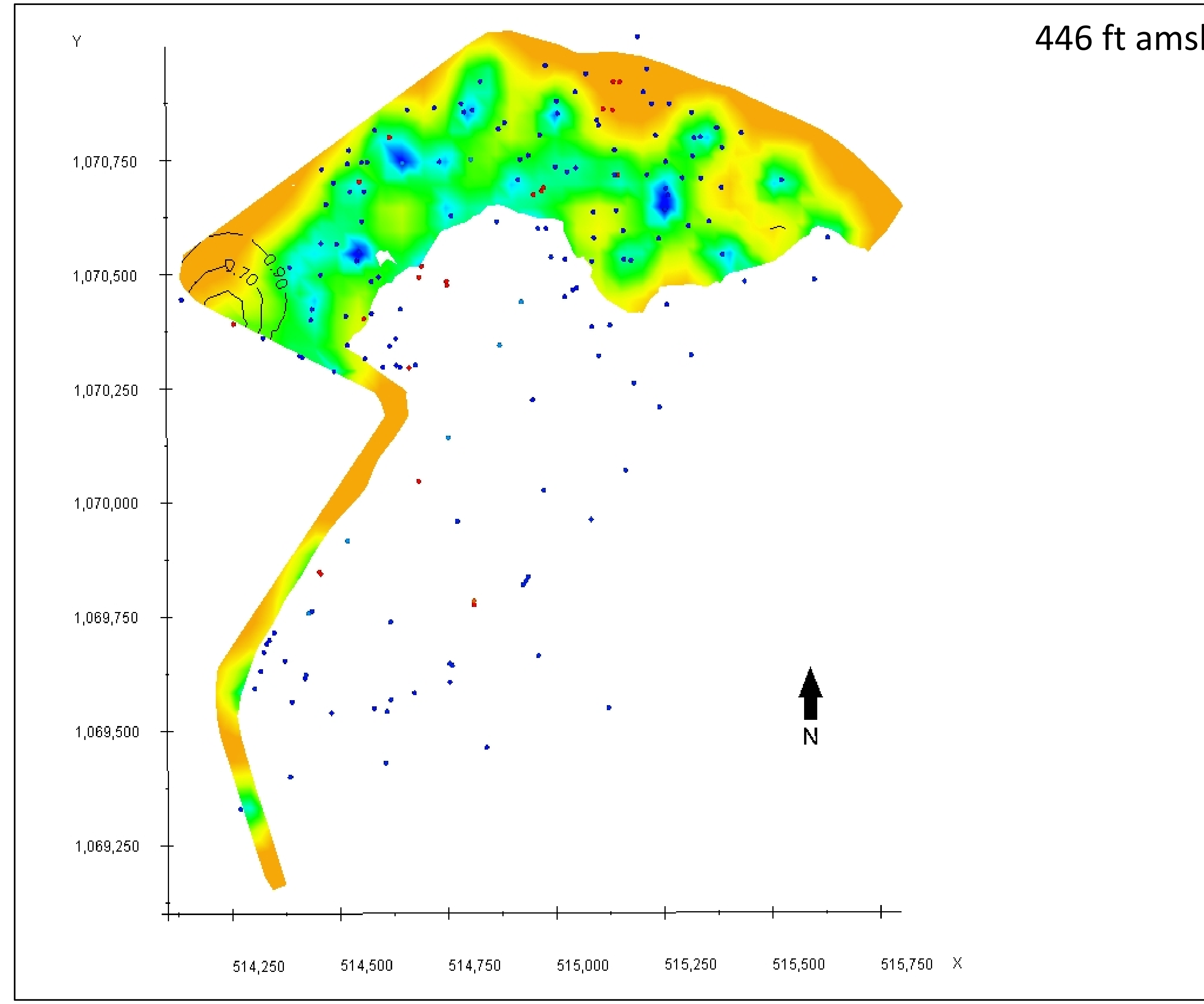
FIGURE E-9t

Area 2
Radium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.19
0.17
0.15
0.13
0.12
0.10
0.08
0.06
0.04

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

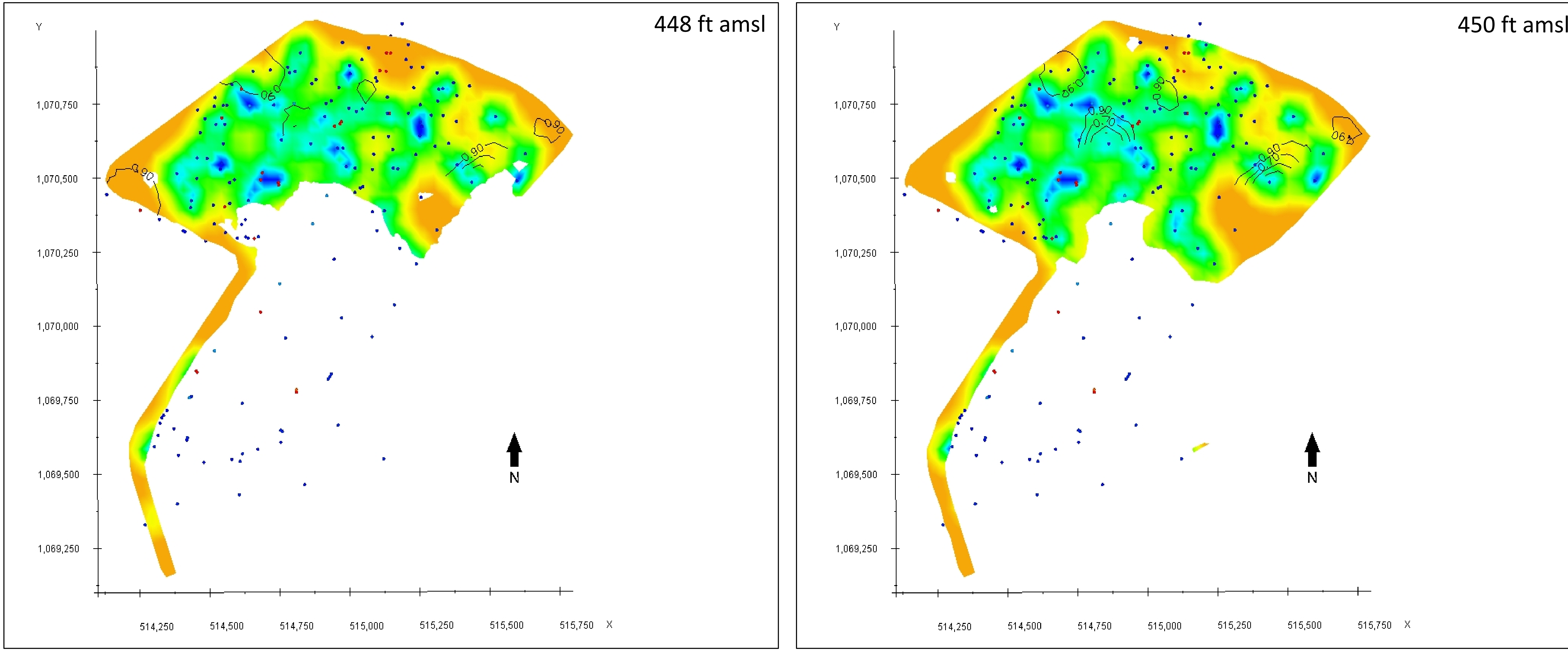
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

FIGURE E-9u

Area 2
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.19
0.17
0.15
0.13
0.12
0.10
0.08
0.06
0.04

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

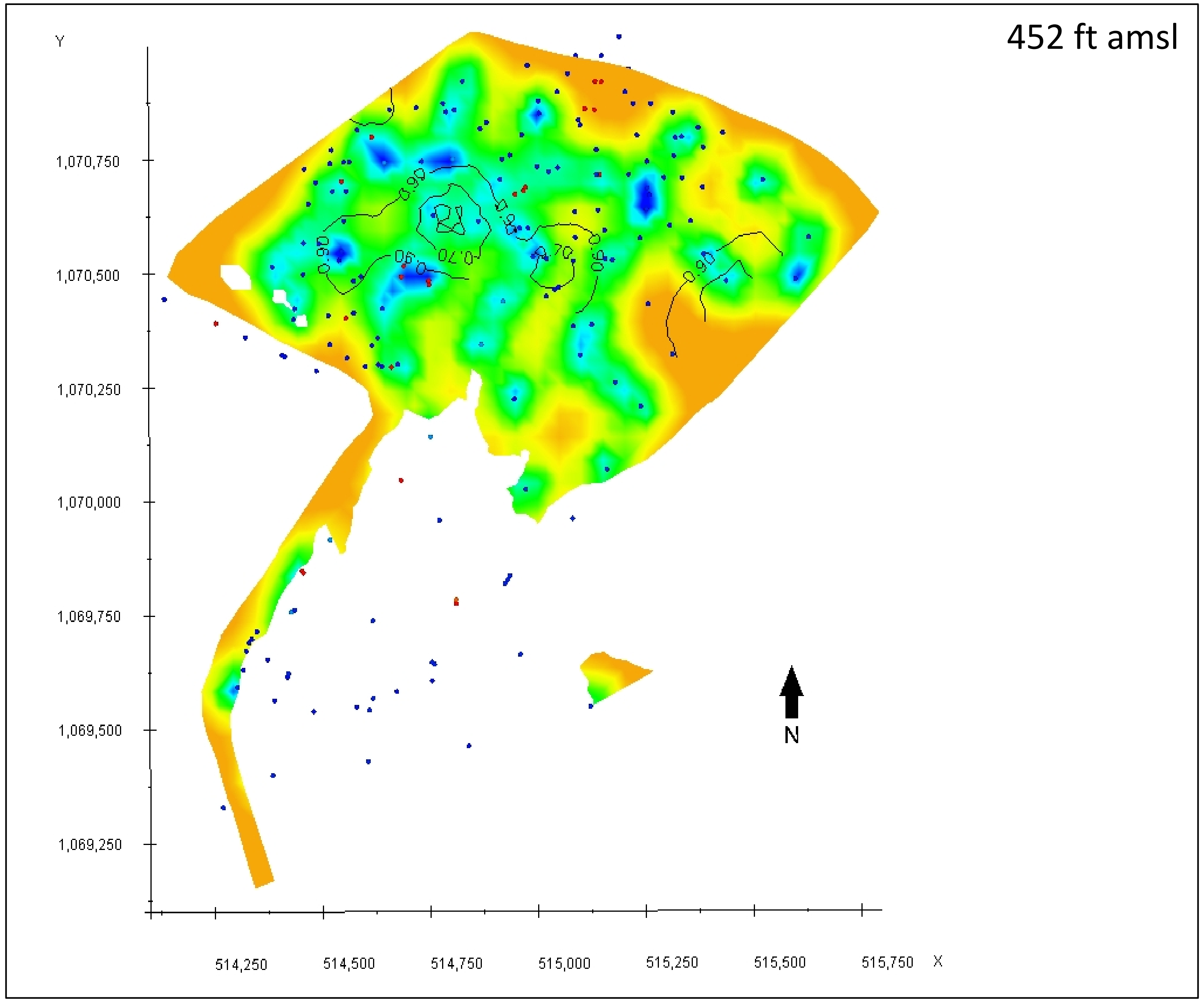
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

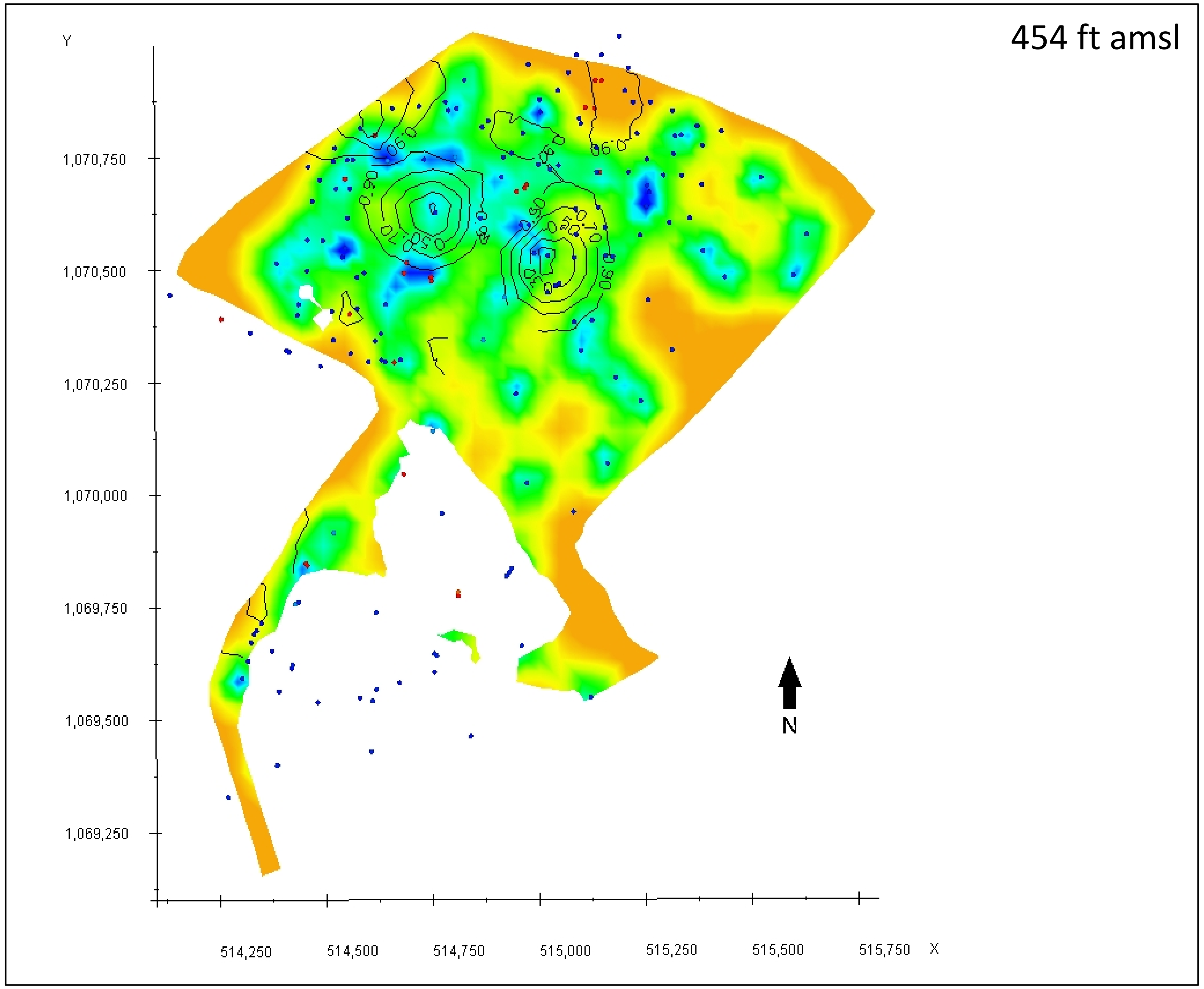
FIGURE E-9v

Area 2
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.19
0.17
0.15
0.13
0.12
0.10
0.08
0.06
0.04

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

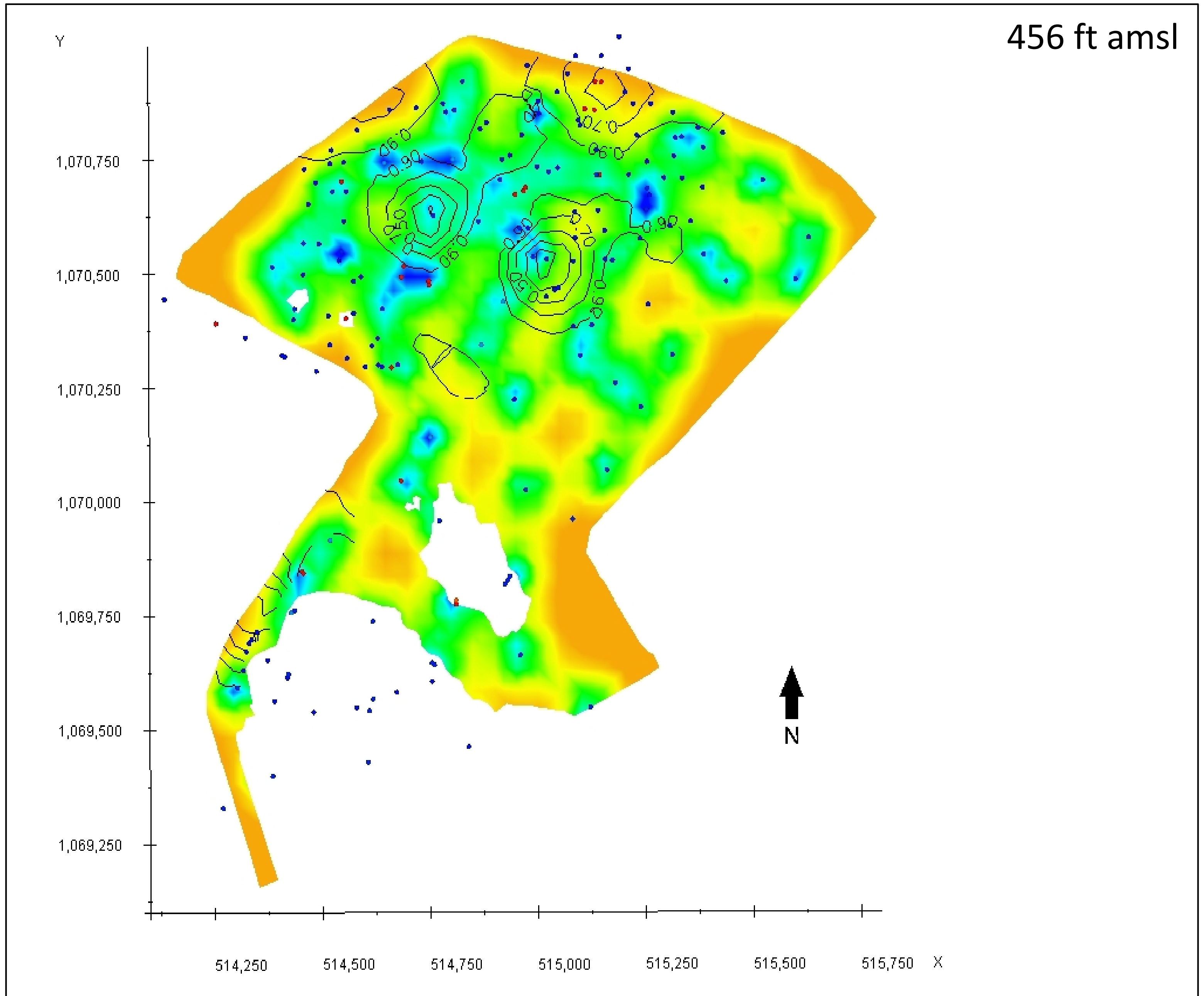
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

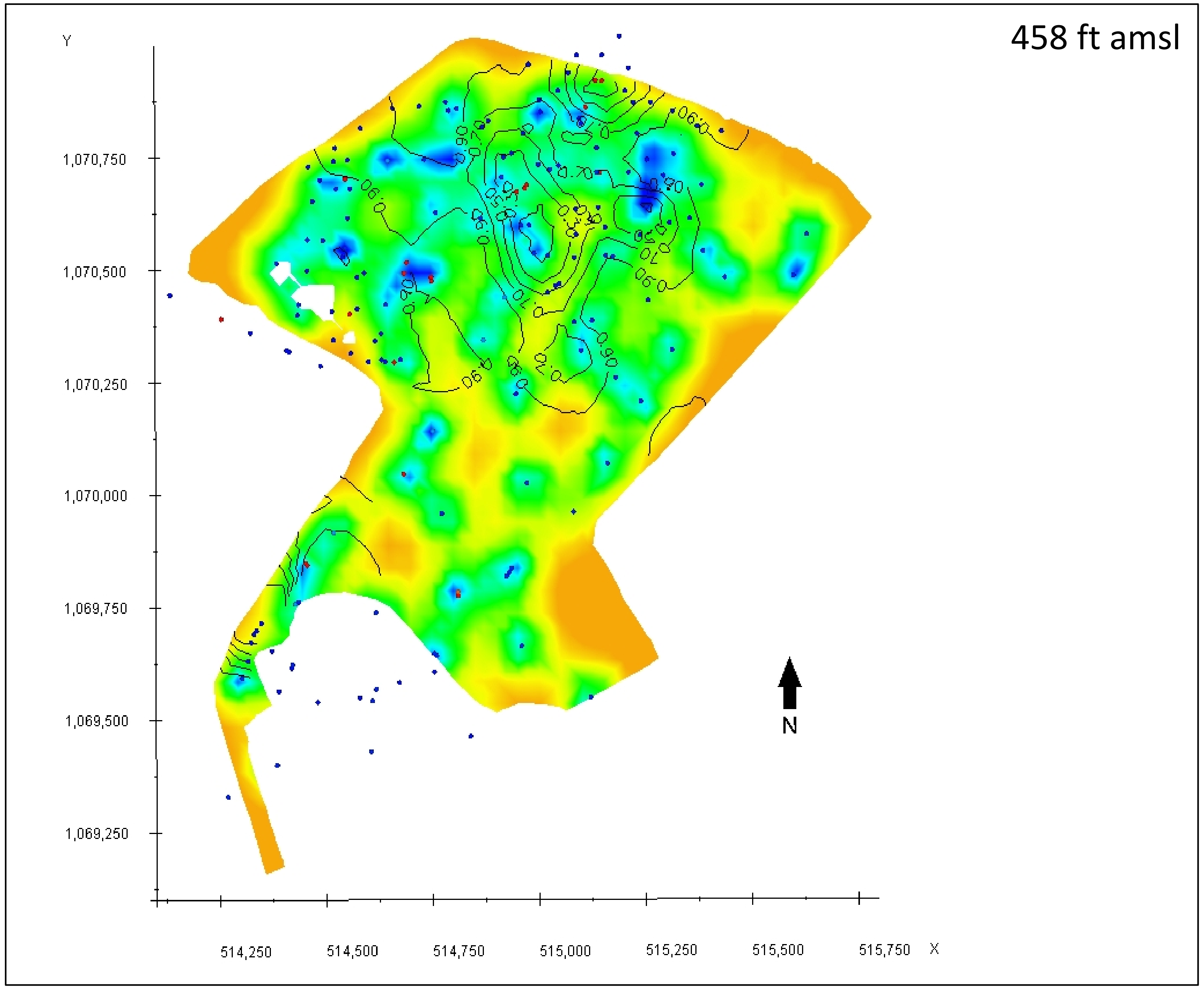
FIGURE E-9w

Area 2
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.19
0.17
0.15
0.13
0.12
0.10
0.08
0.06
0.04

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

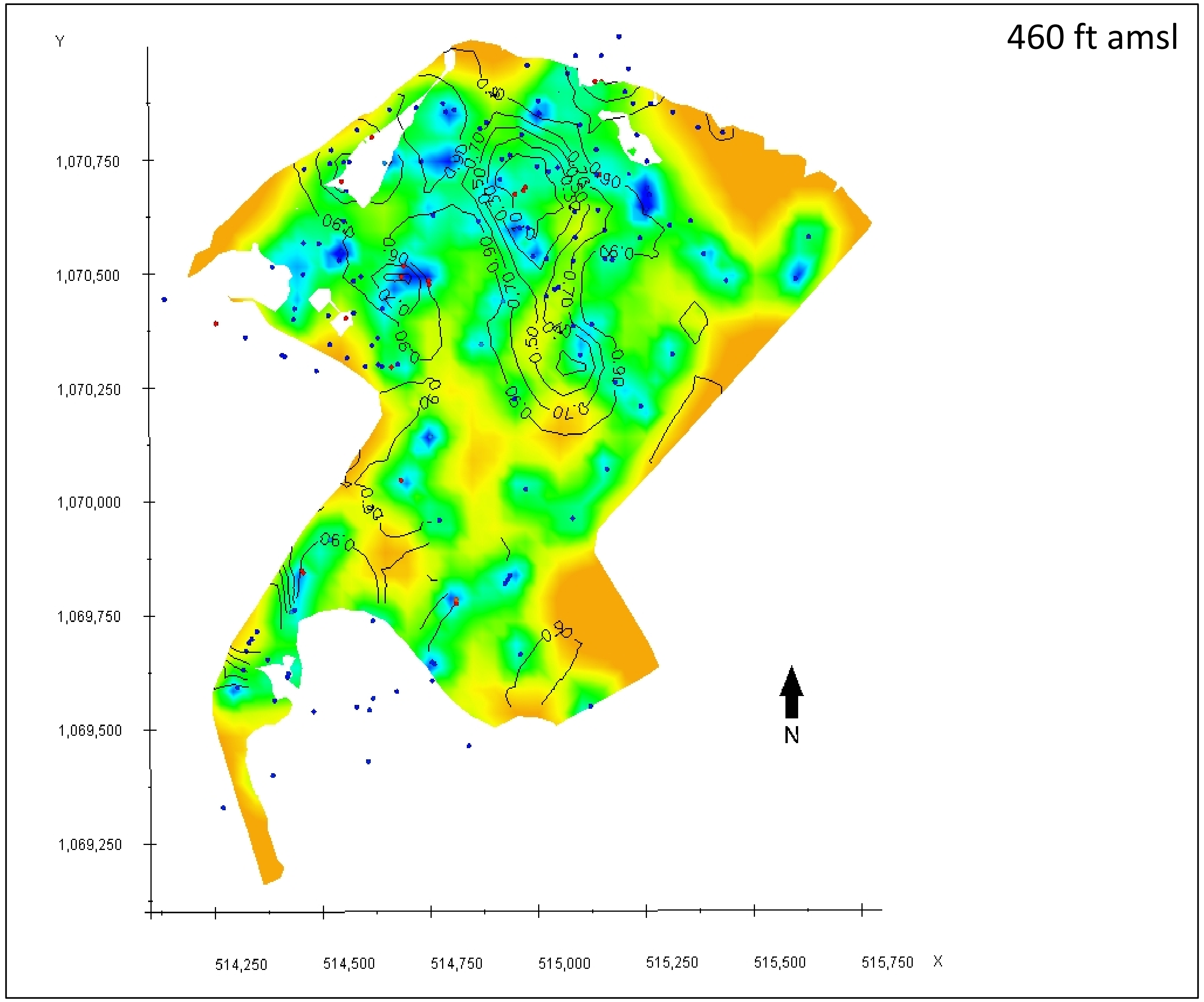
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

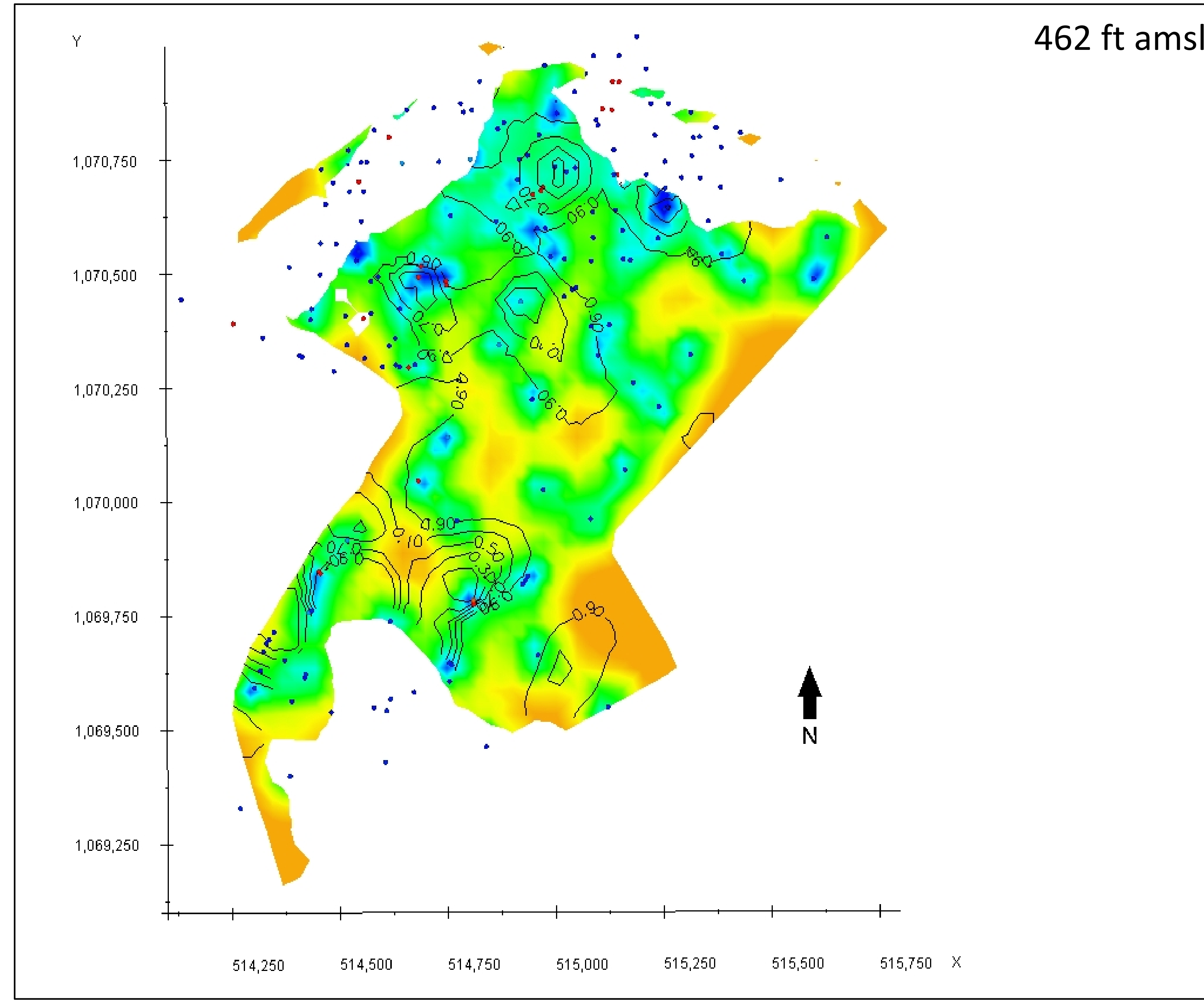
FIGURE E-9x

Area 2
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.19
0.17
0.15
0.13
0.12
0.10
0.08
0.06
0.04

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

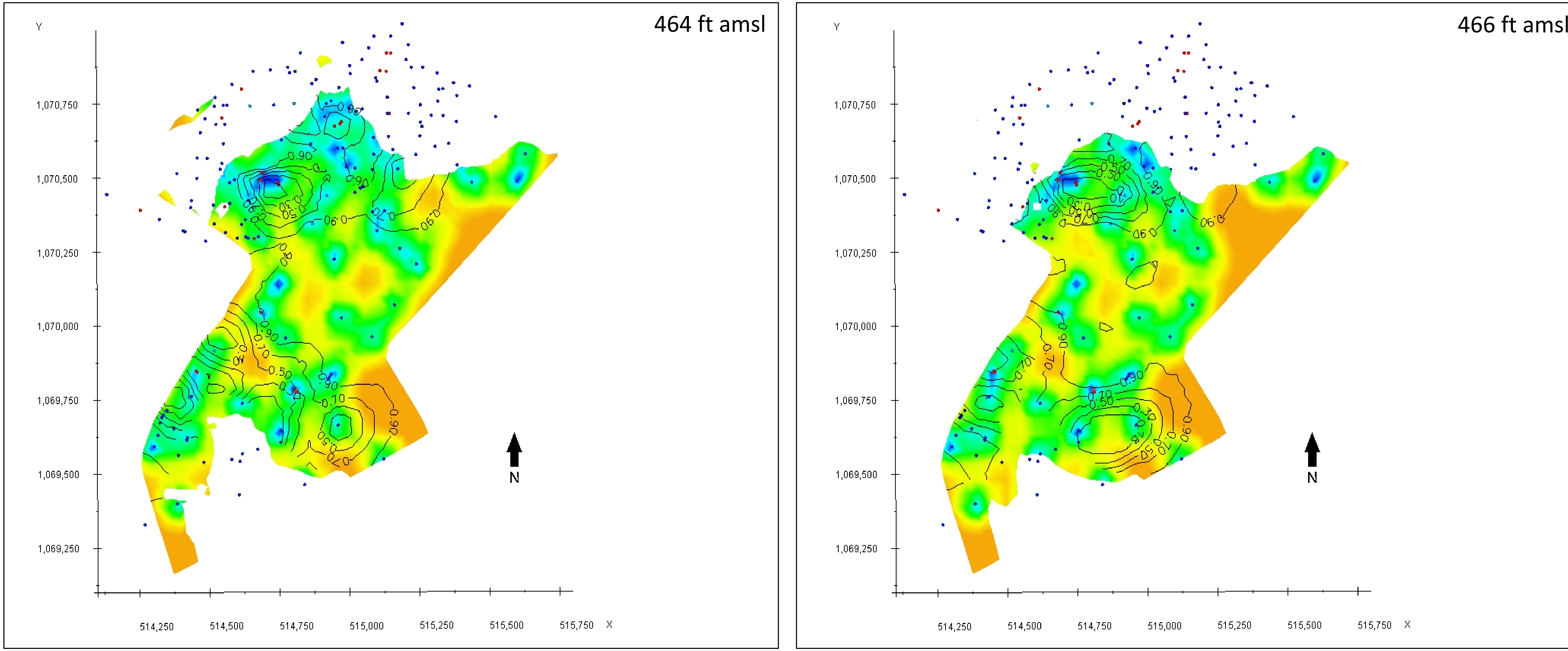
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

FIGURE E-9y

Area 2
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.19
0.17
0.15
0.13
0.12
0.10
0.08
0.06
0.04

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

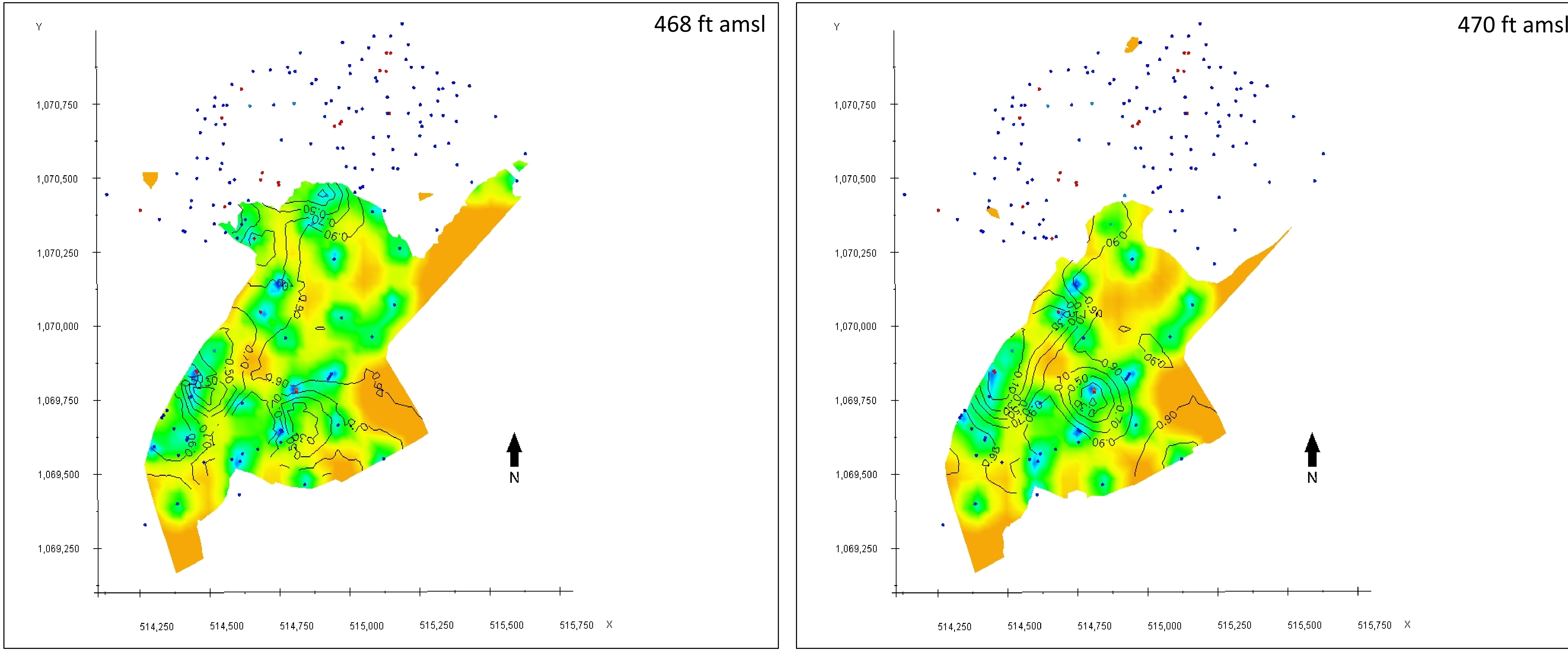
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

FIGURE E-9z

Area 2
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Std Dev

0.19
0.17
0.15
0.13
0.12
0.10
0.08
0.06
0.04

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

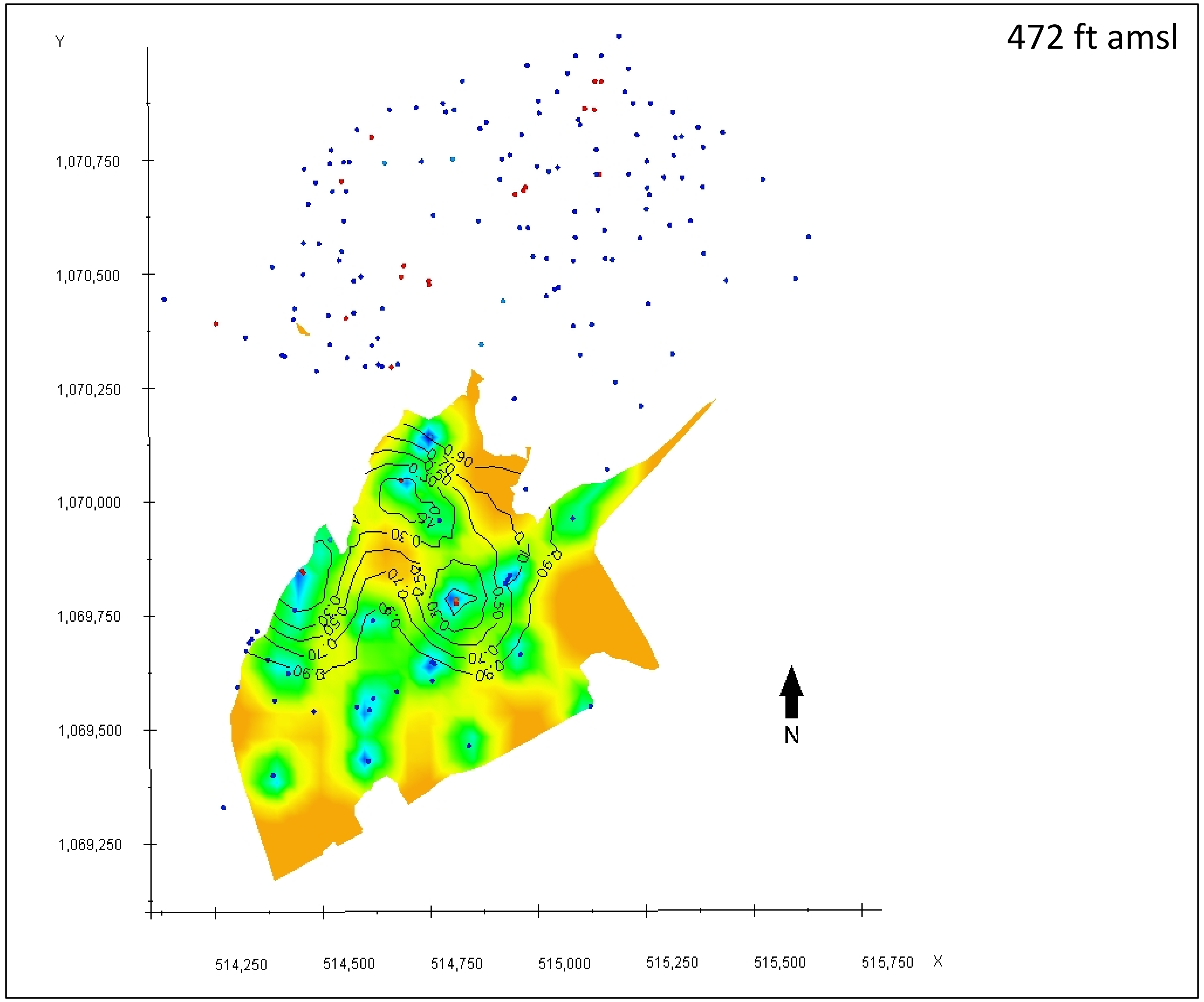
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

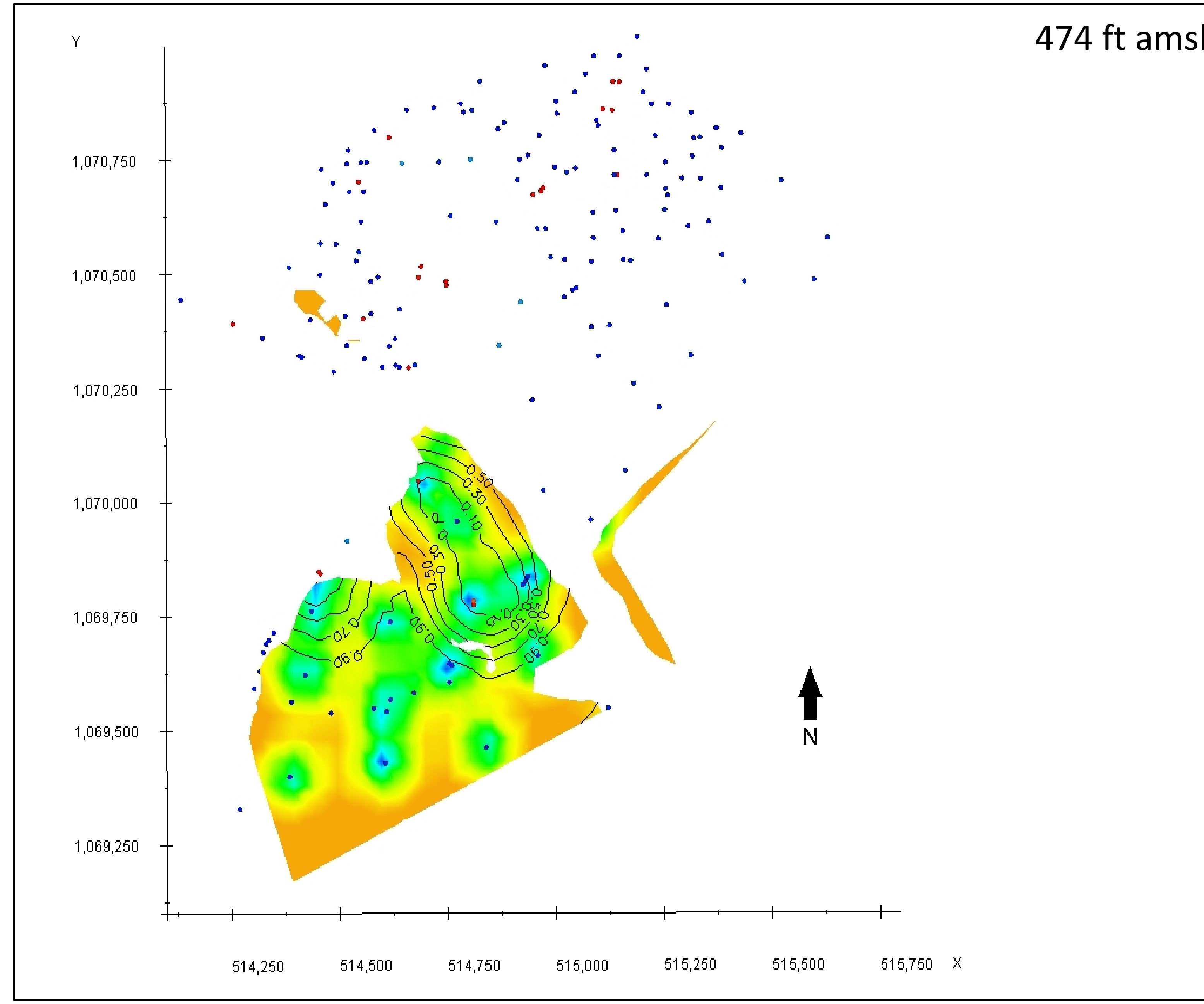
FIGURE E-9aa

Area 2
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

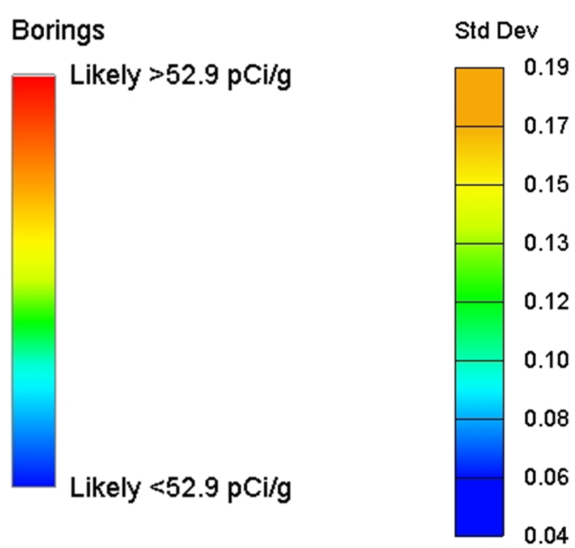
PARSONS

Syracuse, NY





Legend



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9.

FIGURE E-9ab

Area 2
Thorium Standard Deviation by Elevation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

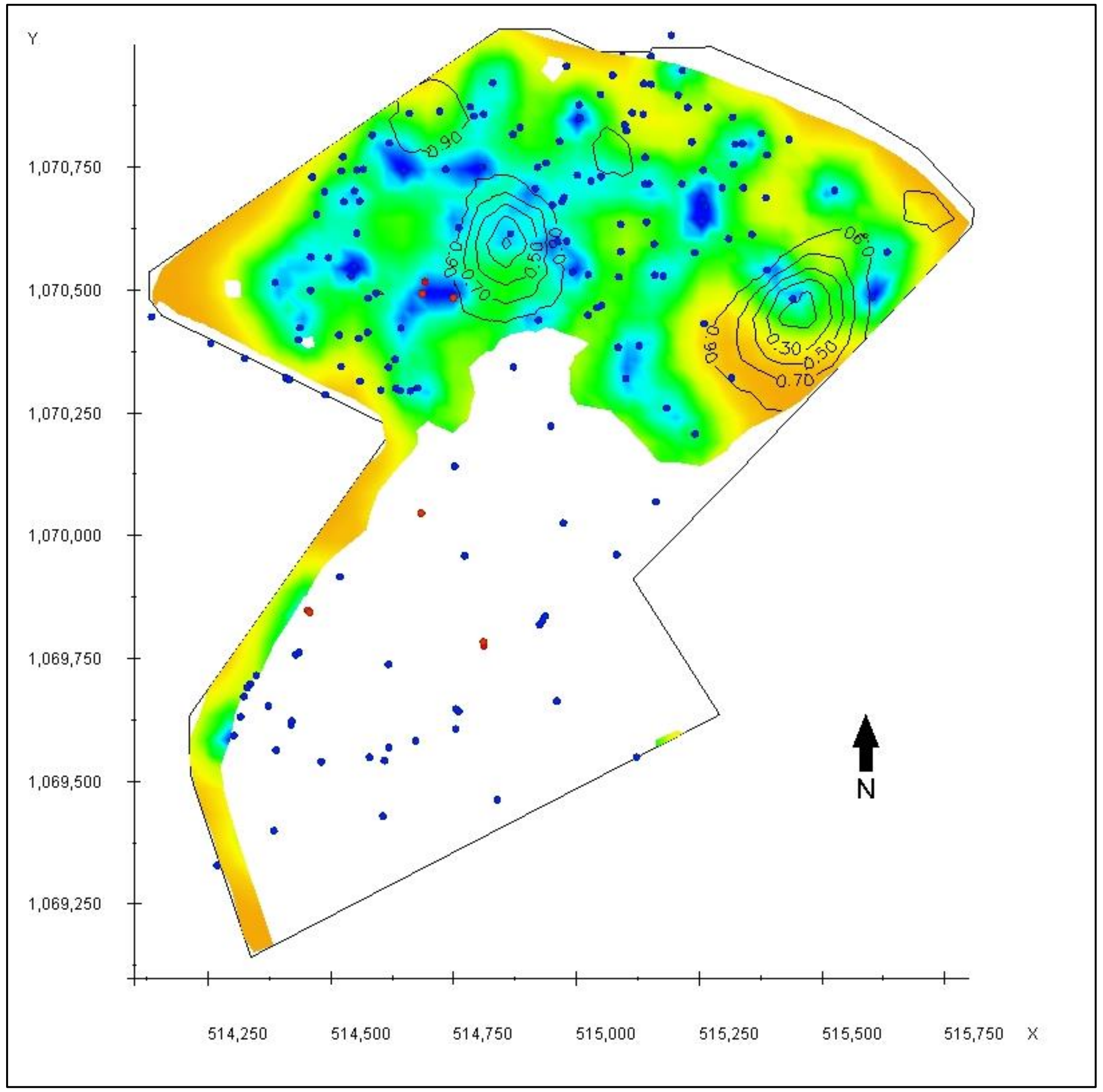
PARSONS

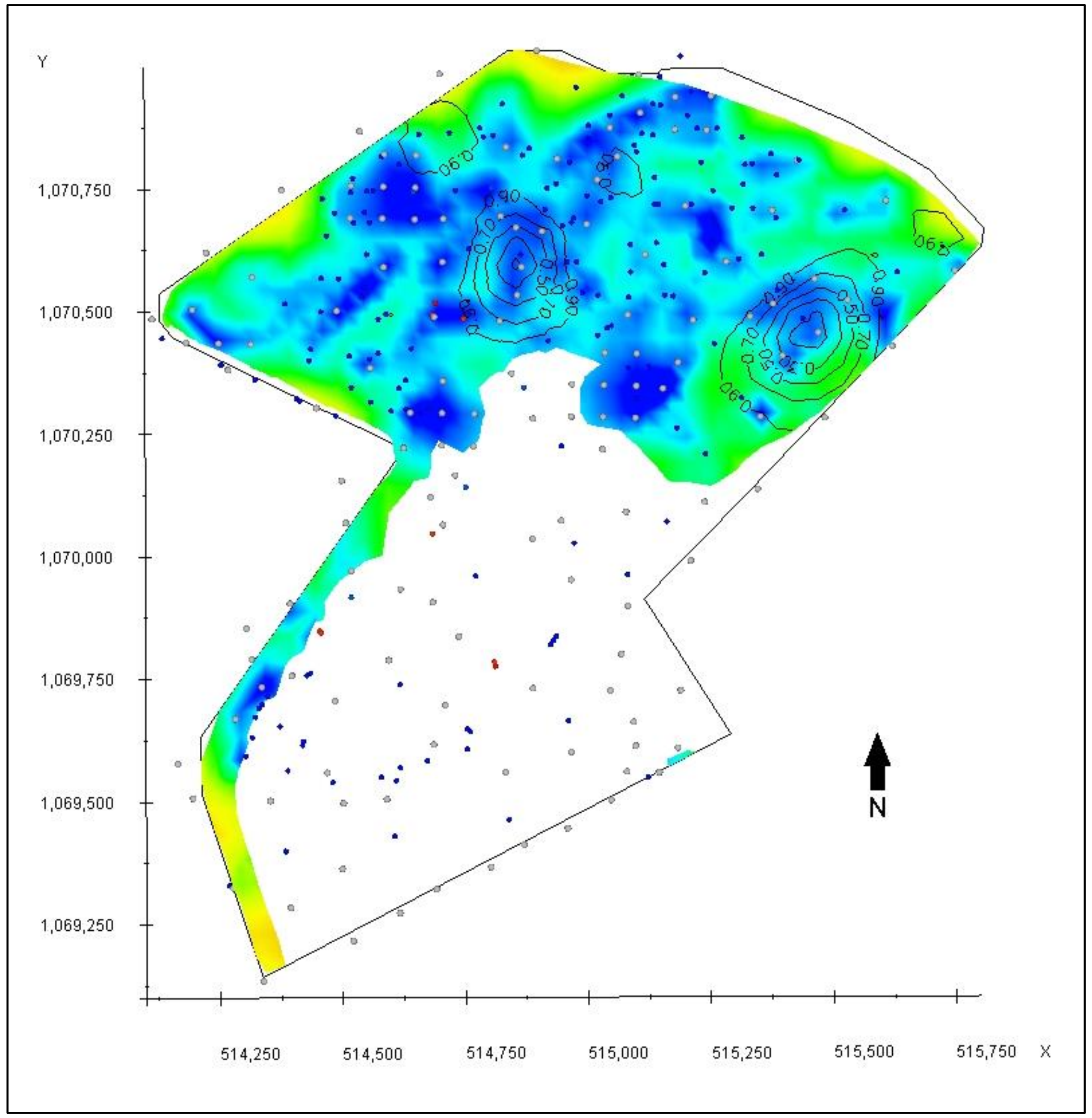
Syracuse, NY

CURRENT MODEL

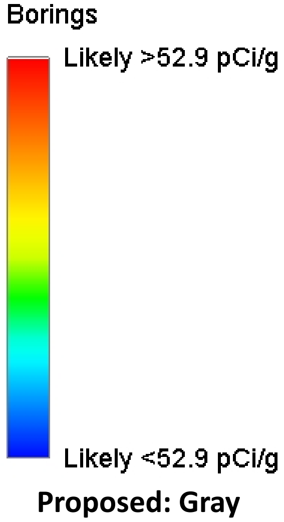
450 ft amsl

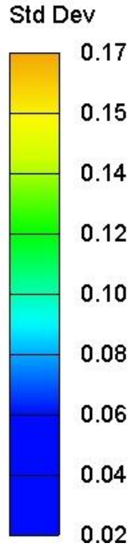
PROPOSED MODEL





Legend





Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

FIGURE E-10a

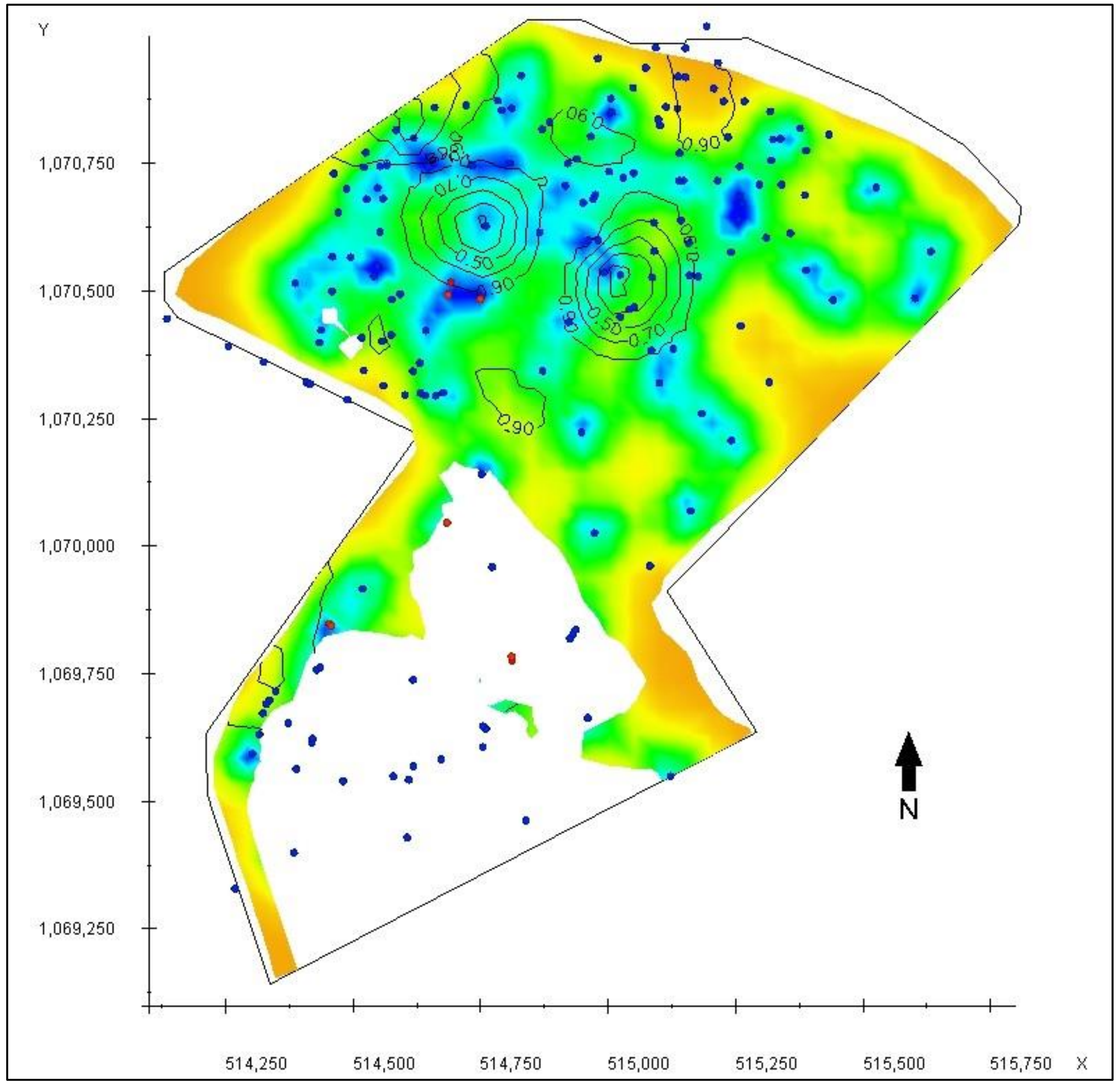
Area 2
Radium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

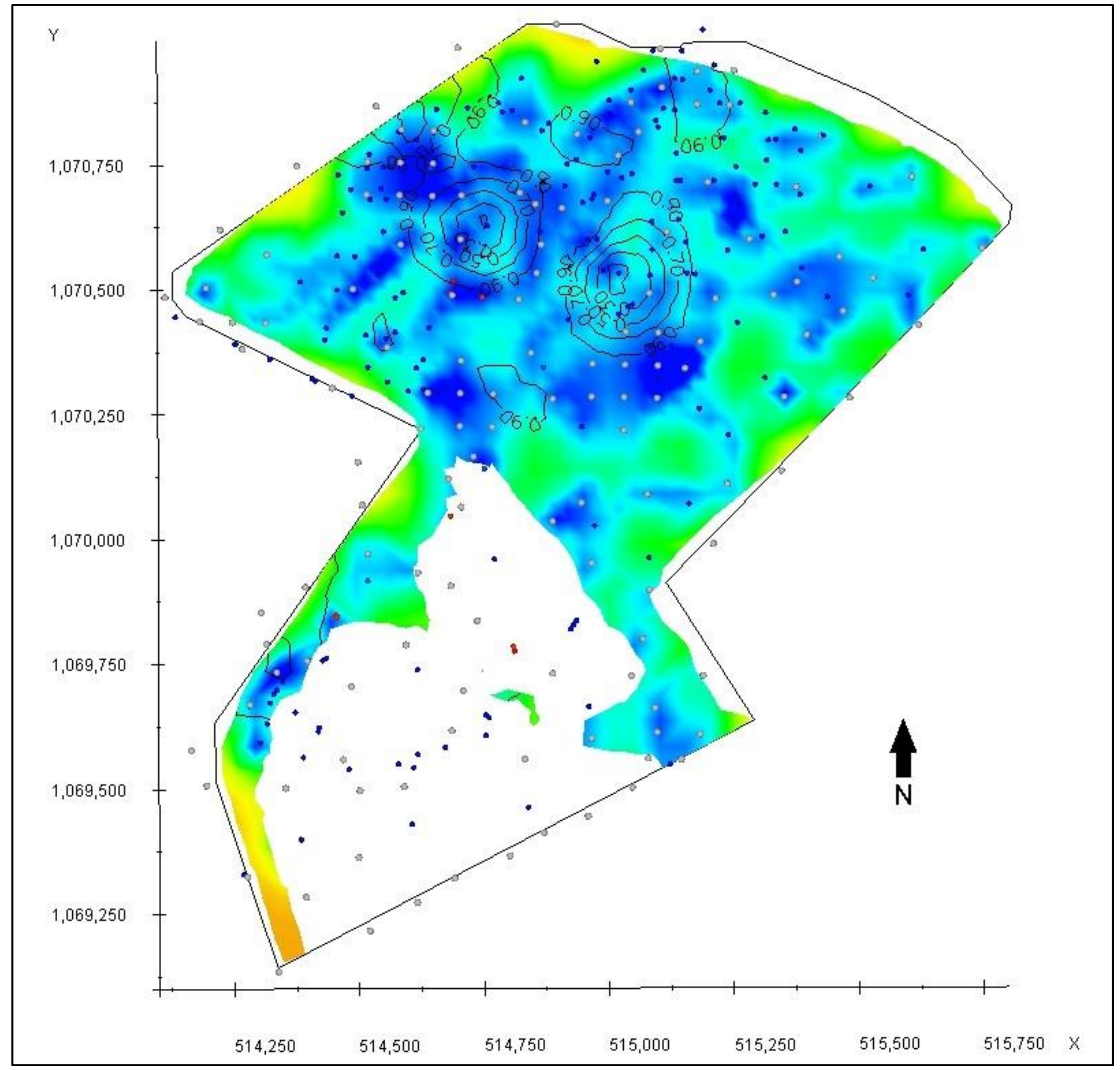
Syracuse, NY

454 ft amsl

CURRENT MODEL



PROPOSED MODEL



Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Proposed: Gray

Std Dev

0.17
0.15
0.14
0.12
0.10
0.08
0.06
0.04
0.02

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

FIGURE E-10b

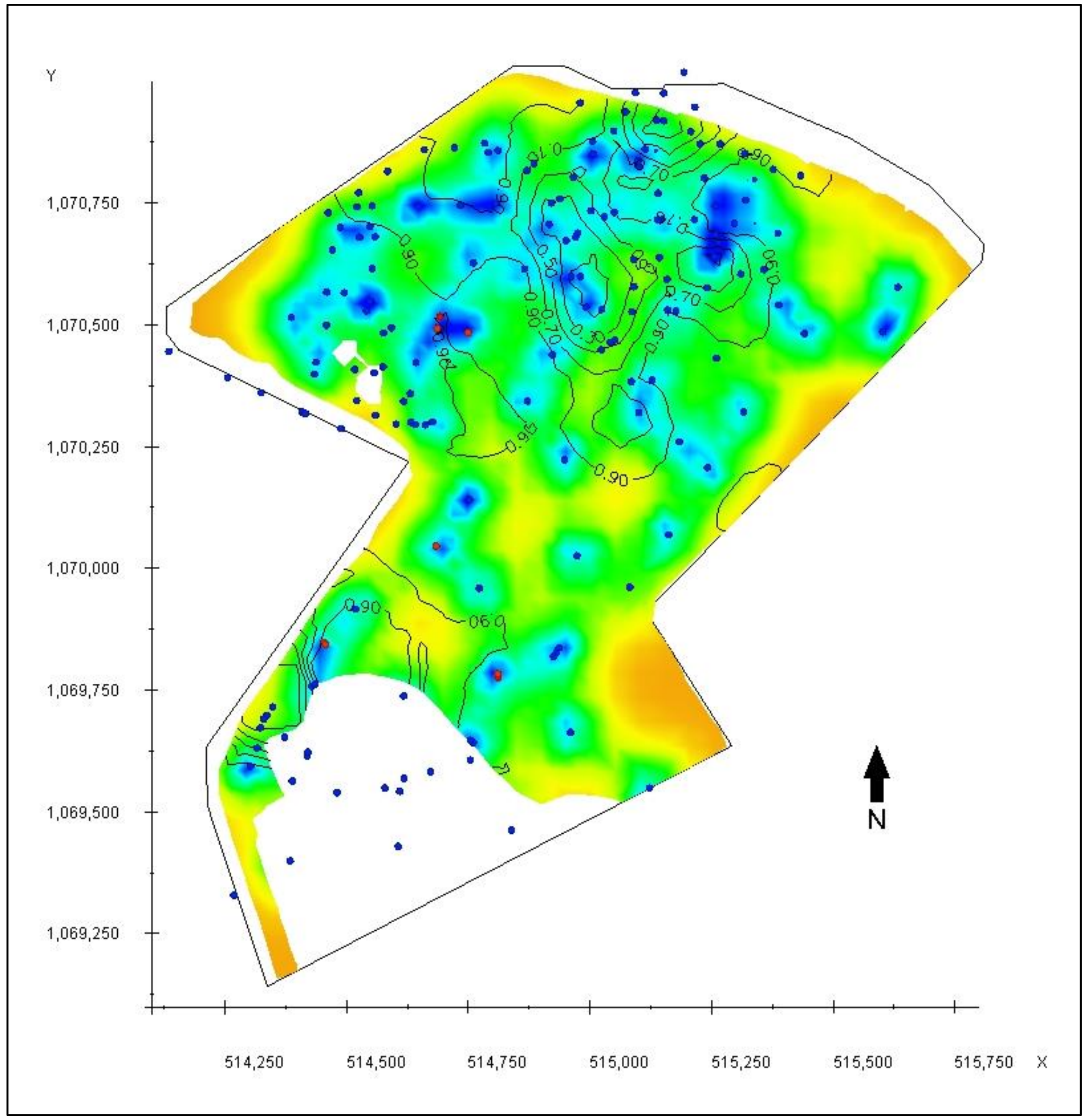
Area 2
Radium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

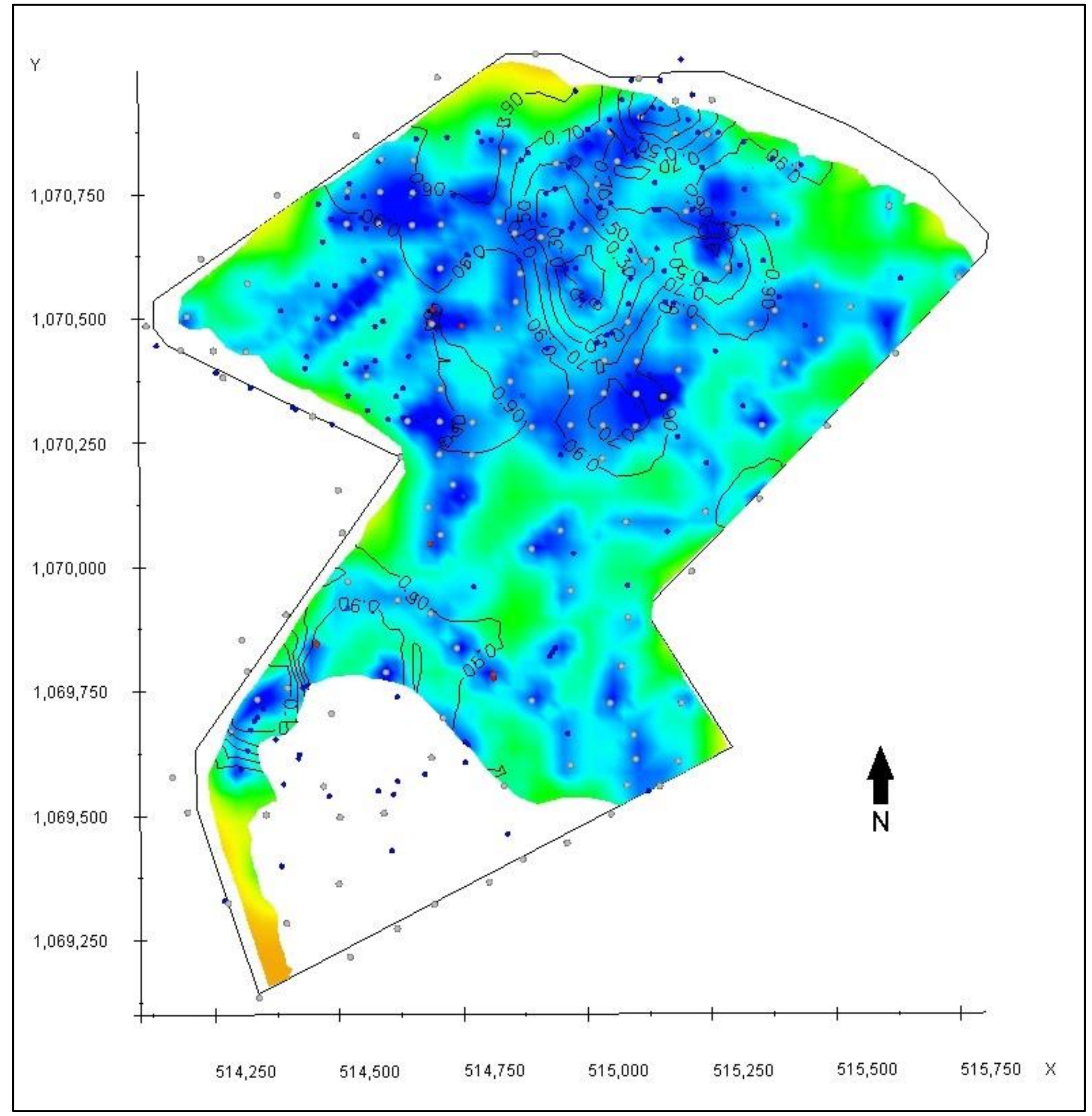
Syracuse, NY

458 ft amsl

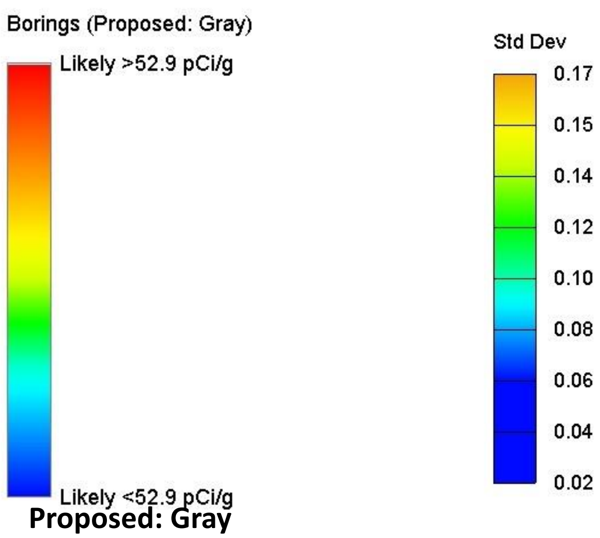
CURRENT MODEL



PROPOSED MODEL



Legend



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

Figure E-10c

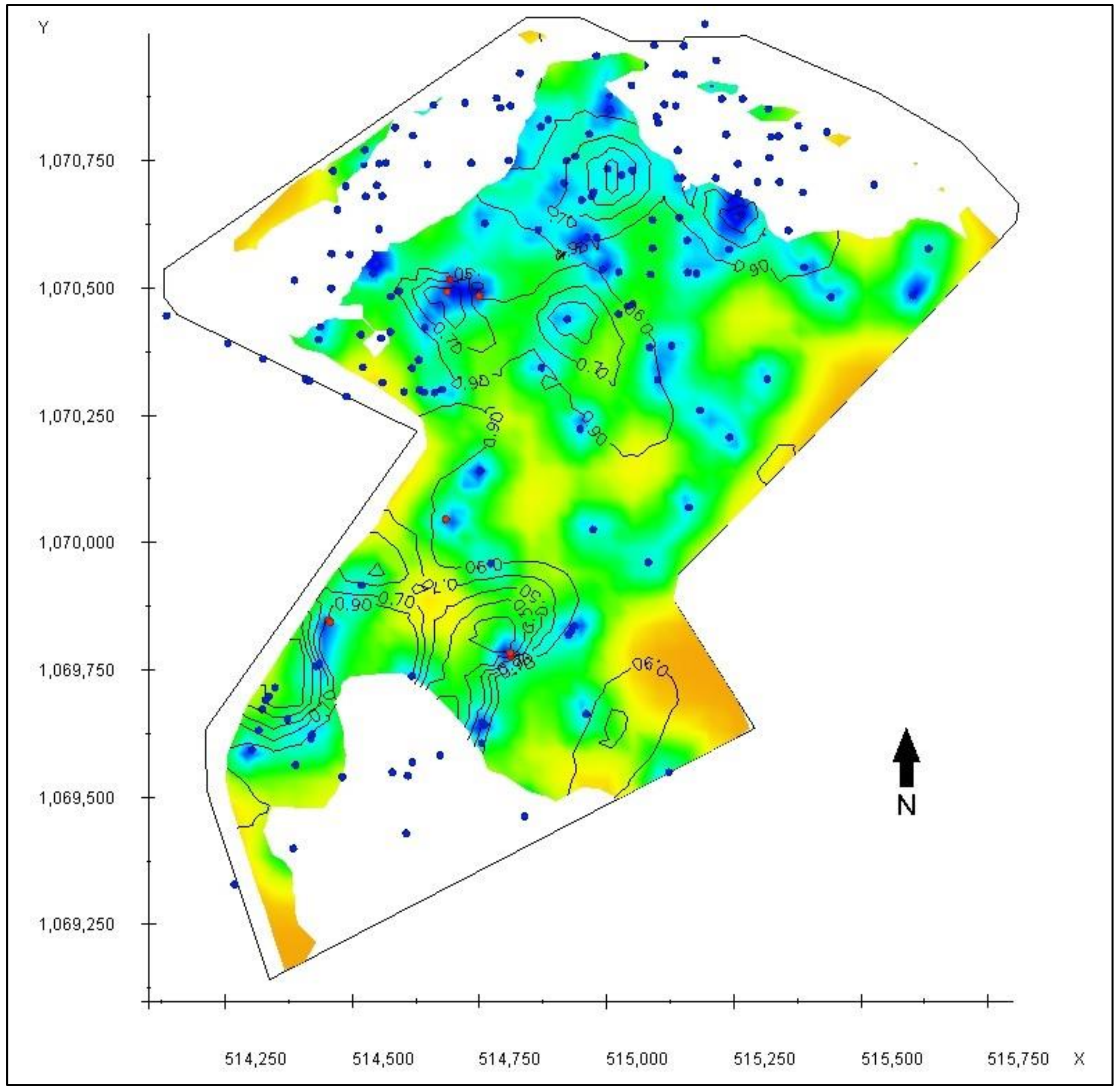
Area 2
Radium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

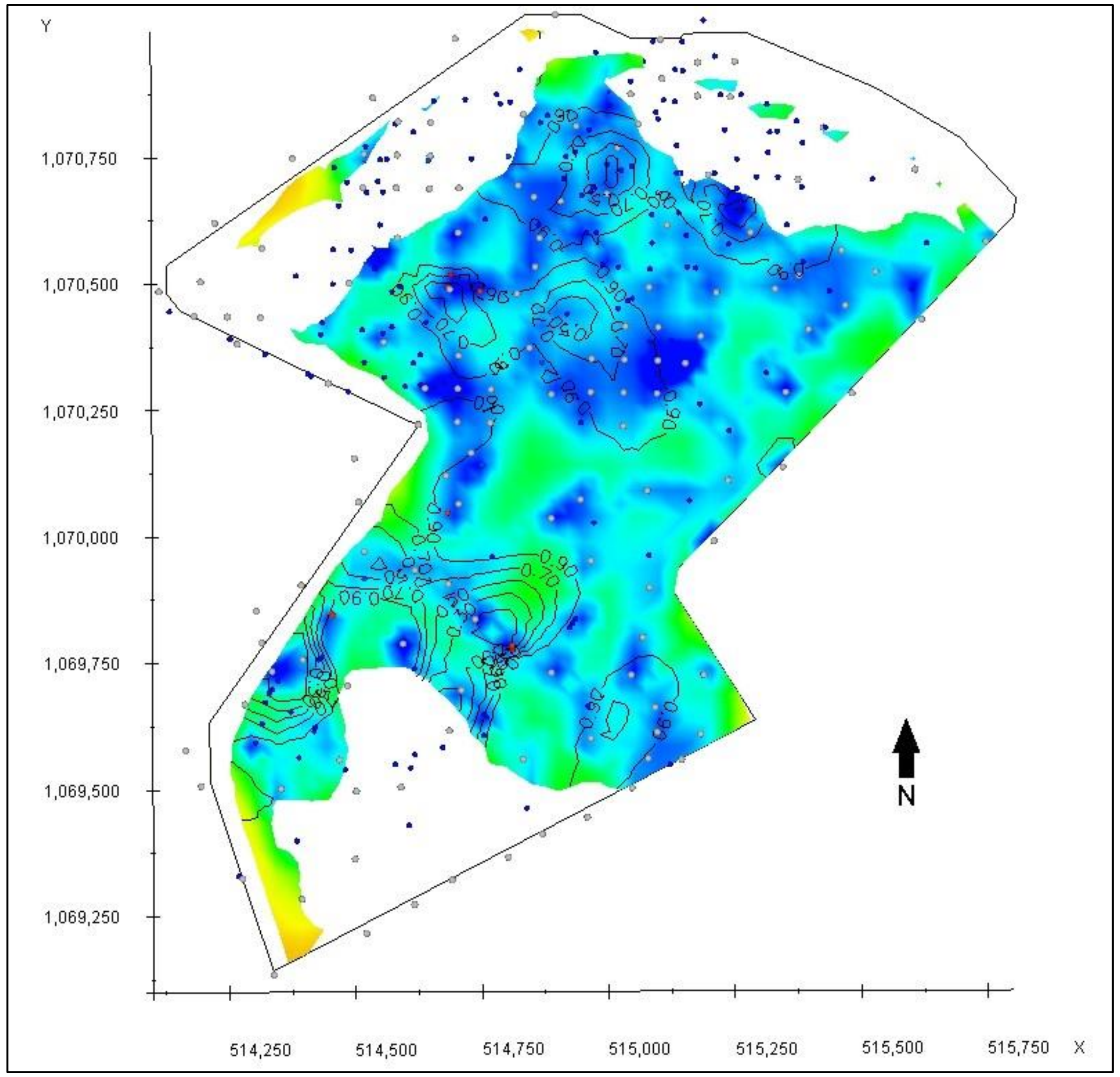
Syracuse, NY

462 ft amsl

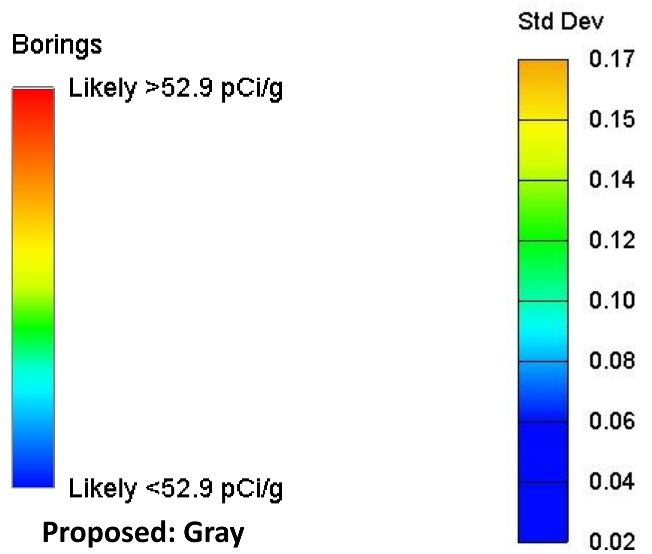
CURRENT MODEL



PROPOSED MODEL



Legend



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

Figure E-10d

Area 2
Radium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

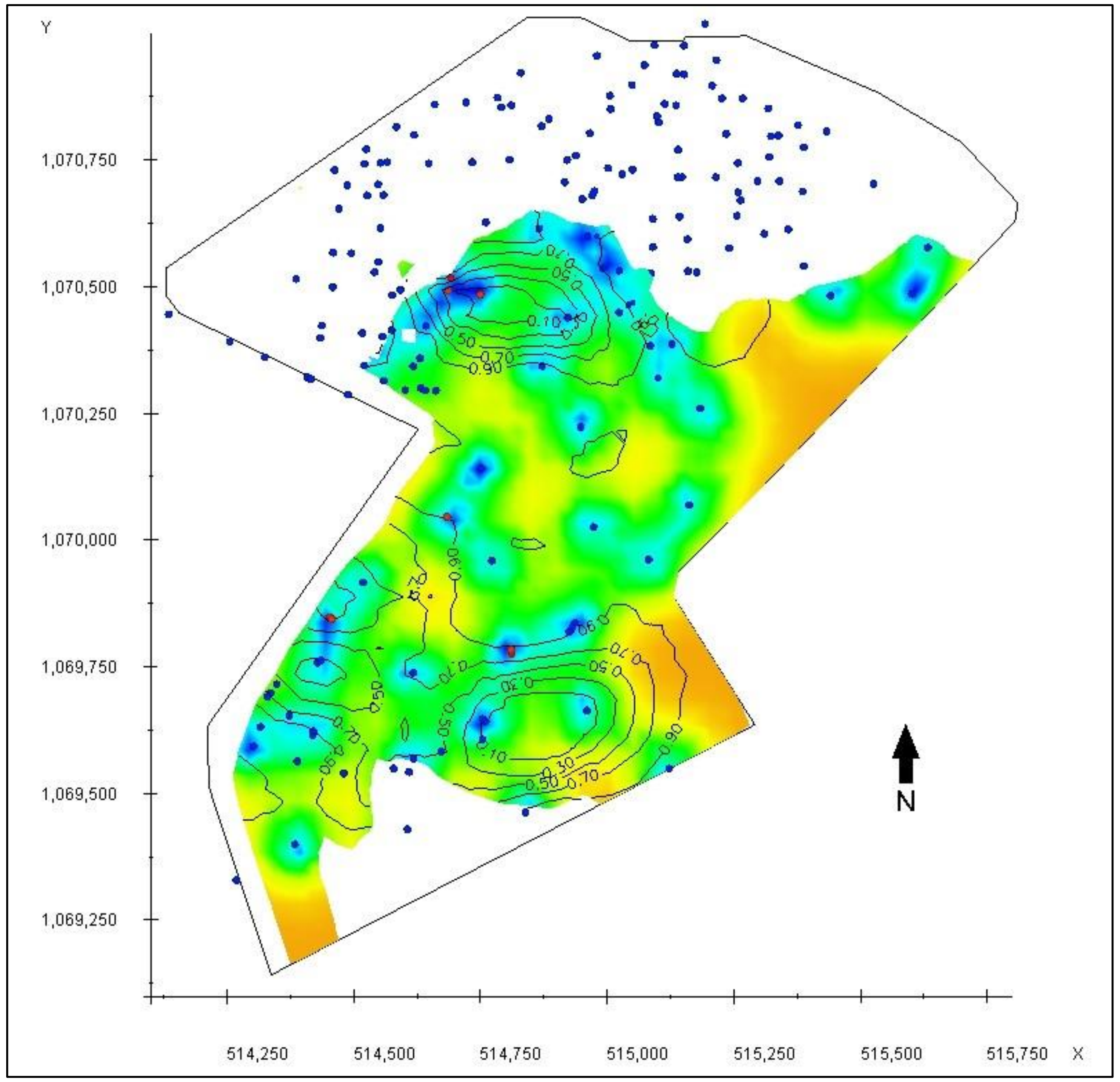
PARSONS

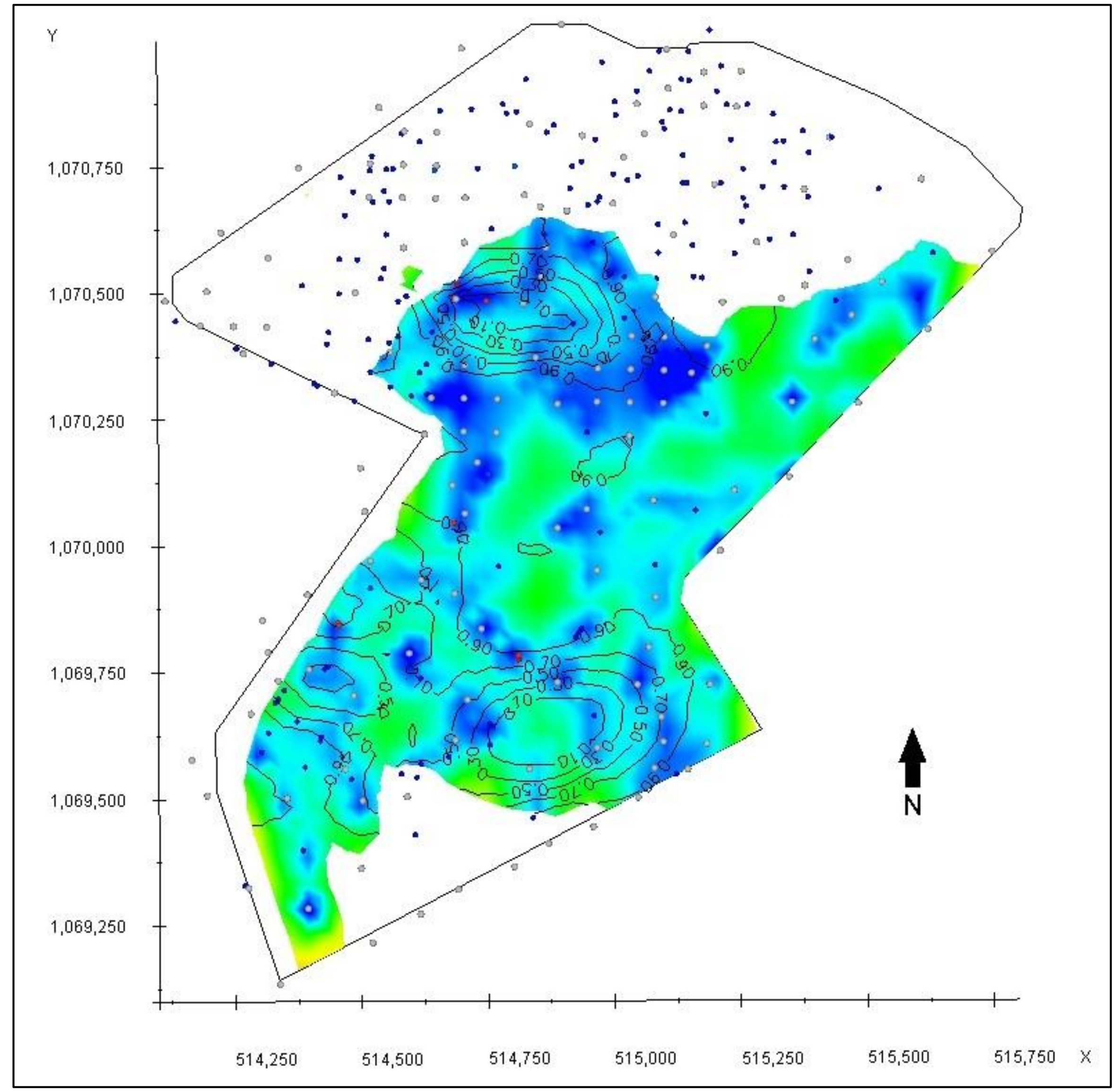
Syracuse, NY

CURRENT MODEL

466 ft amsl

PROPOSED MODEL





Legend

Borings

Likely >52.9 pCi/g

Likely <52.9 pCi/g

Proposed: Gray

Std Dev

0.17
0.15
0.14
0.12
0.10
0.08
0.06
0.04
0.02

Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

Figure E-10e

Area 2
Radium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

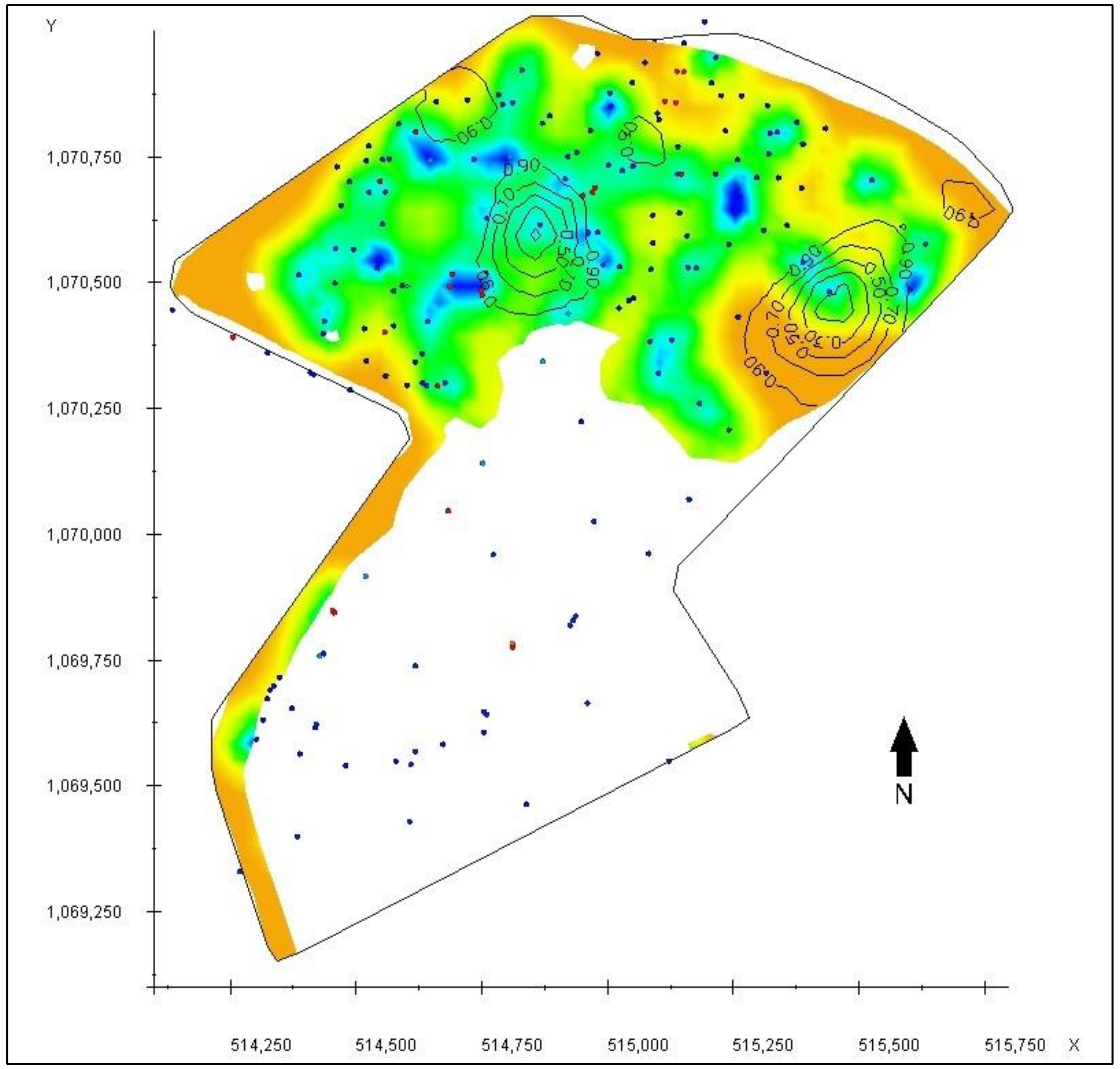
PARSONS

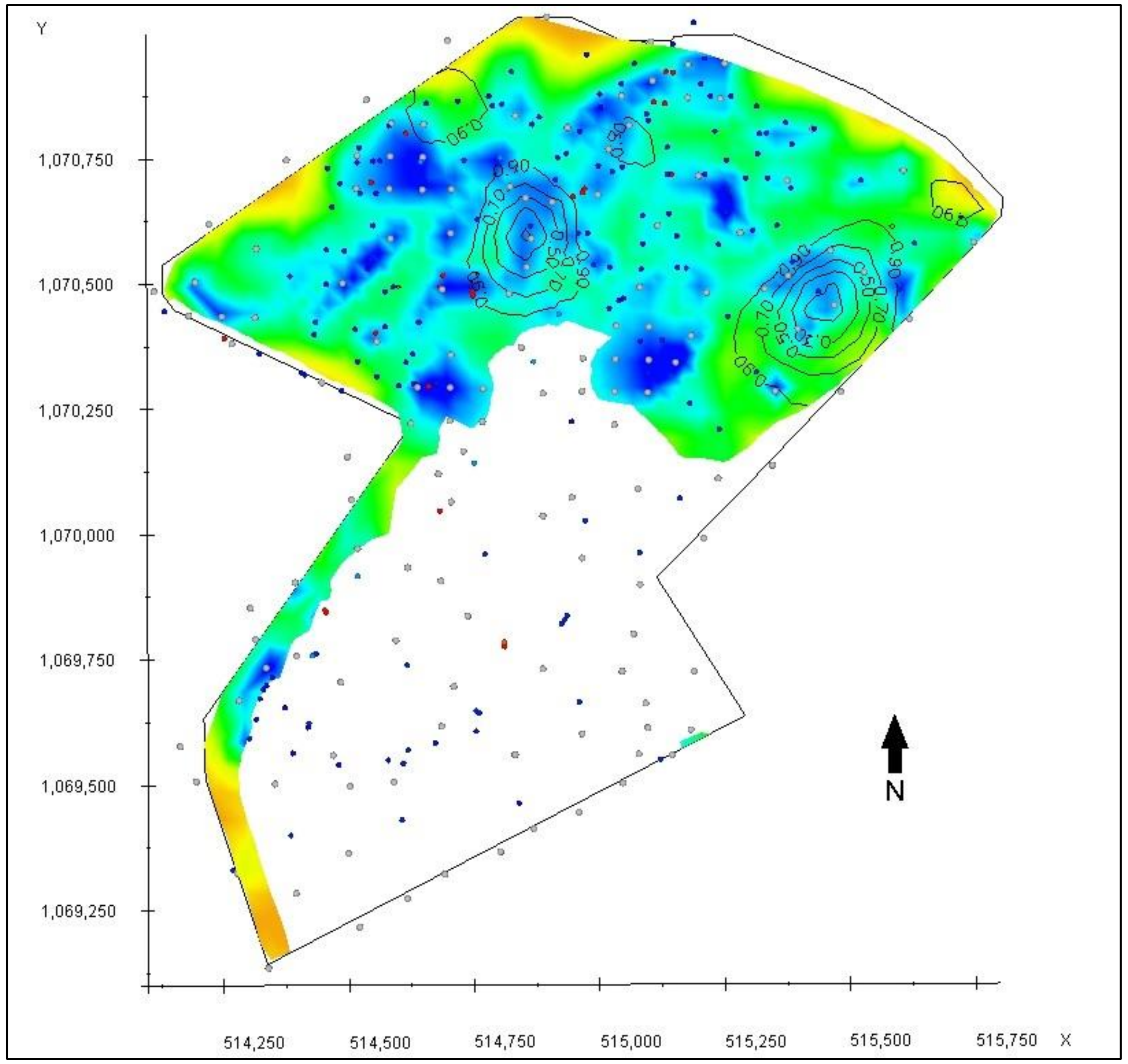
Syracuse, NY

CURRENT MODEL

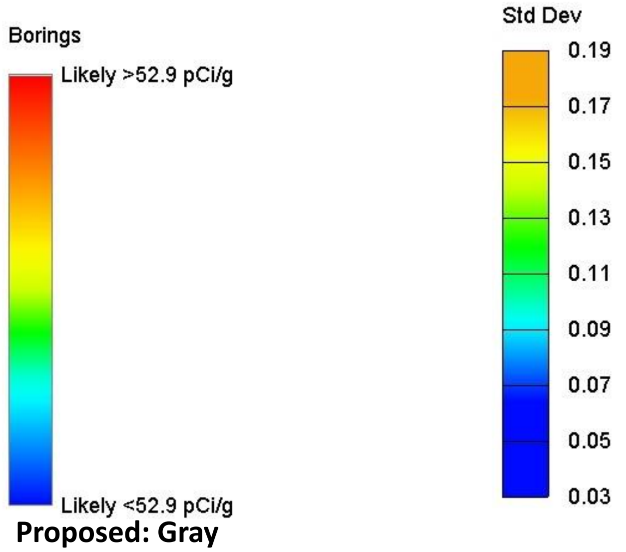
450 ft amsl

PROPOSED MODEL





Legend



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

Figure E-10f

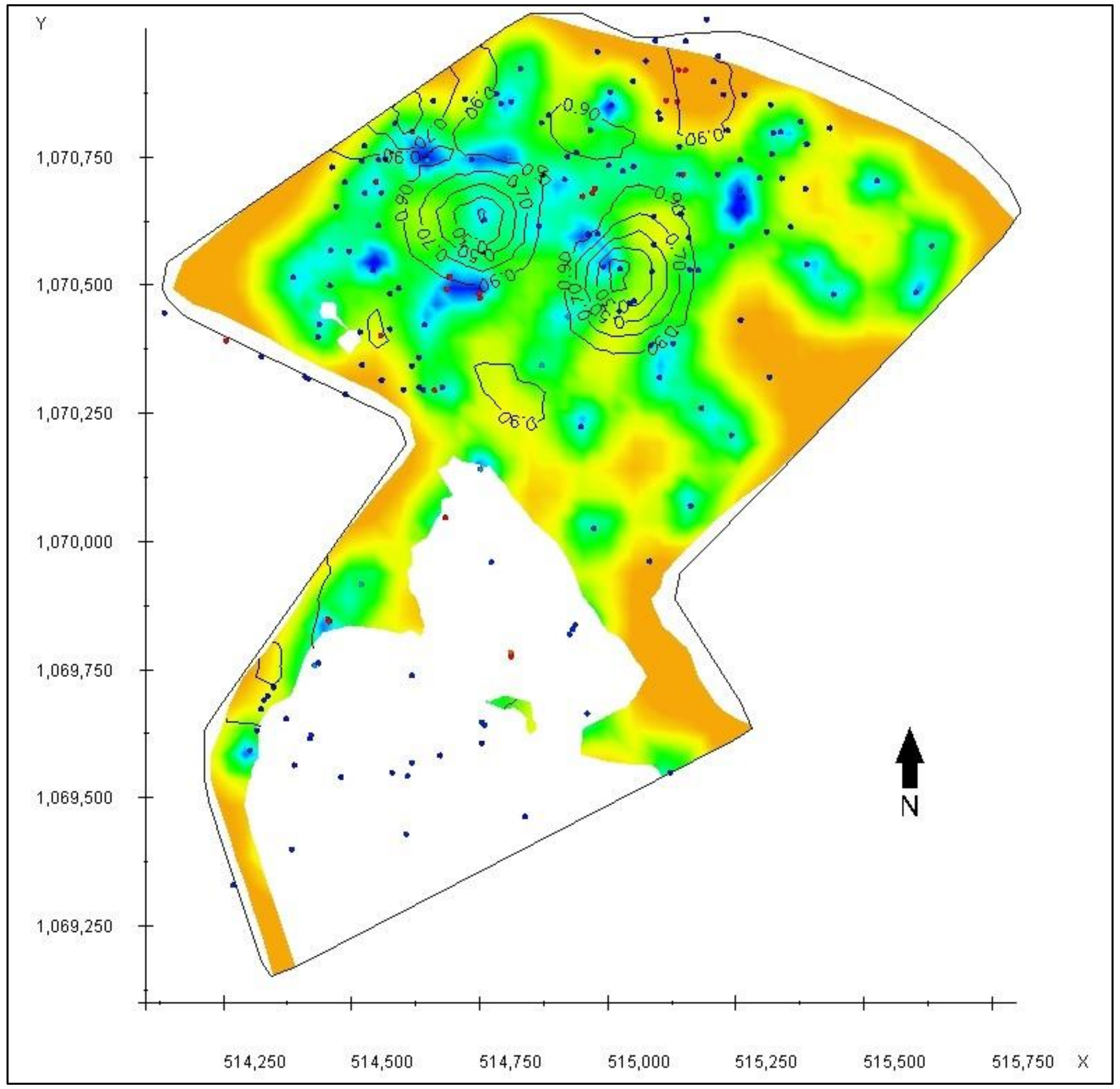
Area 2
Thorium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

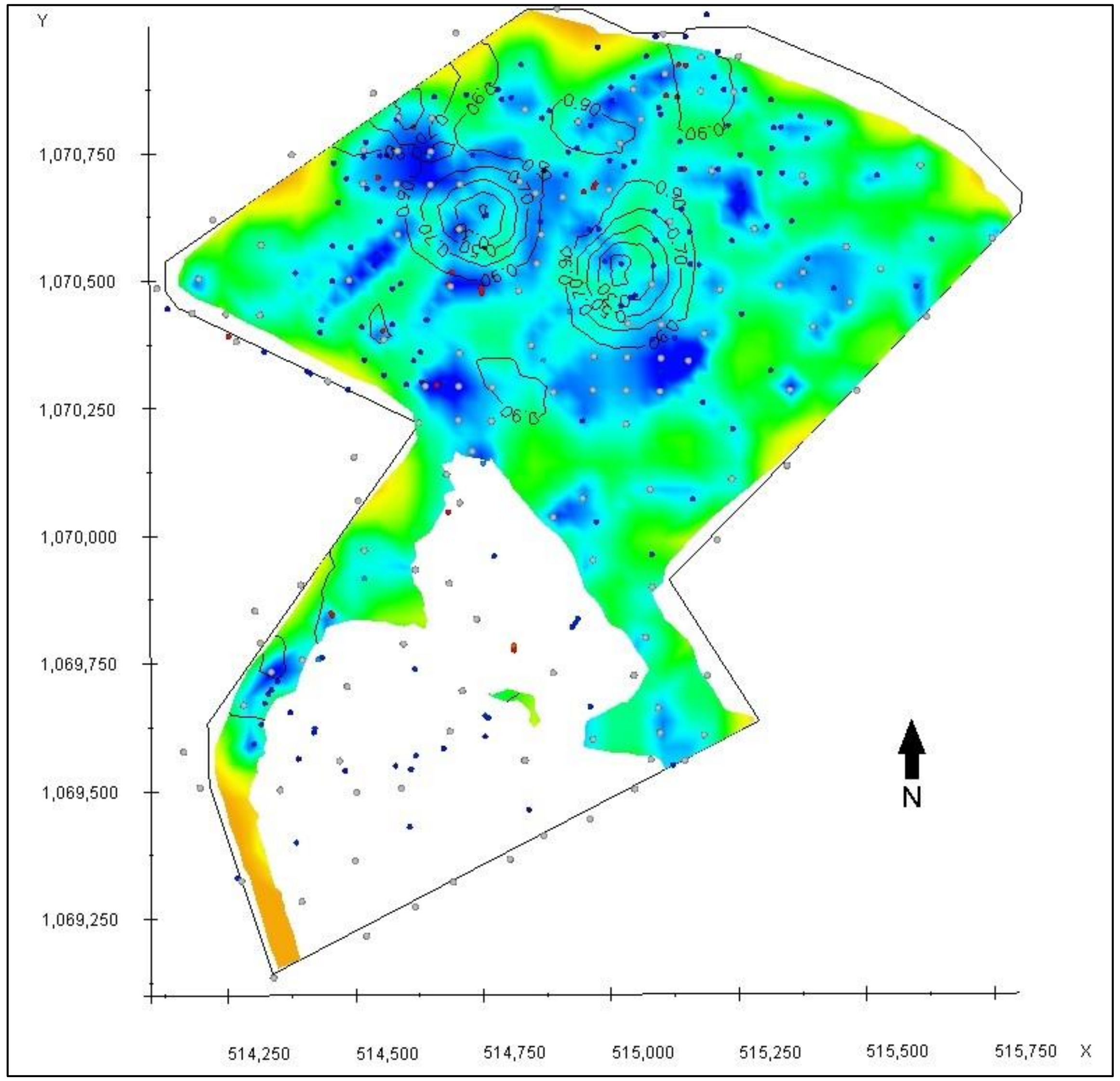
Syracuse, NY

454 ft amsl

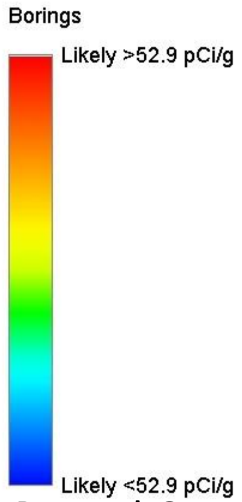
CURRENT MODEL



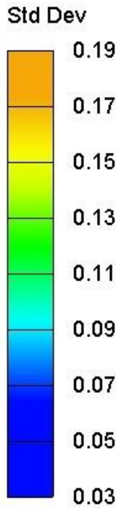
PROPOSED MODEL



Legend



Proposed: Gray



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

Figure E-10g

Area 2
Thorium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

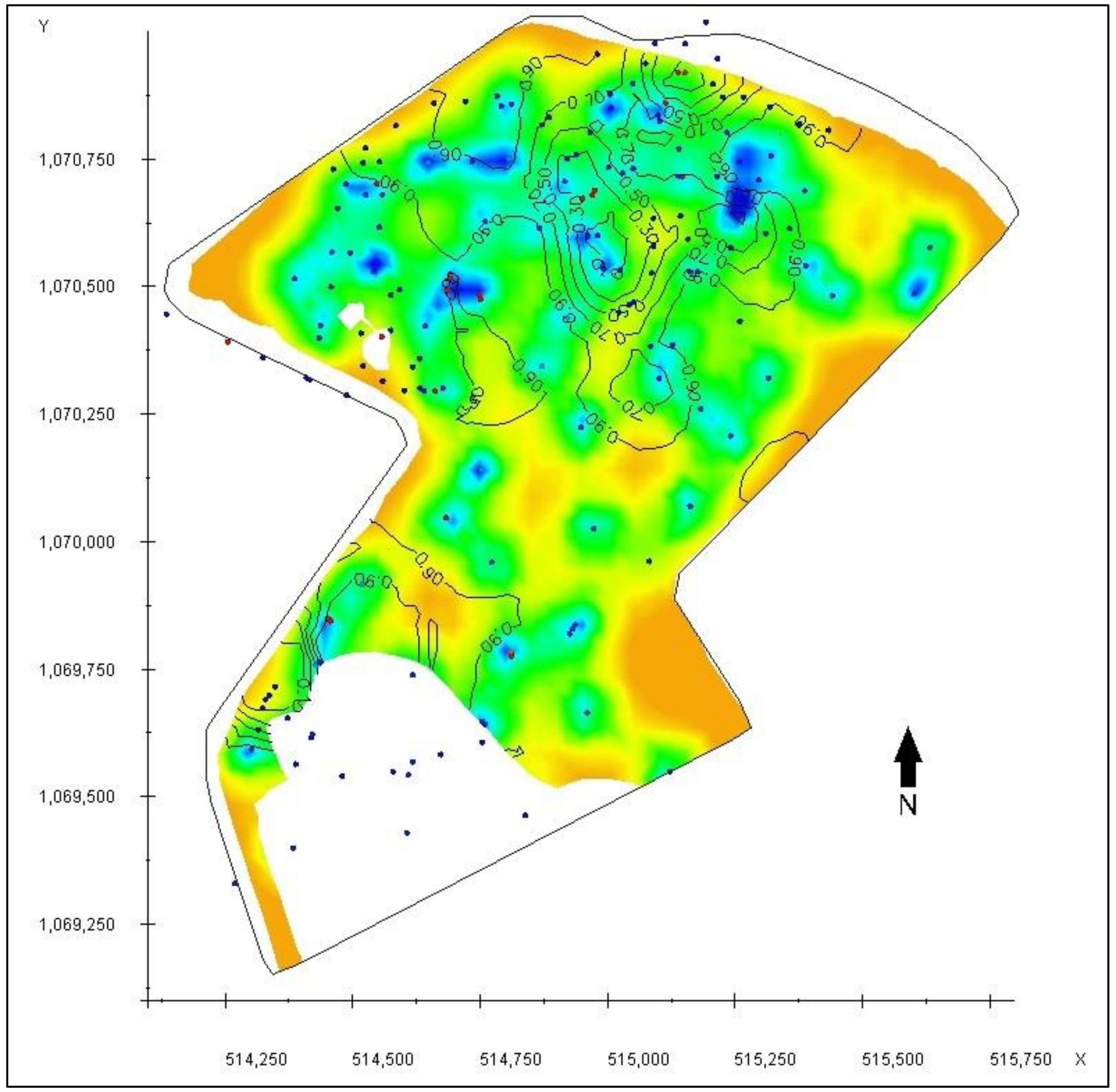
PARSONS

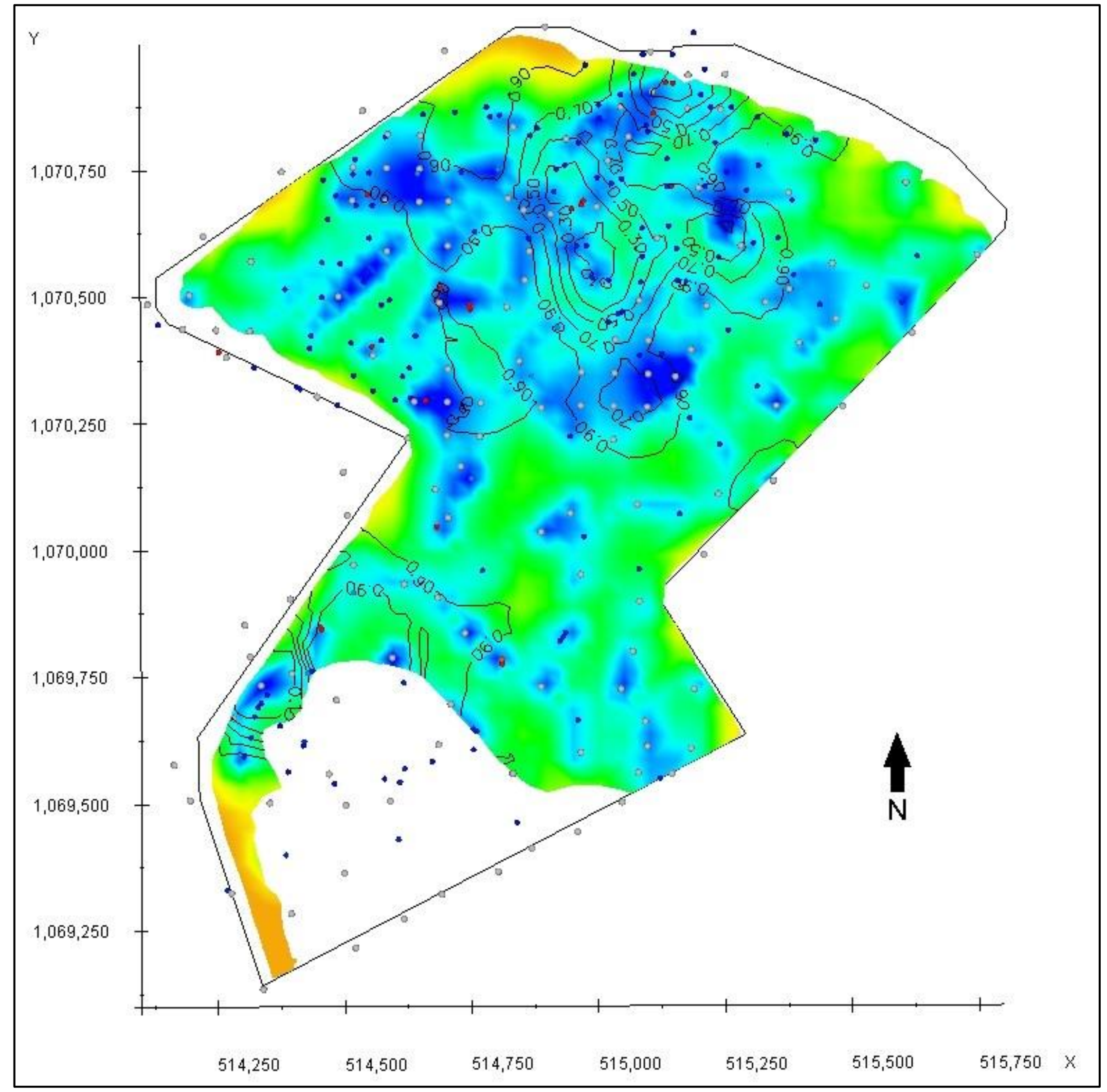
Syracuse, NY

CURRENT MODEL

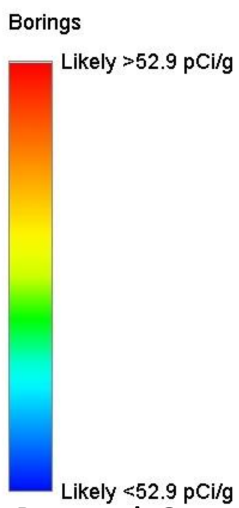
458 ft amsl

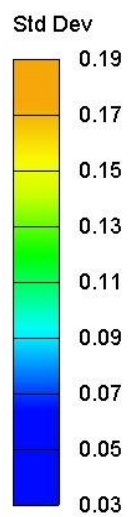
PROPOSED MODEL





Legend





Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

Figure E-10h

Area 2
Thorium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

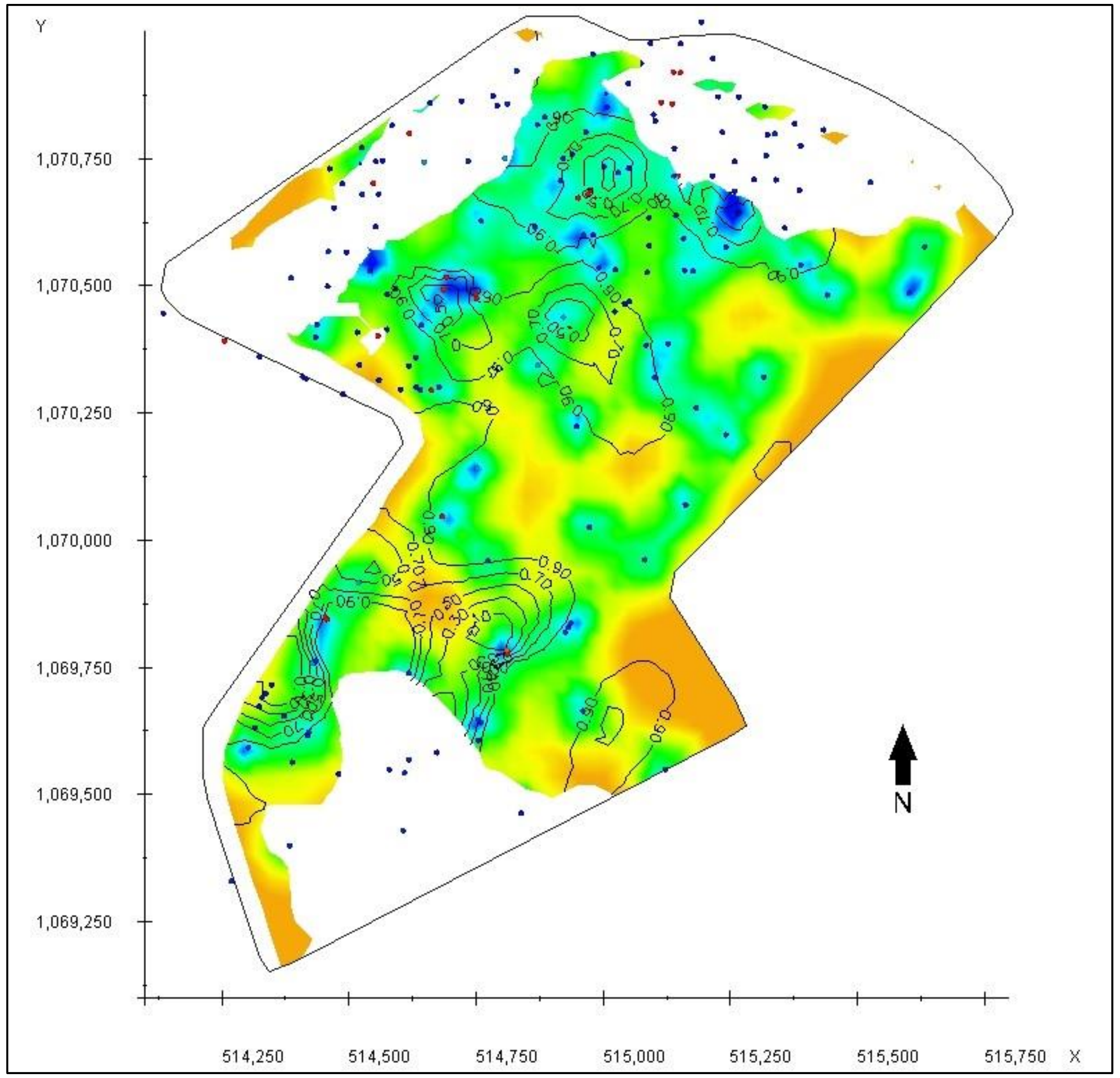
PARSONS

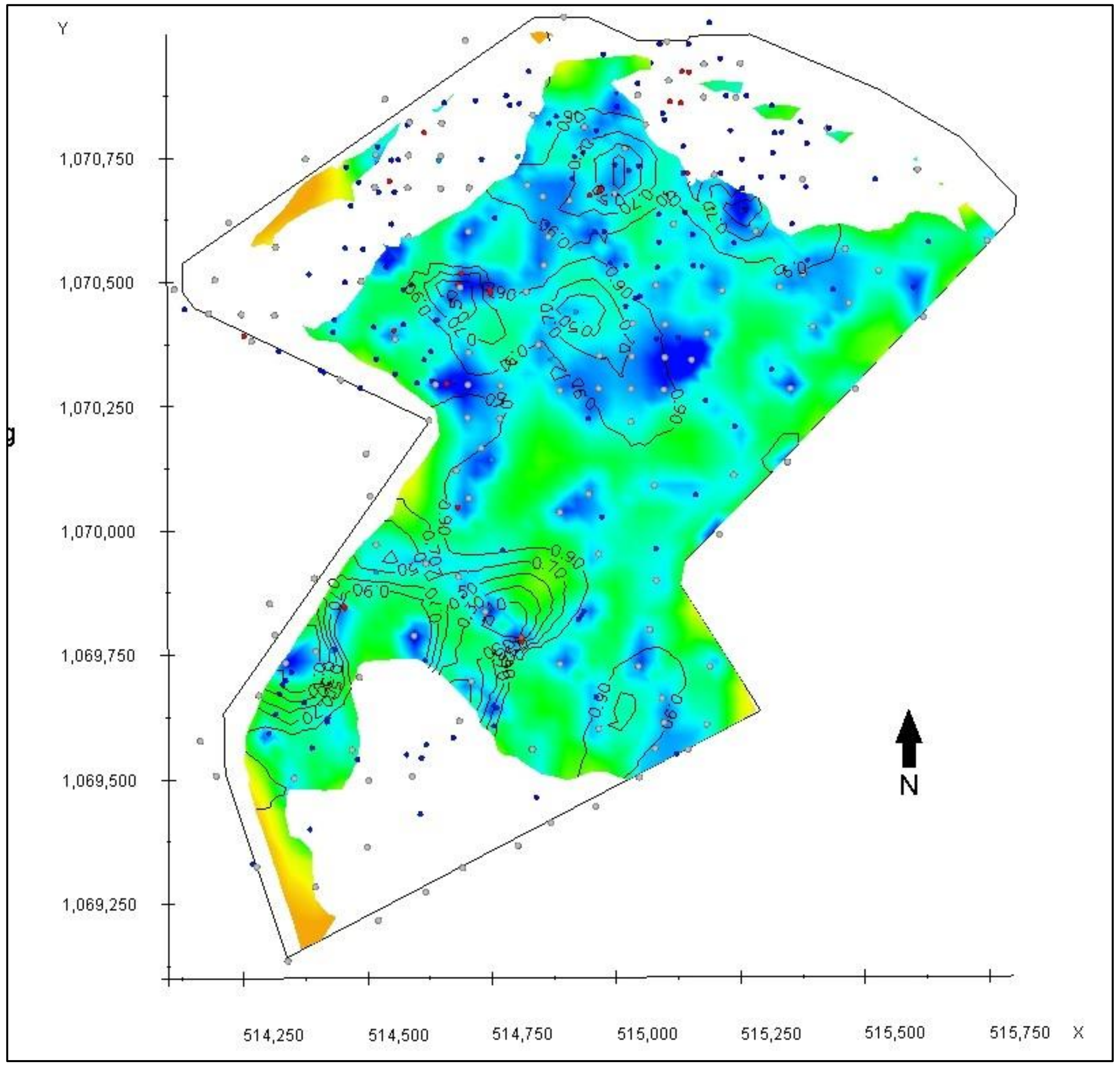
Syracuse, NY

CURRENT MODEL

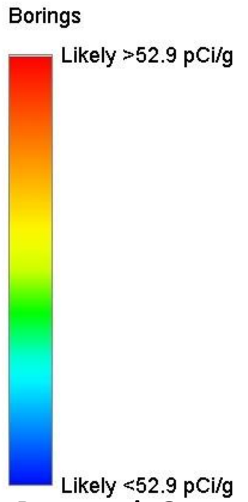
462 ft amsl

PROPOSED MODEL

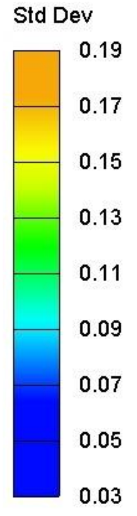




Legend



Proposed: Gray



Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

Figure E-10i

Area 2
Thorium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

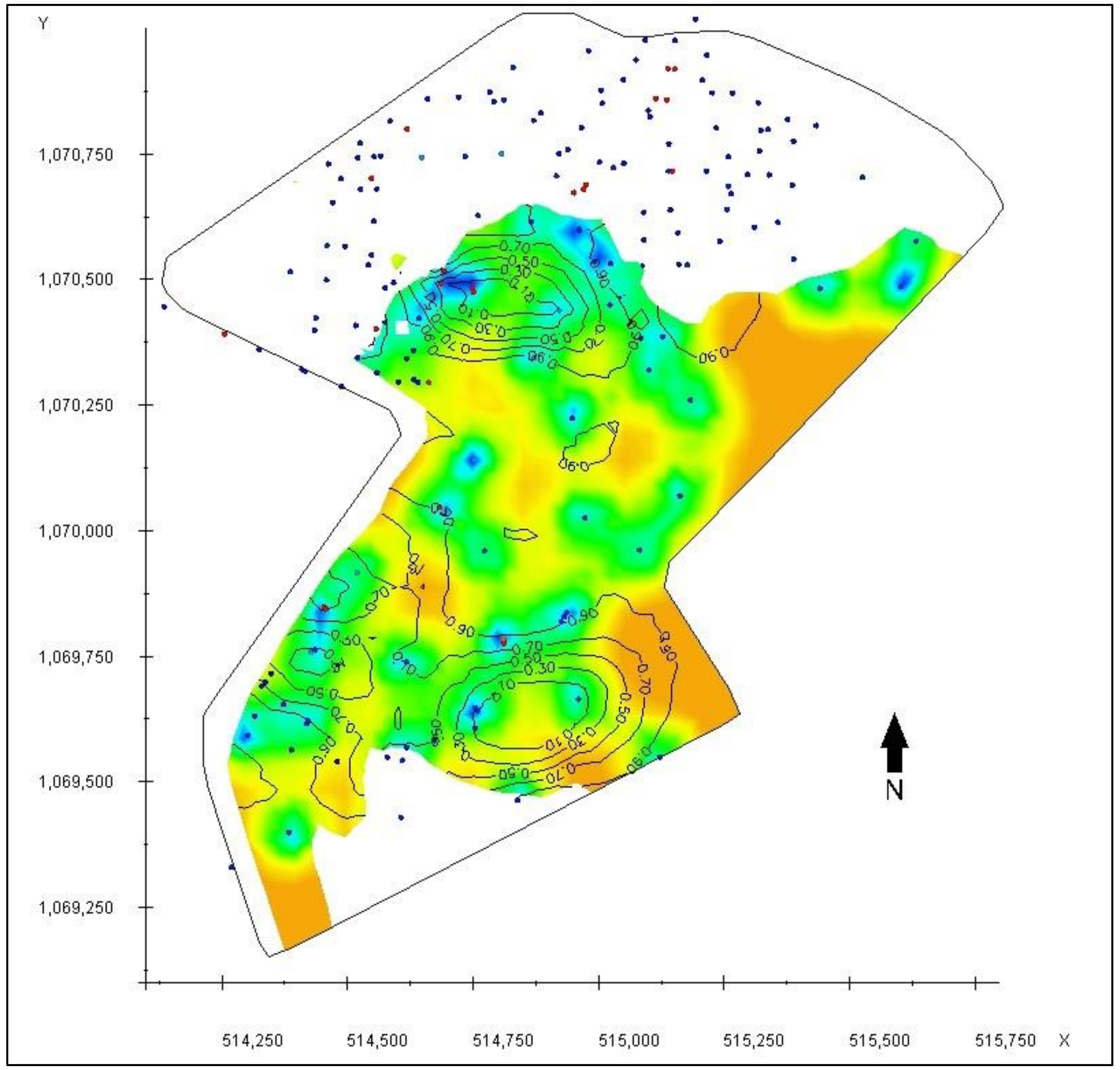
PARSONS

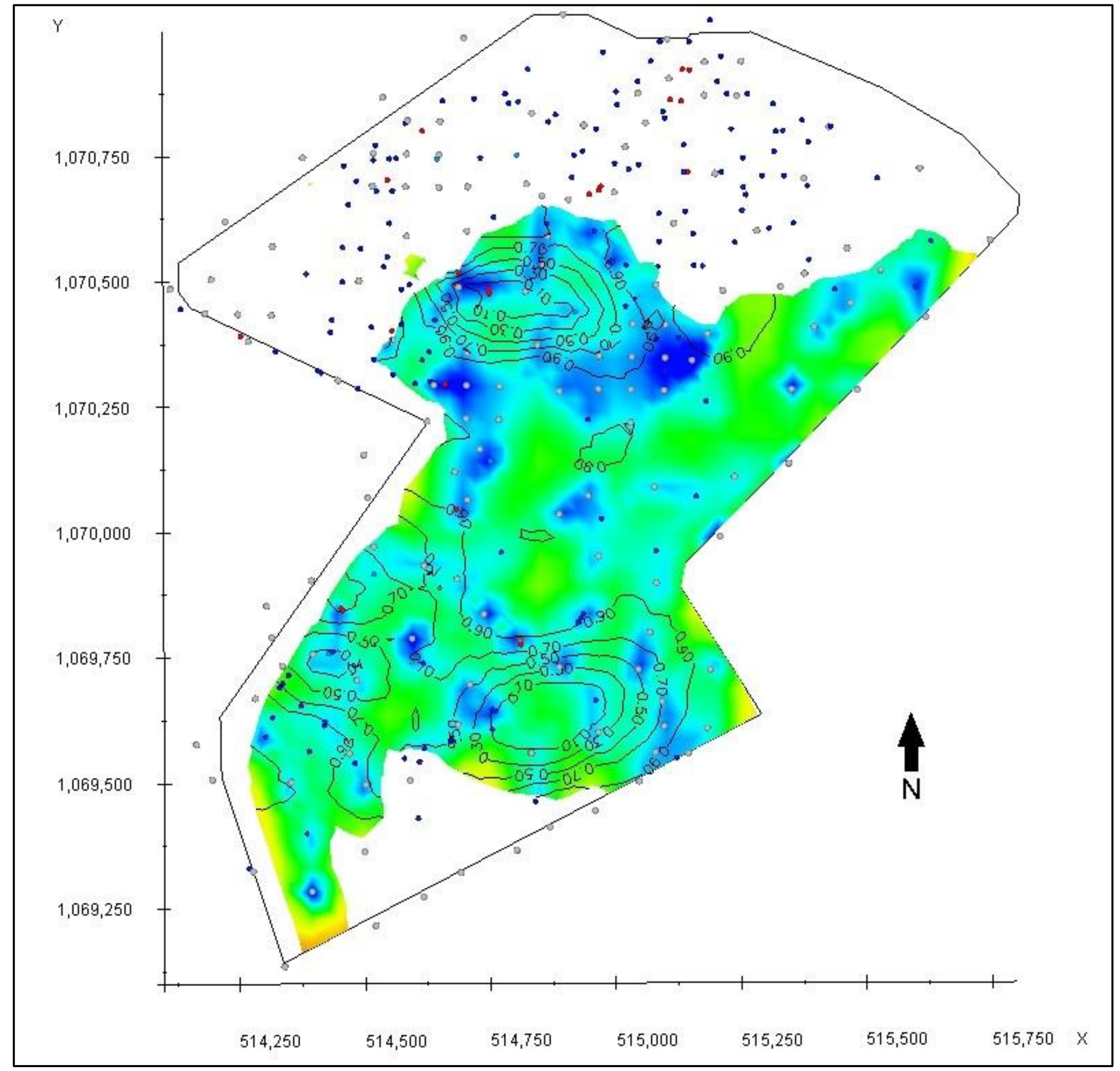
Syracuse, NY

CURRENT MODEL

466 ft amsl

PROPOSED MODEL





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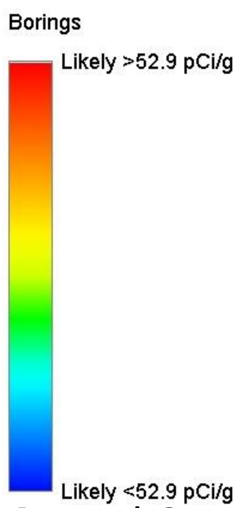
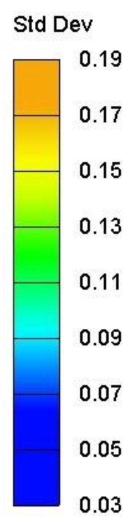




Notes:

ft amsl – feet above mean sea level
RIM – radioactive impacted material

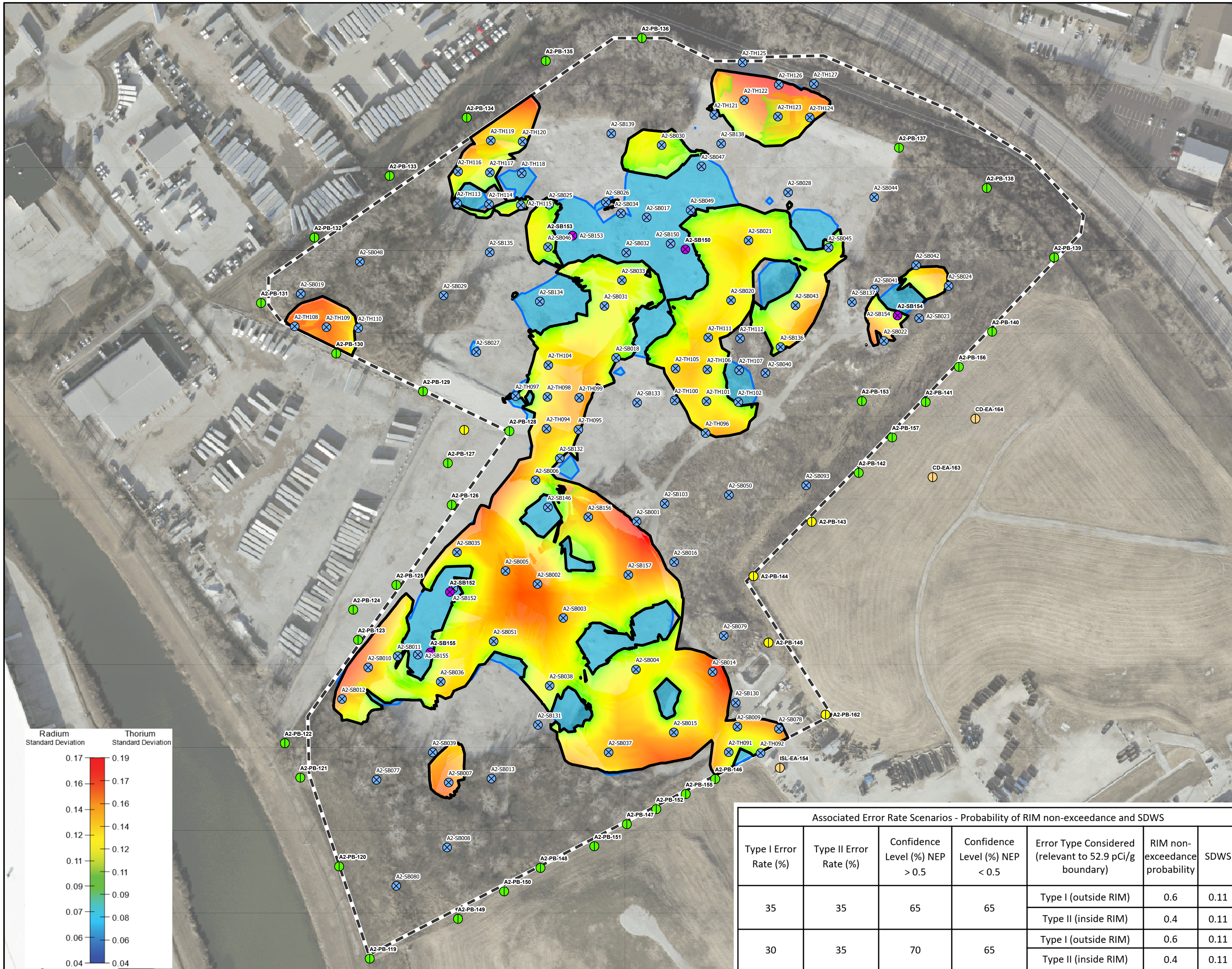
Contours displayed are probabilities of non-exceedance of RIM indicator (52.9 pCi/g), in a range of 0 to 1. Contours presented at 0.1, 0.3, 0.5, 0.7, and 0.9 for current modeled RIM (Ra+Th) extent on all images.

Figure E-10j

Area 2
Thorium Standard Deviation by Elevation – Current & Proposed
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY



Associated Error Rate Scenarios - Probability of RIM non-exceedance and SDWS						
Type I Error Rate (%)	Type II Error Rate (%)	Confidence Level (%) NEP > 0.5	Confidence Level (%) NEP < 0.5	Error Type Considered (relevant to 52.9 pCi/g boundary)	RIM non-exceedance probability	SDWS
35	35	65	65	Type I (outside RIM)	0.6	0.11
				Type II (inside RIM)	0.4	0.11
30	35	70	65	Type I (outside RIM)	0.6	0.11
				Type II (inside RIM)	0.4	0.11

Note:

Use the layer tool (left side of screen in Adobe®) to turn layers on and off. The layer label identifies the content.

See Appendix E including Attachment E-3 for further details regarding SDWS.

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings
- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- OU-1 Area Boundary

0 87.5 175 350 Feet

N

Figure E-11a

Standard Deviation Warranted to Sampling Analysis 35/35% and 30/35%

PARSONS
301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-451-9560

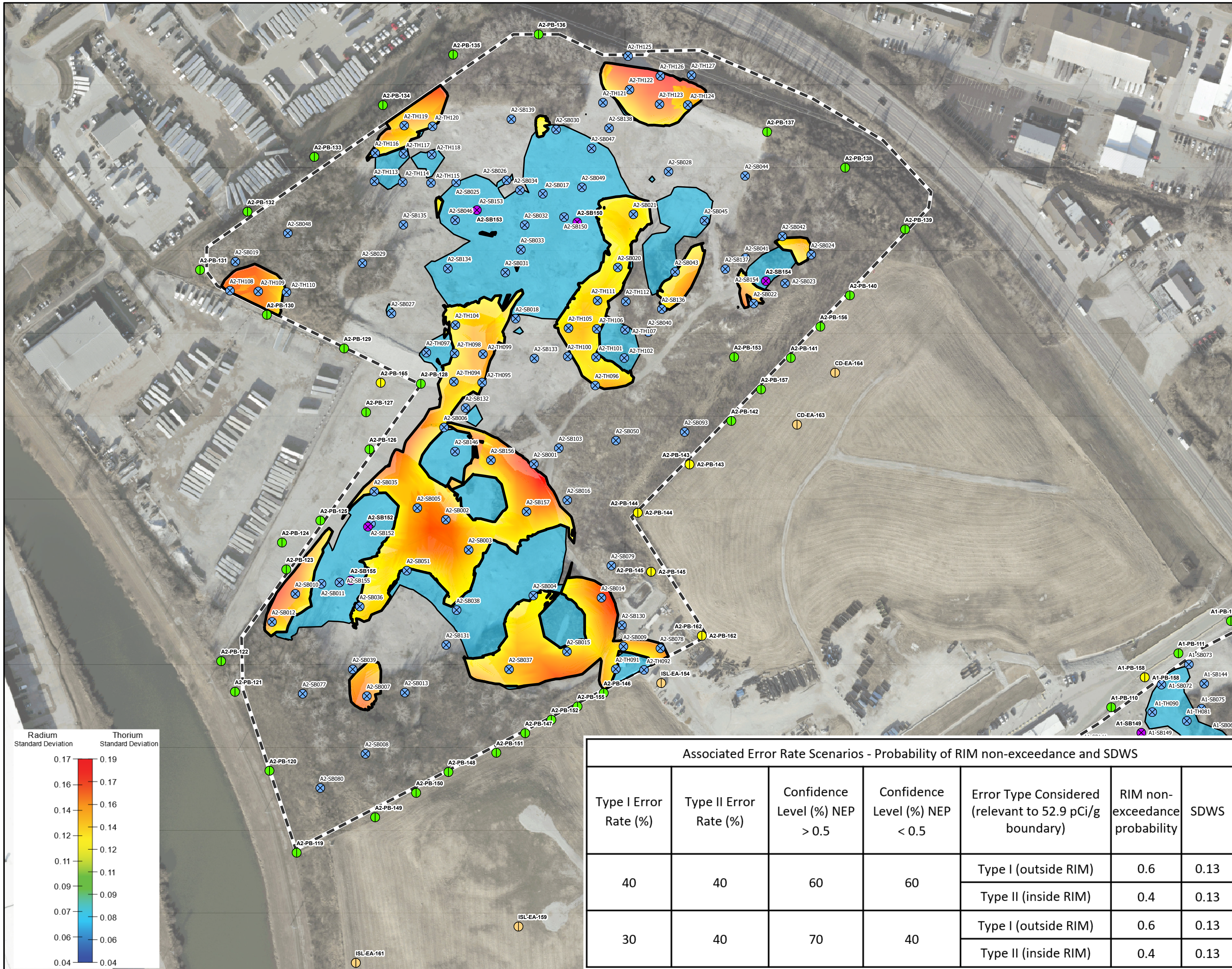
Plot Date: 9/4/2020 Plotted By: CS

Document Path: C:\Users\p002737e\Documents\West Lake\ArcMap Data\DIWP Figures\West Lake Package.aprx

Note:

Use the layer tool (left side of screen in Adobe®) to turn layers on and off. The layer label identifies the content.

See Appendix E including Attachment E-3 for further details regarding SDWS.



Associated Error Rate Scenarios - Probability of RIM non-exceedance and SDWS						
Type I Error Rate (%)	Type II Error Rate (%)	Confidence Level (%) NEP > 0.5	Confidence Level (%) NEP < 0.5	Error Type Considered (relevant to 52.9 pCi/g boundary)	RIM non-exceedance probability	SDWS
40	40	60	60	Type I (outside RIM)	0.6	0.13
				Type II (inside RIM)	0.4	0.13
30	40	70	40	Type I (outside RIM)	0.6	0.13
				Type II (inside RIM)	0.4	0.13

Proposed Borings

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings
- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- OU-1 Area Boundary

0 100 200 400 Feet

N

Figure E-11b

Standard Deviation Warranted to Sampling Analysis 40/40% and 30/40%

PARSONS
301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-451-9560

Plotted By: CS

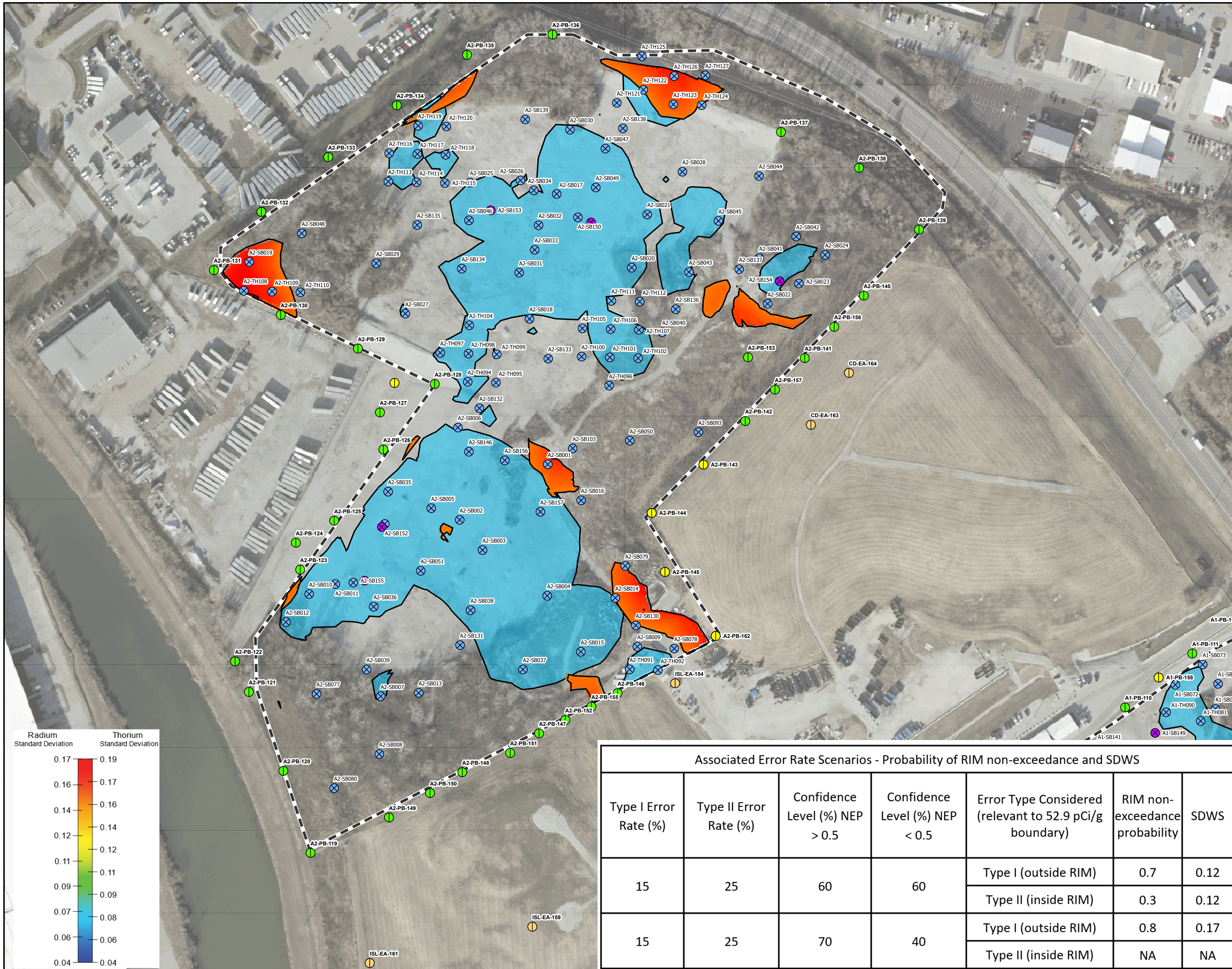
Plot Date: 9/8/2020

Document Path: C:\Users\p002737e\Documents\West Lake\ArcMap Data\DIWP Figures\West Lake Package.aprx

Note:

Use the layer tool (left side of screen in Adobe®) to turn layers on and off. The layer label identifies the content.

See Appendix E including Attachment E-3 for further details regarding SDWS.



Proposed Borings

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings
- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- OU-1 Area Boundary

0 100 200 400 Feet

N

Associated Error Rate Scenarios - Probability of RIM non-exceedance and SDWS						
Type I Error Rate (%)	Type II Error Rate (%)	Confidence Level (%) NEP > 0.5	Confidence Level (%) NEP < 0.5	Error Type Considered (relevant to 52.9 pCi/g boundary)	RIM non-exceedance probability	SDWS
15	25	60	60	Type I (outside RIM)	0.7	0.12
				Type II (inside RIM)	0.3	0.12
15	25	70	40	Type I (outside RIM)	0.8	0.17
				Type II (inside RIM)	NA	NA

Figure E-11c

Standard Deviation Warranted to Sampling Analysis 15/25%

PARSONS
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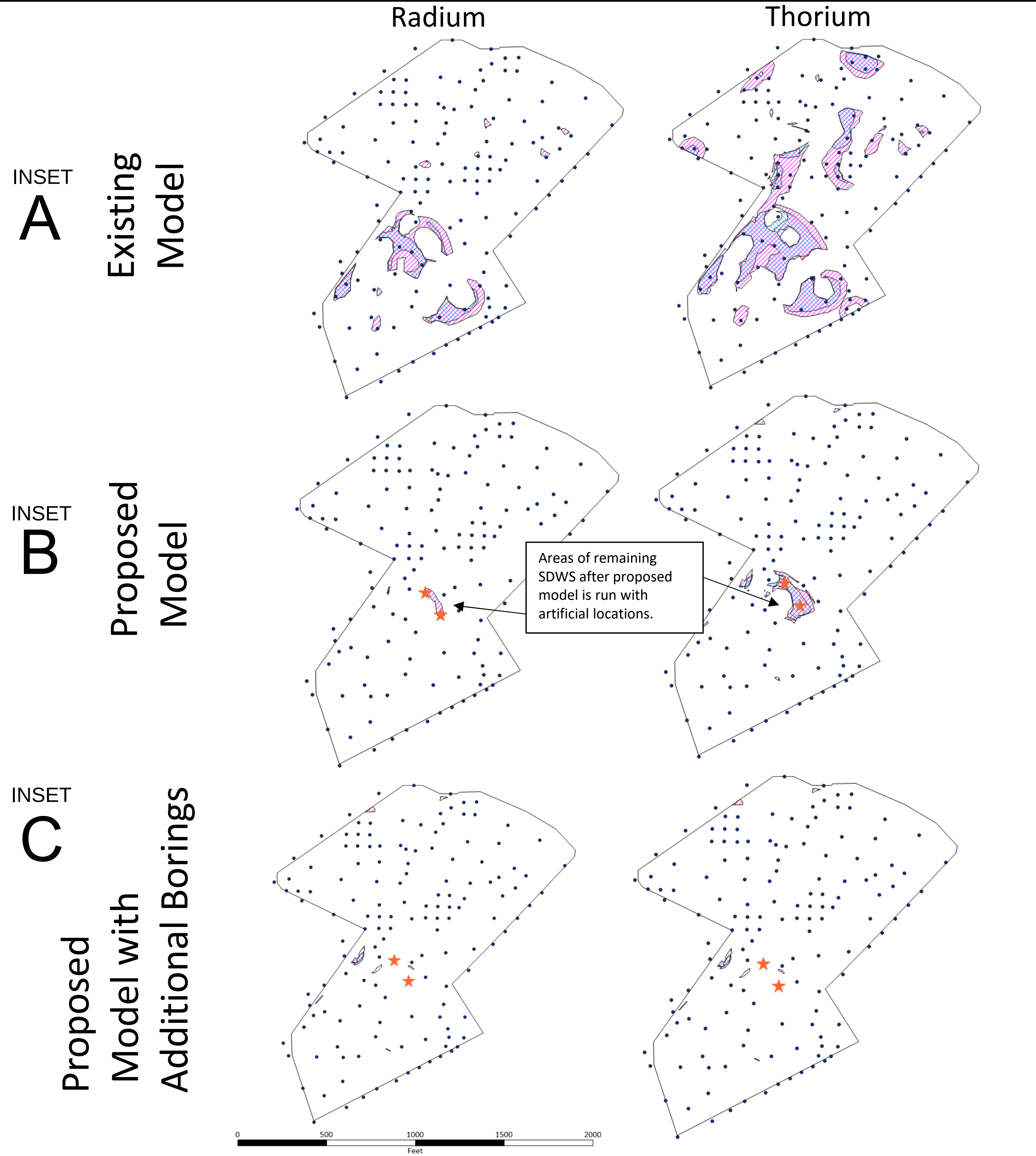

Non-exceedance probability = 0.4

Non-exceedance probability = 0.6

Proposed Boring Locations

Additional Proposed Boring Locations for SDWS

FIGURE E-11d

70/60% Type I/Type II Confidence Intervals - Additional Boring Locations to Assess SDWS

PARSONS
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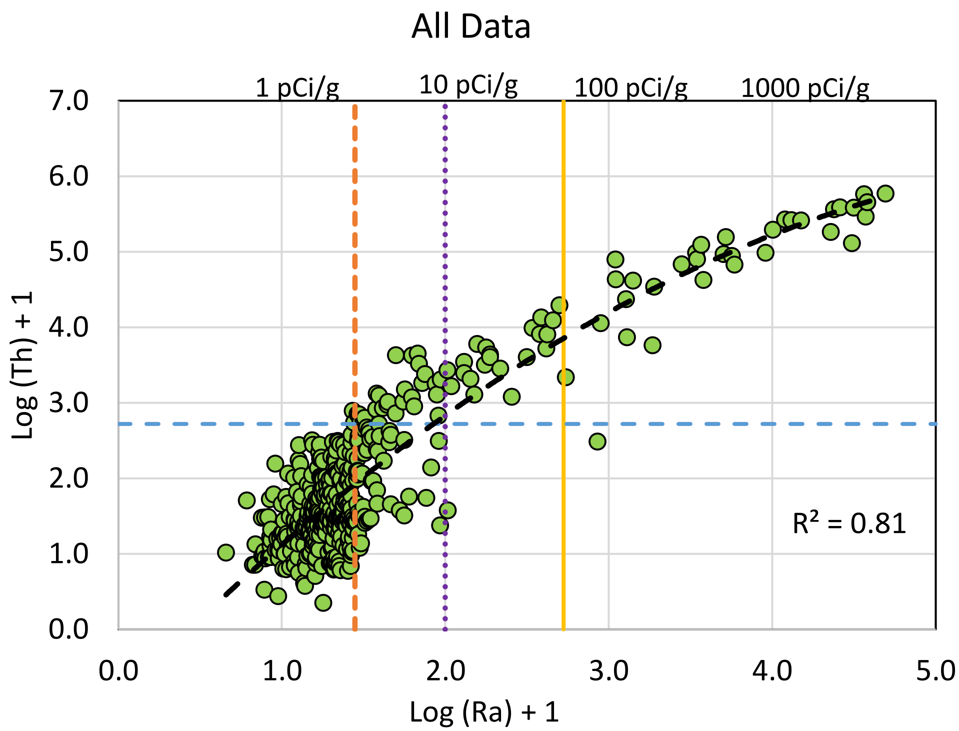
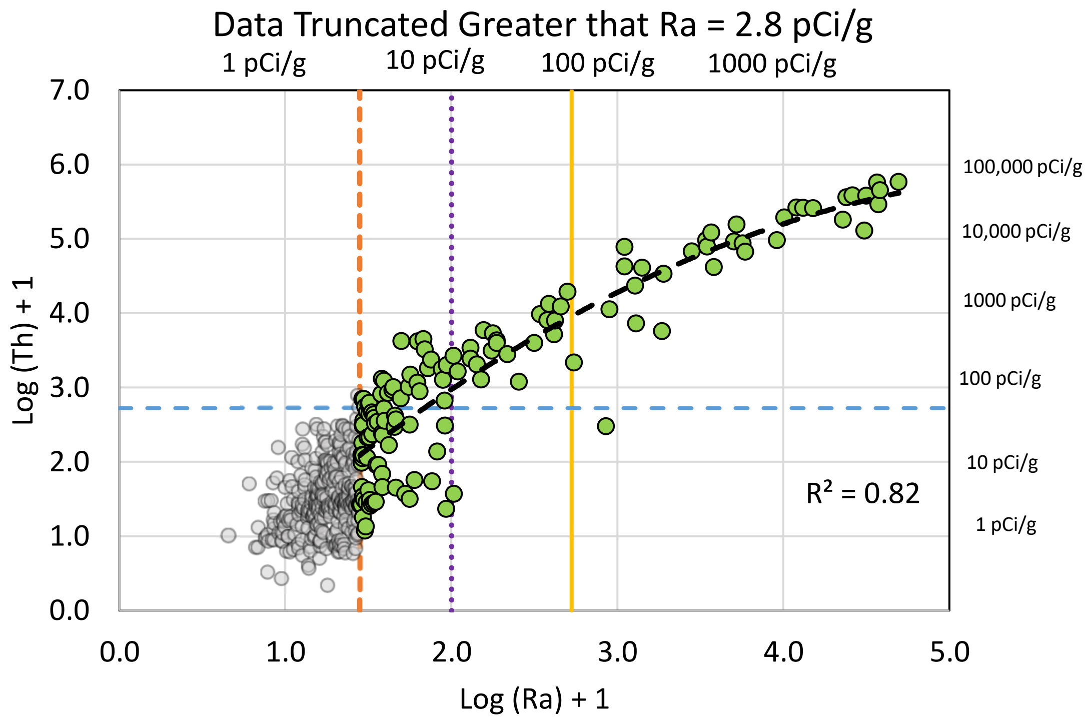
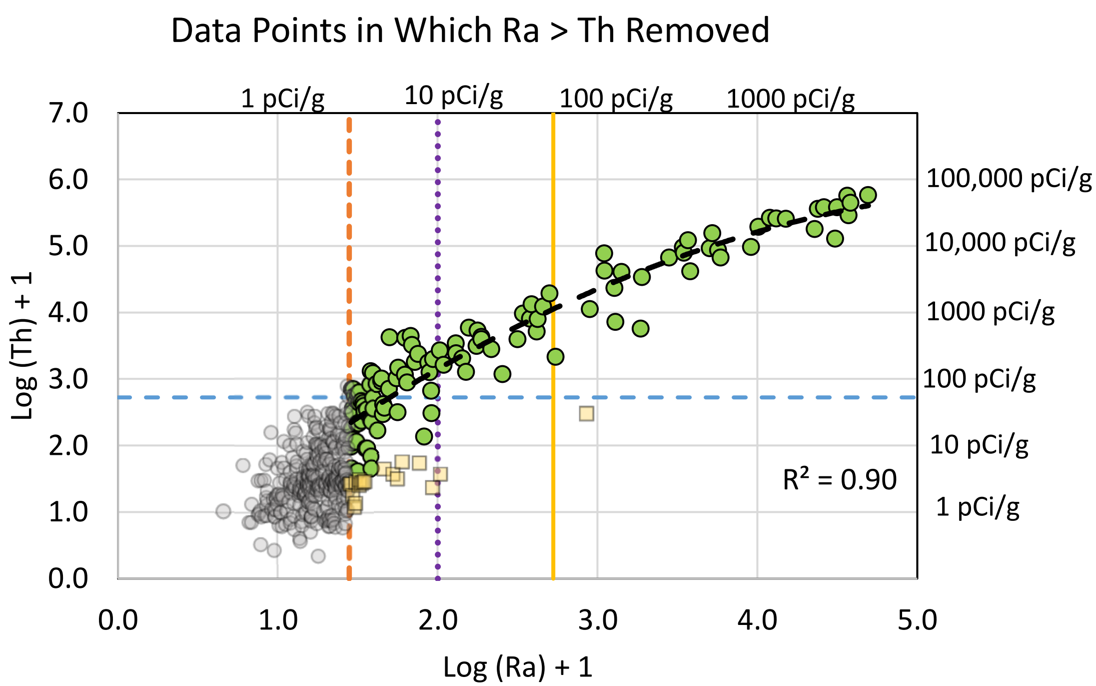
Thorium Quantification Analysis – Combined Radium vs Combined Thorium







- Log(Th) and Log(Ra) Data
- Th and Ra data below 2.8
- Data in which Th value is > Ra
- Ra = 10 pCi/g
- Ra = 52.9 pCi/g
- Th = 52.9 pCi/g
- Ra = 2.8 pCi/g

Notes:
Data is the log of Ra and Th concentrations (pCi/g) offset by 1
Quadratic fit is not meant to be quantitative, but for R^2 estimation

FIGURE E-12

Thorium Approximate Quantification Limit Analysis - Thorium Versus Radium

PARSONS
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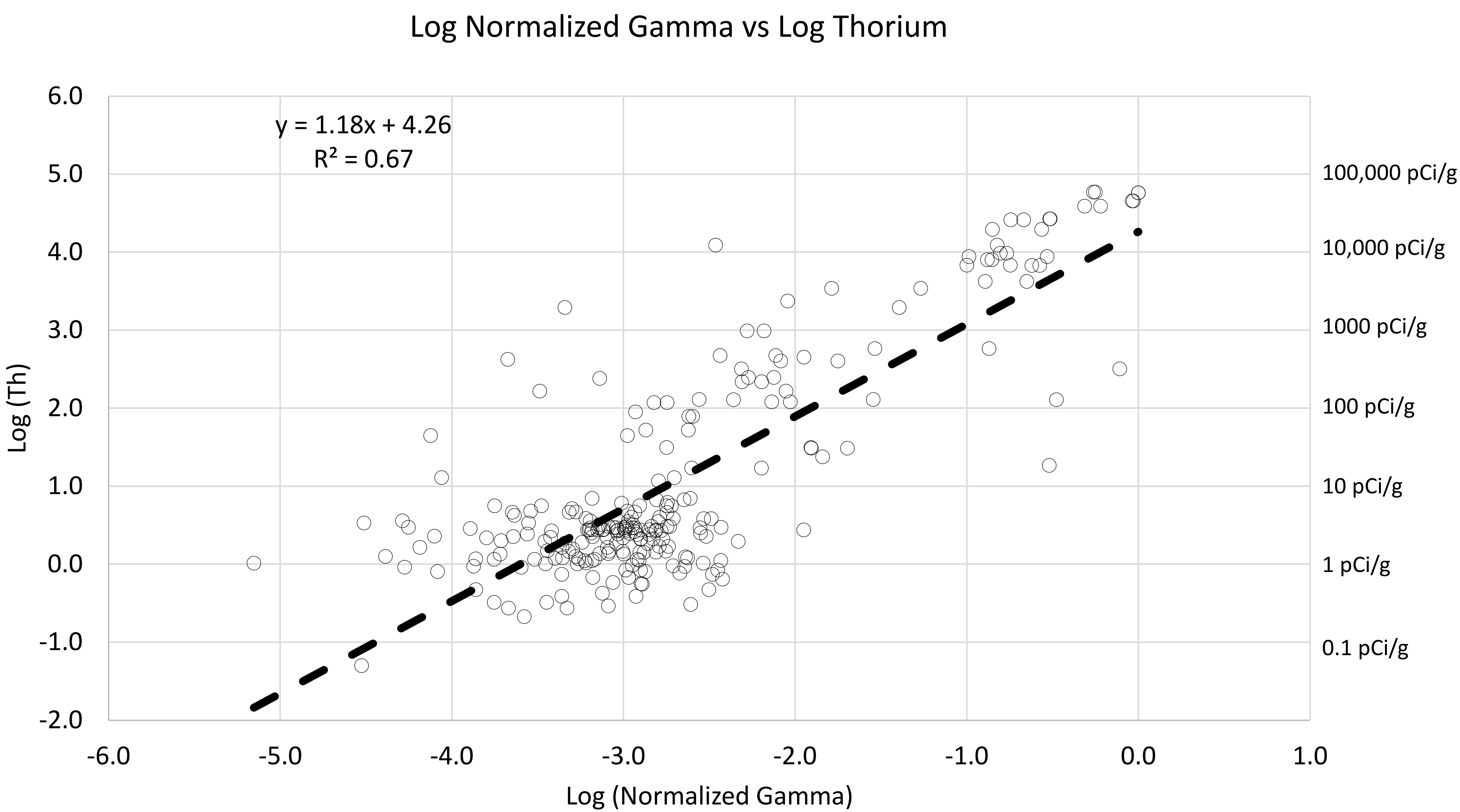


FIGURE E-13

Thorium Approximate
Quantification Limit Analysis
Core & Borehole – Combined Thorium

PARSONS
301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-431-9560

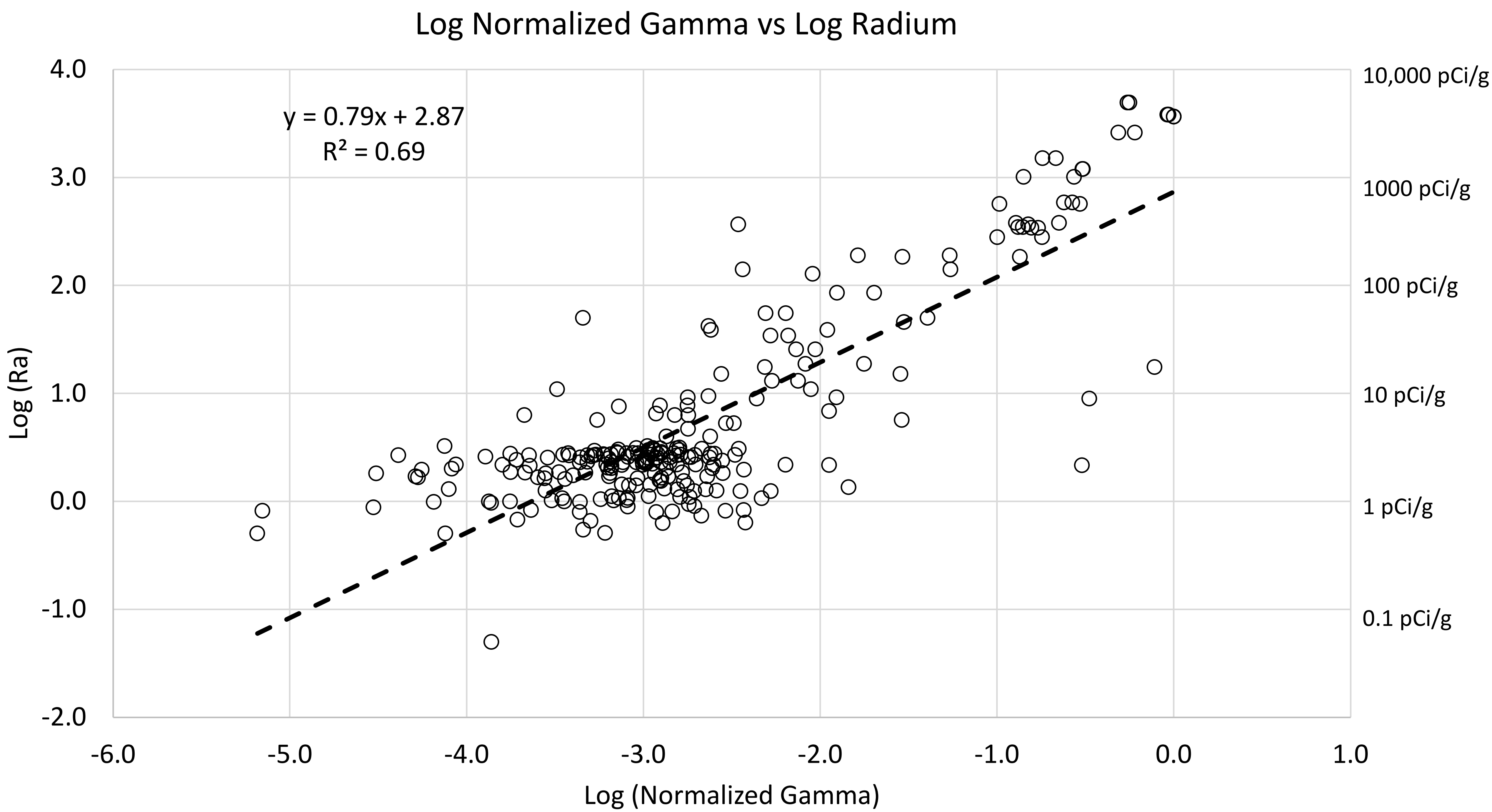


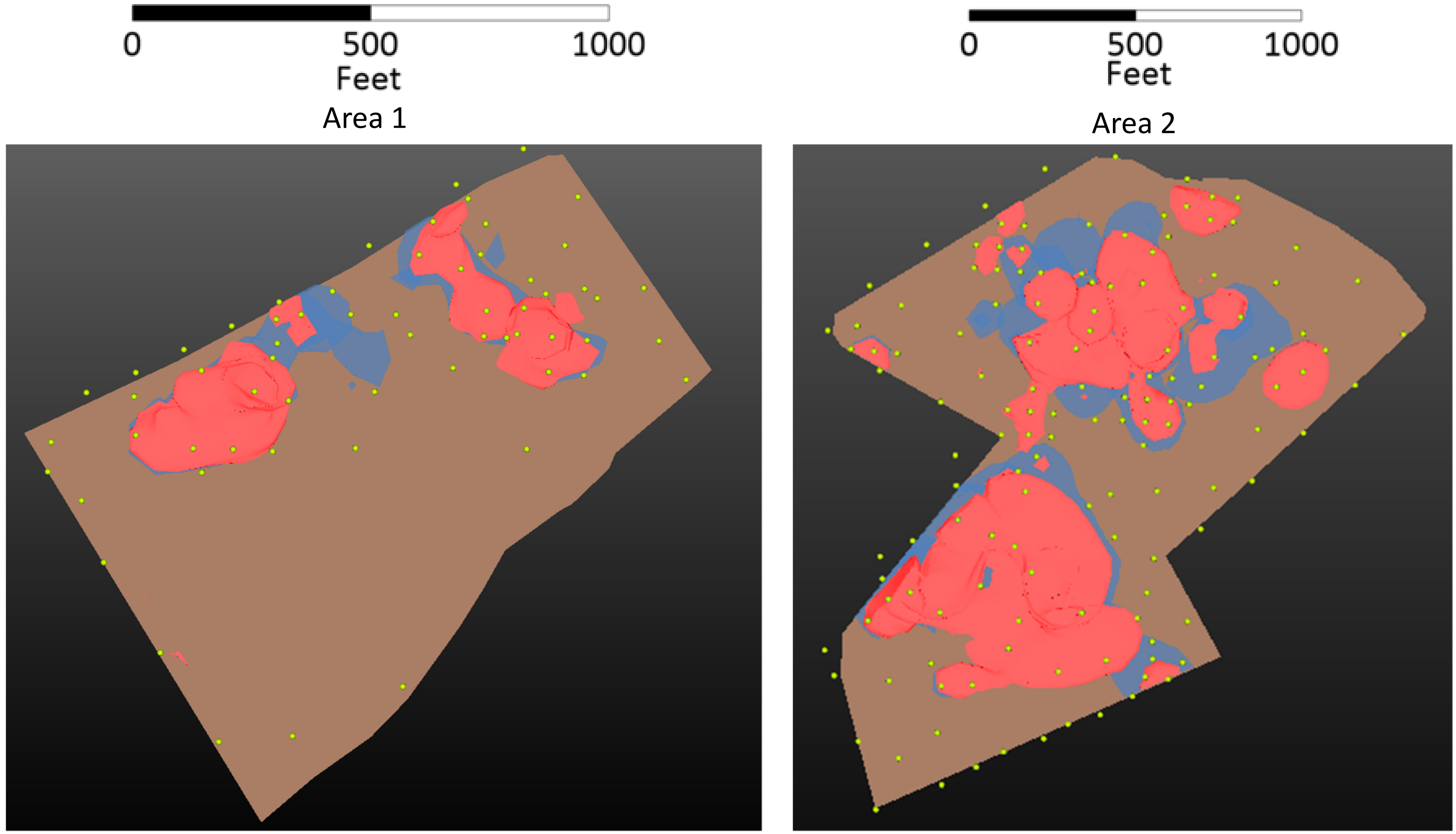
FIGURE E-14

Thorium Approximate Quantification Limit Analysis

Core & Borehole – Combined Radium

PARSONS

301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-431-9560



Existing Combined RIM >52.9 pCi/g 0-20 feet B2005GS

Radium RIM >7.9 pCi/g 0-20 feet B2005GS

Proposed Boring Location

FIGURE E-15

Radium >7.9 pCi/g Extent

West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY

ATTACHMENTS

ATTACHMENT E-1 - RESPONSE TO LIMITATIONS OF SSP&A MODEL

ATTACHMENT E-1 - TECHNICAL MEMORANDUM

To: West Lake Team Date: March 23, 2020

From: Parsons Geostatistical Team

Subject: Response to Limitations of S.S. Papadopulos & Associates, Inc. Model

This attachment provides discussion on the potential model improvements cited in the “Estimated Three-Dimensional Extent of Radiologically Impacted Material, West Lake Landfill Operable Unit 1, Bridgeton, Missouri” (S.S. Papadopulos & Associates, Inc. [SSP&A] 2017). Given that the potential model improvements were originally from SSP&A’s document, the discussion below elaborates on the potential areas for improvement by SSP&A, as well as elaboration on the potential improvements in the Parsons response to each potential improvement. These potential model improvements are not only recognized and discussed herein, but the Design Investigation Work Plan (DIWP) has been developed to address these areas of possible improvement as the remedial status progresses into the remedial design phase.

In general, the potential model improvements are based on details regarding the pre-processing, kriging, and post-processing of data as related to hard and soft data. More specifically, the potential improvements are centered around: the grid size, variograms, regressions between hard and soft data, cumulative distribution functions (CDFs), and the potential use of block kriging.

(1) “The uncertainty associated with these extent and volume estimates has implications for remedy design and cost, because many aspects of the cost of certain remedy alternatives would increase (possibly linearly or at a greater rate) as the extent or volume increases.”

(Page II – Executive Summary)

SSP&A Response: This statement is supported by the calculations presented in the report, and by illustrations and tabulations of the possible ranges of volume and extent of both RIM and of overburden and setback required for excavation. Examples of cost factors that increase non-linearly with increasing RIM volumes, extents and depths include the setback volume; excavation at the margins where setback can affect landfill perimeters, roads, etc.; and, time required for sample acquisition and turn-around. These, and other, examples were discussed with United States Environmental Protection Agency (USEPA) as the RIM extent was being evaluated.

Parsons Response: A level of uncertainty exists in all models, as a model is intended to provide a prediction based on the data available. Quantifying uncertainty in a model can be challenging, as it involves assumptions about parameters and decision variables. For example, the associated level of uncertainty from sample collection and lab error would compound on uncertainties related to the regression, CDF development, and indicator kriging. While fully quantifying uncertainty in the model is difficult, there are approaches for qualitatively reducing model uncertainty through additional data collection and analysis. Parsons has identified areas where these improvements are possible and will focus on these areas in the DIWP with the inclusion of geostatistical data objectives (GSMOs). The GSMOs are considered only semi-quantifiable, and thus are not considered true Data Quality Objectives (DQOs).

(2) "The value ascribed to the sill does not alter the value of the interpolated estimate that is obtained at intermediate locations when kriging; however, it does alter the value of the kriging variance. If kriging variances are not employed for any purpose, then the actual values ascribed to the sills are not of great importance, and emphasis is instead placed upon estimating and modeling the form of the variogram and the range-lengths in the horizontal and vertical directions. If kriging variances are to be used in future calculations, then greater emphasis should be placed on obtaining accurate estimates of the variogram sills.”

"If kriging variances were to be used to support analyses of uncertainty associated with the estimate obtained from the indicator kriging, then additional effort and focus should be placed upon the variogram development to ensure that values ascribed to the sill of any single or nested variogram structures can support such an analysis."

(Page 4-2 Section 4.2 Variogram Modeling)

SSP&A Response: This statement is supported by kriging theory, by presentations and discussions shared with USEPA as the RIM extent was being evaluated, and by subsequent work completed by Parsons to verify the validity of this statement in the specific context of the West Lake RIM extent evaluation. It is important to note, however, that even when kriging variances (KVs; or, standard deviations, often used and referred to as KSDs) are used to identify data gaps, etc., the pattern of their relative values is unchanged by changing the variogram sill. Only the absolute values of the KVs and KSDs change when the sill is altered.

If the KVs or KSDs are to be used in any calculations or analyses where their absolute values are important, then further evaluation of the variogram sill values is warranted. If the KVs or KSDs are to be used in relative comparisons to help guide data gap analyses for example, then further analysis of the variogram sill is likely not warranted. Further evaluation of the variogram range lengths may be warranted, for example, if additional sample data are collected, or if alternate data sets are used to develop and evaluate variograms that focus on samples exhibiting values closer to the 52.9 pCi/g threshold.

Parsons Response: As stated by SSP&A, the sill does not change the kriging estimation. This is supported by kriging theory and has been demonstrated by Parsons in the sensitivity section of the Preliminary Excavation Plan (PEP). However, the sill does affect kriging variance, which is directly related to standard deviation. Parsons has proposed using the spatial distribution of standard deviation for the determination of data gap sampling locations. It is important to point out (and as noted by SSP&A above) that the sill does not affect the spatial distribution or relative values of standard deviation or kriging variance, only the absolute values. This implies that using the standard deviation for anything more than a spatial tool requires that additional analysis be placed on the sill. The original intent was to update the variogram once new data were collected, as mentioned in the PEP. However, based on meetings and comments received on the PEP, Parsons updated the variogram analysis in order to use the standard deviation as part of the DIWP and locations of boring. After the collection of additional data, variogram modeling will again be performed on both the indicator kriging process and the activity calculations as further described in the DIWP.

(3) "Indicator kriging at multiple thresholds could employ variograms that are specific to each threshold: at West Lake, this would result in, for example, four potentially different variograms to represent one constituent (e.g., combined radium) across four thresholds. <u>However, because the proportion of samples exceeding higher values declines quickly, the development of empirical variograms specific to high activity concentration thresholds can be difficult."</u>

(Page 4-2 Section 4.2 Variogram Modeling)

How high is high? – USEPA direct question

SSP&A Response: There is no fixed number, as there is a continuum of samples across several orders of magnitude. This question is best evaluated by either preparing a cumulative frequency plot of sample values; or performing a count of the number of sample values above and below either the four thresholds used in the study (i.e., from <7.9 on up to >1000); or making a moving-count on a linear or geometrically continuing basis – e.g., from <7.9 up at geometrically increasing intervals until reaching >1000 (e.g., 7.9, 15.6, 31.25, 62.5, 125, 250, 500, 1000, 2000). The number of sample results in each "bin" could then be compared with common suggestions for the number of points and point-pairs needed to estimate a stable variogram, helping illustrate if and where this is a substantial drop off in the number of available point-pairs. It should be noted this situation is very common in environmental data sets that exhibit tailing and “outliers” (extreme values) and is encountered and wrestled with regardless of the geostatistical method used. Note that in the report we did develop variograms separately across all thresholds (Appendix I), to demonstrate that it can be attempted, however the number of data points available across higher thresholds drops considerably. Appendix I of the report presents discussion on the difficulties encountered when developing variograms across multiple thresholds and illustrates (Figure I-1, for example) that at higher thresholds the short-range shape is difficult to determine due to the smaller number of samples at those concentrations.”

Parsons Response: For the DIWP, and potentially the remainder of the project (per the Record of Decision Amendment [RODA]), the 52.9 pCi/g threshold will be the focus of evaluating Radiologically Impacted Material (RIM). Additional thresholds (potentially 100, 250, etc.) within the multiple indicator process will be considered during the development of the CDF, with the goal of improving the CDF, not producing additional indicator kriging models. Once additional data are collected, the data can be evaluated, as suggested by SSP&A, for a number of thresholds. The GSMOs, as provided in the DIWP, were developed to assist in addressing this limitation.

(4) “Indicator kriging at multiple thresholds was completed using point kriging for computational expediency and because sample replicates were not preserved and a zero-valued short-range variance (or, “nugget”) was assumed in the base-case variogram models. Block kriging could be implemented to evaluate the variance within individual blocks if an excavation alternative is under serious consideration and therefore subject to more detailed analysis.

(Page 4-5 Section 4.5 Indicator Kriging at Multiple Thresholds)

SSP&A Response: Point kriging was preferred for these calculations given (a) purposes of calculations at the RIA/FFS stage, (b) particularly as the size of the grid was refined to 5m *x* 5m *x* 0.15m, and (c) as the sample data were assumed to reflect field conditions accurately and a nugget (small-range variance) was not included in the base variograms (note: a nugget was included in the alternate variograms). Use of block kriging, where multiple estimates are made via kriging at regularly-spaced intervals within a block, could provide value particularly if the block size under consideration is considerably larger than the 5m *x* 5m *x* 0.15m blocks used in the RIA/FFS stage and if an attempt is made to determine the accuracy of sample results as part of an assessment of the various contributions to the short-range variance (nugget). This may then provide a means to identify, across all quantified sources of block-variance, whether a sizeable block has small variance and can be presumed with some confidence to meet certain criterion, or whether a sizeable block has large variance that means its relation to a threshold or decision criteria is uncertain in which case additional data may be needed.

Parsons Response: As described in the DIWP, future analyses will examine the nugget and grid cell size with the addition of new data, beyond what is provided in the Geostatistical Attachment of the DIWP and PEP (Parsons 2020). Given the nodal component and the current algorithms provided in C-Tech’s Earth Volumetric Studio (EVS) software, it is expected that increasing the grid size will alleviate many of the concerns recognizing the volumes are relatively the same. The GSMOs, as provided in the DIWP, were developed to assist in addressing this limitation.

(5) “This may or may not reflect actual conditions: if it does reflect actual conditions, the practical consequence of this for remedy design is that this pattern would tend to make it more difficult to accurately design and cost a potential excavation remedy due to the higher level of variability and, thus, unpredictability of field conditions.”

(Page 8-4 Section 8.2.2 Results)

SSP&A Response: This statement is still valid. If the short-range variance is large and represents a high proportion of the total variance (i.e., sill) then this suggests that there is not strong spatial correlation and that kriging predictions even at short ranges are relatively uncertain. Without collecting any additional data, efforts might be made to review the existing data to identify sources of short-range variance, so that they are not lumped together into a single nugget-type term but might be explained and mitigated. Such an exercise will not be able to eliminate short-range variance but may reduce it so that its impact on predictions is mitigated.

Parsons Response: The underlying theory of geostatistics assumes that the "nugget," or the variance of data at the same location, is zero. However, the close-range variance may be non-zero in certain environmental circumstances. The variograms as depicted in the SSP&A geostatistics report indicate the presence of the nugget effect. This nugget effect may be due to sampling error. A thorough review of the data to understand the level of this error could be conducted in order to explain the nugget effect, as described by SSP&A above. The nugget effect could be reduced through this analysis as well. Including a small nugget relative to the sill (total variance) is justified in some circumstances. However, if the nugget effect is both large relative to the sill and is not due to sampling error, but rather accurately represents the site conditions, then this is indicative of relatively weak spatial correlation. If that is the case, then predicting the extent of RIM becomes difficult no matter the technique used, since a sampling data point cannot be used to make predictions of the nearby areas. Including a large nugget relative to the sill in the kriging estimation will reduce the area of RIM and introduce a new level or error. This difficulty is part of the justification for multiple indicator kriging, in that the estimate is a probability of being above or below 52.9 pCi/g as opposed to a particular estimate of concentrations. Parsons will review the data thoroughly when additional data are collected and consider whether the nugget effect is due to sampling error and can be neglected, or if it is appropriate to be included in the final kriging estimation of RIM. Parsons intends to collect additional hard data and collocate borings in order to further test the nugget effect. The GSMOs, as provided in the DIWP, were developed to assist in addressing this limitation.

(6) "The relative absence of unverifiable RIM that is predicted within and beyond the convex hull of the sample data resulting from the application of Method 1 is from a certain standpoint desirable for developing and costing a base-case design of a (partial) excavation remedy: however, the results of the various kriging analyses completed as described in Appendix I, together with the conceptual site model (CSM) detailed the disposal of RIM within Areas 1 and 2, suggest that if an excavation remedy is implemented, there is a likelihood of encountering unanticipated disconnected RIM within the landfill body."

(Page 8-5 Section 8.4 Discussion)

SSP&A Response: This statement is still valid. Maps of KVs, KSDs or perhaps even more reliably maps of conditional variances from the kriging exercise provide some indication of where such RIM might be most likely to be anticipated. This situation is common in environmental data sets and is encountered and wrestled with regardless of the geostatistical method used. Efforts to evaluate and understand contributions to short-range variance may help mitigate this. However, it should be noted that the potential for encountering unanticipated, disconnected, RIM is higher at higher thresholds (activity concentrations) and the key activity concentration threshold forming a basis for the excavation remedy – 52.9 – is fairly low.

Parsons Response: Parsons agrees with SSP&A's response to this statement. In general, this is a common occurrence in environmental data sets and a well-accepted assumption in any modeling/kriging exercise. Parsons is using kriging standard deviation maps to establish locations for new borings in order to reduce this effect to the extent practical. Parsons will perform additional analyses on the short-range variance (nugget effect).

(7) "The sample data used to estimate the extent and volume of RIM exhibit strong tailing (as documented elsewhere in this report), and as described elsewhere may be better described as bimodal or multi-modal. Such data are difficult to evaluate, and some subjective decisions were made to develop the CDFs described. Other methods could be considered for this analysis, however, the methods described were considered appropriate to provide approximate values for the extent and volume of RIM for purposes of the RIA and FFS. Further and more detailed analyses may be warranted should a remedy be selected that rests in part or in whole upon the geostatistical studies completed thus far, such as undertaking local-scale uncertainty analyses in regions of the landfill that may be subject to excavation."

(Page D-1-10 Section 2 – Assumptions and Limitations)

SSP&A Response: This statement is still valid. "Global" (per-area) kriging models were used to evaluate the entire body of each landfill Area (i.e., Area 1 and Area 2) for purposes of the RIA and FFS, and as detailed in the report and above, alternate CDFs and variograms were used in the development of those "global" kriging models. Review of the development of the base and alternate CDFs, and base and alternate variograms as well as the correlations constructed between soft and hard data, including the point pairs used in constructing the scatter plots underpinning those correlations, would be a reasonable step in refining these kriging models. Once completed, block kriging could be considered for use with larger (i.e., not 5m *x* 5m *x* 0.15m blocks used in the RIA/FFS) to provide estimates of block variances together with maps of broader KV/KSD patterns to guide additional data collection and excavation.

Parsons Response: Parsons intends to revisit the regressions, CDFs, grid size, nugget, and kriging types with the collection of new data. Parsons has agreed that the SSP&A methods put forth are reasonable given the objective of identifying extent of RIM based on a threshold and the existing data set. The GSMOs, as provided in the DIWP, were developed to assist in addressing this limitation.

(8) "Imperfect knowledge of the extent and volume of RIM is just one source of uncertainty in designing, evaluating and estimating costs for potential remedies. This Appendix does not present an exhaustive analysis of uncertainty: emphasis is placed on estimating the extent and volume of RIM ... to illustrate the range of potential outcomes that is associated with those inputs and calculations. The primary objective of this analysis is to identify whether the estimates provided in the RIA and FFS are likely reasonable for the purposes required of those documents."

(Page I-1 Evaluation of Uncertainty Introduction)

SSP&A Response: This statement is still valid. Although it was never documented, and nor was it a rigorous evaluation, the uncertainty analyses from the different variograms and CDFs suggested that the "spread" of likely RIM volumes using the 52.9 threshold (Appendix I, Figure I-3) was in almost all cases within the +50/-30 range that is often used as a rough guide in costing. There was discussion at the time (possibly not with USEPA, but internally) that this sort of spread at the 0.5 probability was in line with the needs for these kinds of estimates.

Parsons Response: While quantifying uncertainty may not be possible given the scope of this project, qualitatively reducing uncertainty is. Parsons is establishing data collection objectives based around the areas within the model that have the highest relative uncertainty. Following data collection, Parsons will perform a thorough review of the data beginning with the regressions and a thorough sensitivity analysis relating to volume and extent to understand and minimize the model uncertainty to the extent practical. The GSMOs, as provided in the QAPP, were developed to assist in addressing this limitation.

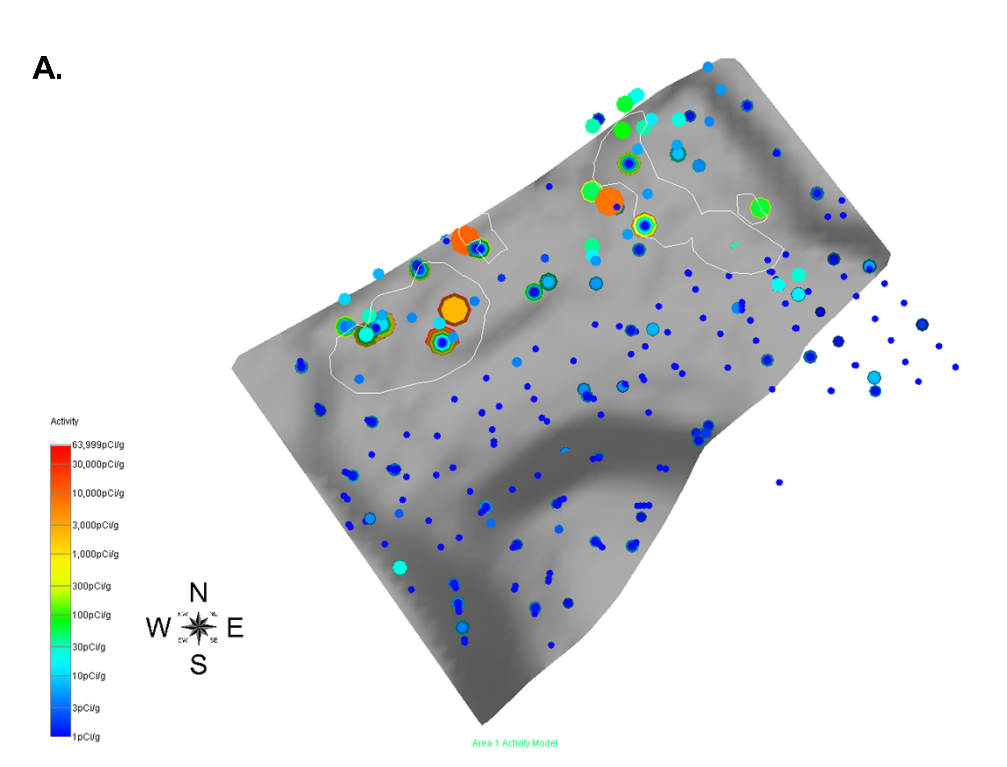
(9) "The effect appears to be subtle at some thresholds and stronger at other thresholds, and was not modeled as a hole-effect structure for purposes of this uncertainty evaluation: nonetheless, a hole-effect structure could be explored further for predictive purposes beyond the immediate needs of the FFS, as this structure is plausible given the typical disposal practices in landfills and the expectation of disconnected RIM extents particularly at higher concentration thresholds."

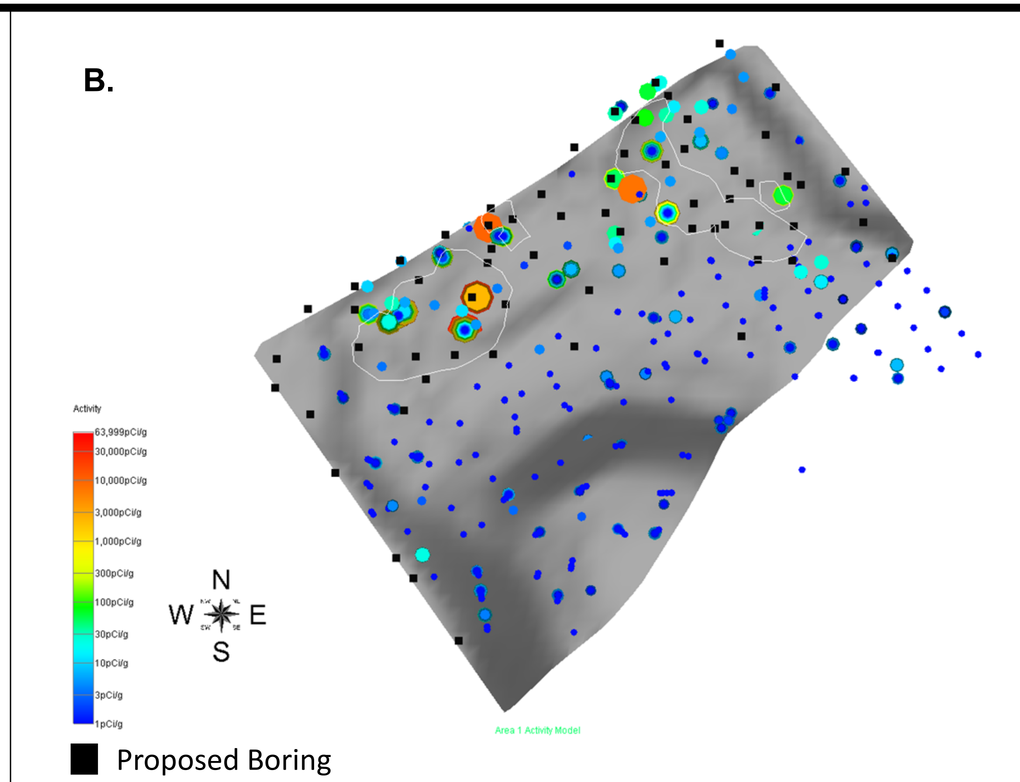
(Page I-5 Section 2.3.1 – Alternate Variograms)

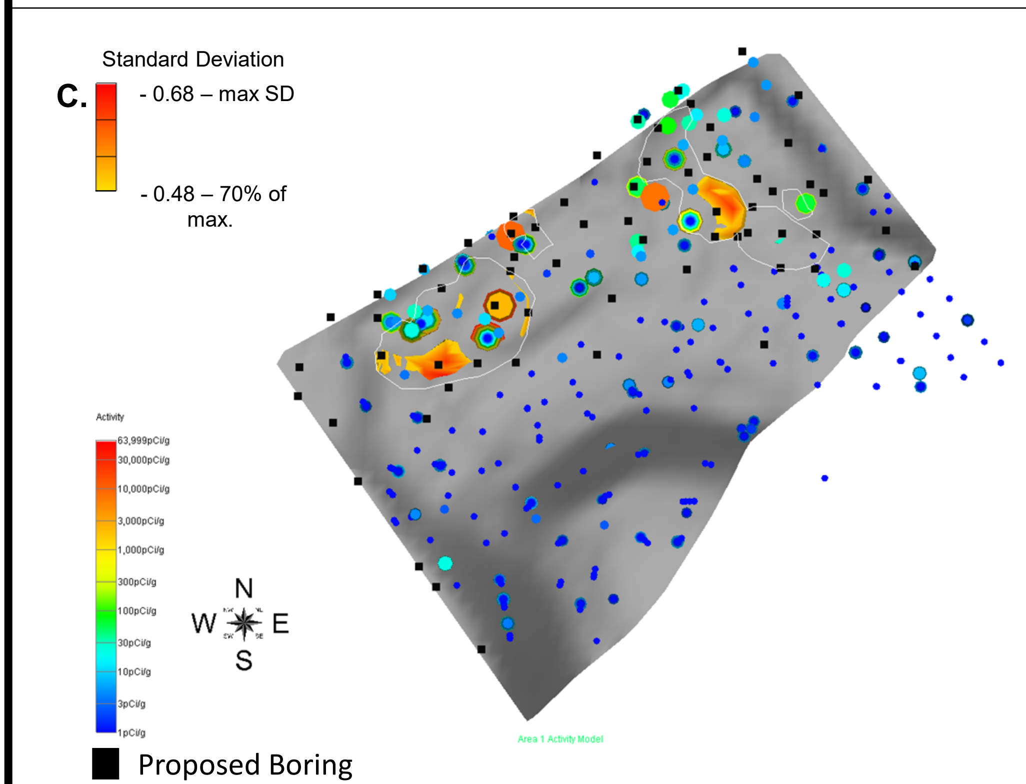
SSP&A Response: This statement is still valid, in the sense that the apparent hole-effect could be explored to determine whether it provides any useful or reliable information regarding the distribution of RIM "pockets". For example, depending on the size of daily / other periodic cells used for disposal, it is possible the oscillations in the hole model relate to these practices. However, if there is a systematic cause it may be different to this, and differential settlement may be either a cause or may obscure a cause.

Parsons Response: Parsons recognized the hole-effect structure and its potential relationship to RIM distribution at the site and disposal methods at the landfill; however, it had not been considered as another device for RIM extent prediction. Following additional data collection, analyses will further evaluate the hole-effect structure and what it potentially means to the remedial design, to the extent practical.

ATTACHMENT E-2 – ACTIVITY MODEL SAMPLE CONCENTRATIONS AND STANDARD DEVIATION







Notes:

1. White outline shows RIM >52.9 pCi/g at 50% non-exceedance probability from 0-16 ft B2005GS.
2. Gray background shows elevation surface at 12 ft B2005GS within Area 1 boundary.

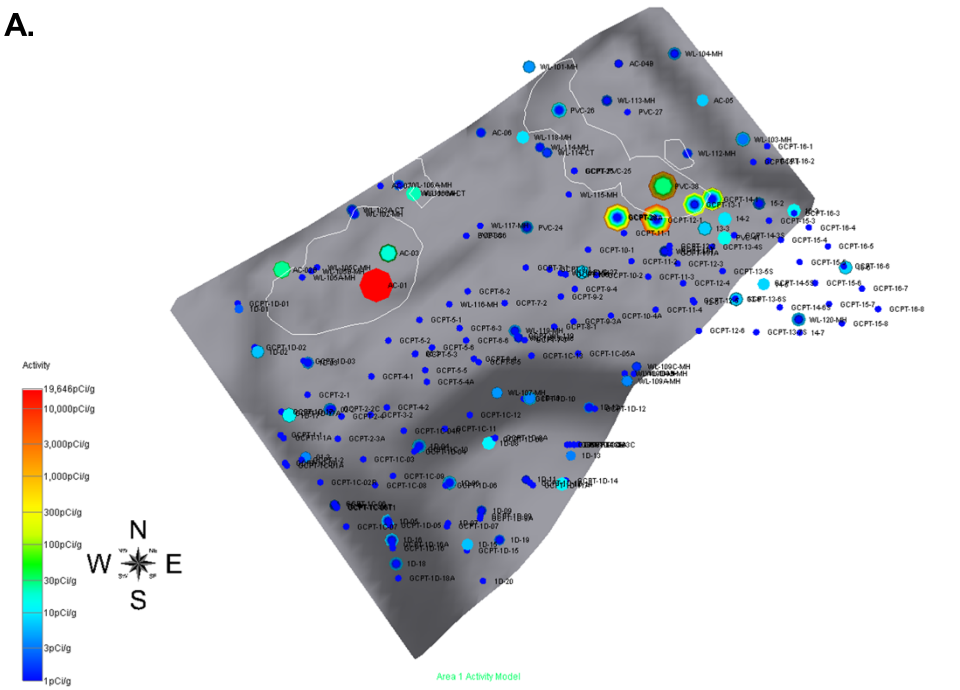
FIGURE ATTACHMENT E2-1a

Activity Model – Area 1
2005 GS – 12 ft B2005GS
Sample Activities, Proposed Boring Plan and Highest Standard Deviation
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY

A.



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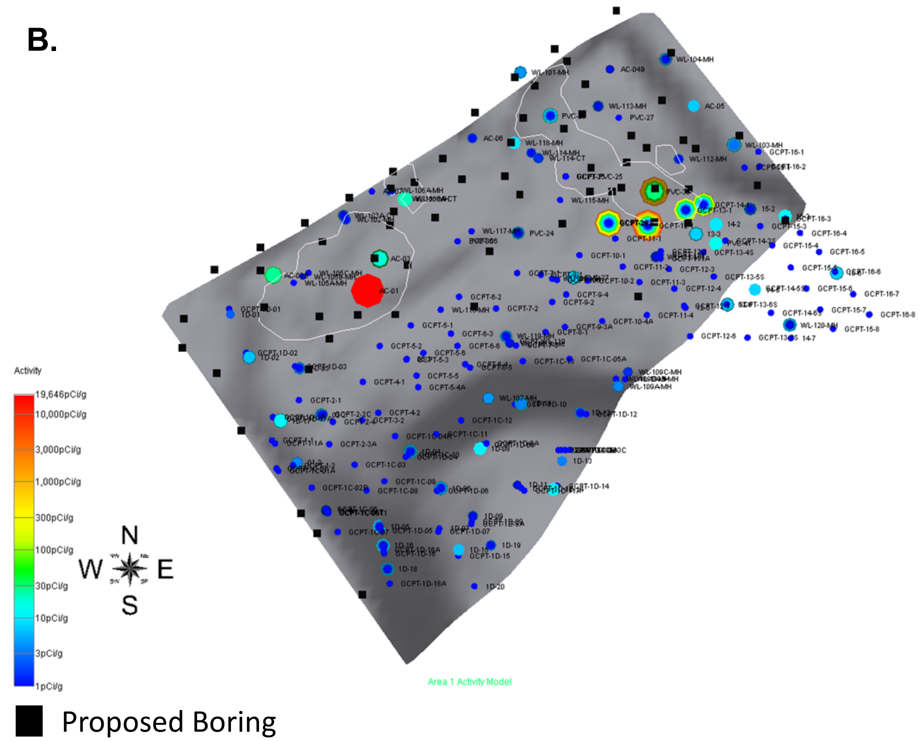
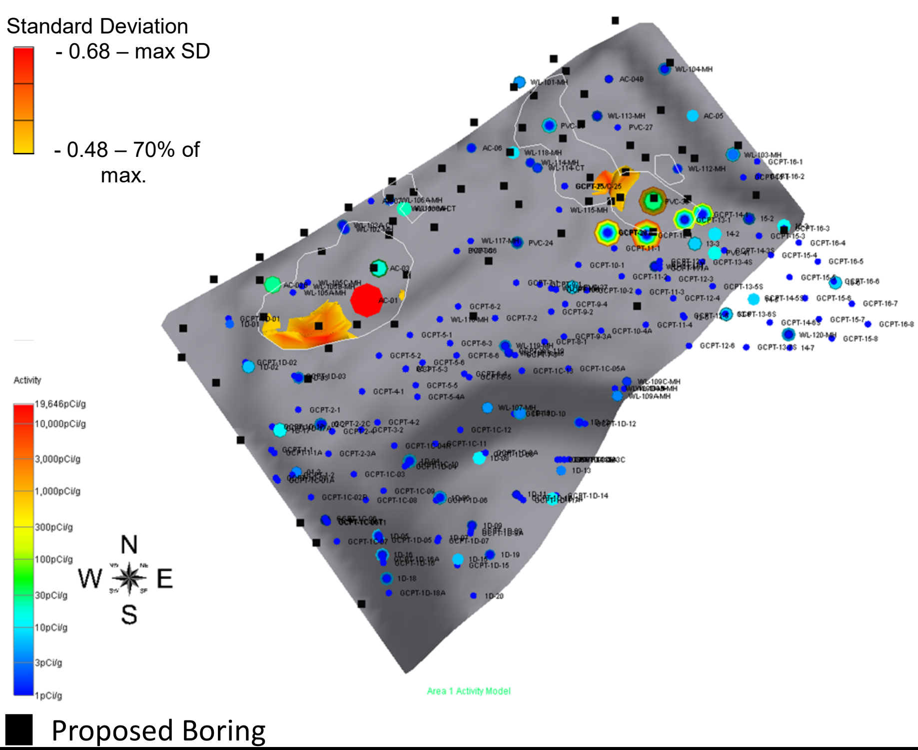


C.



Notes:

1. White outline shows RIM >52.9 pCi/g at 50% non-exceedance probability from 0-16 ft B2005GS.
2. Gray background shows elevation surface at 20 ft B2005GS within Area 1 boundary.

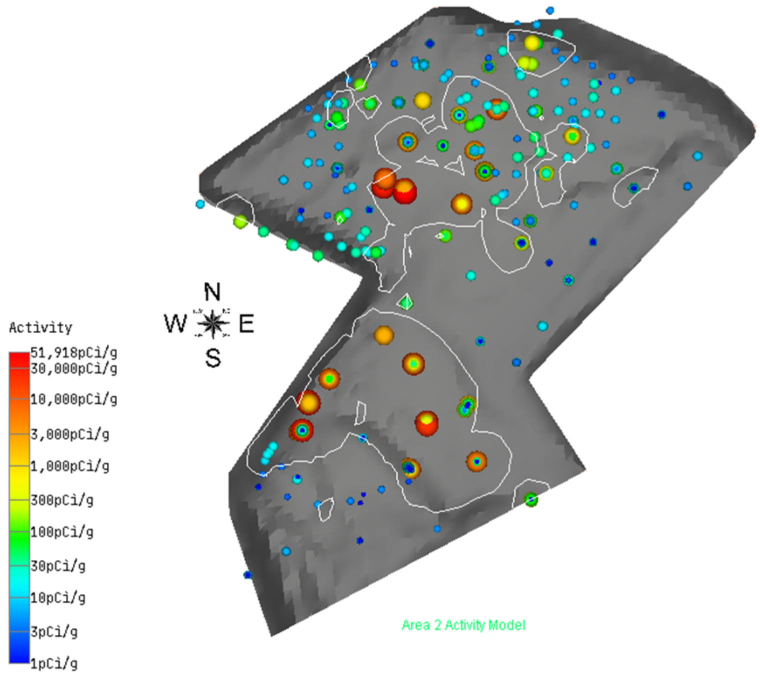
FIGURE ATTACHMENT E2-1b

Activity Model - Area 1
12 – 20 ft B2005GS
Sample Activities, Proposed Boring Plan and Highest Standard Deviation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

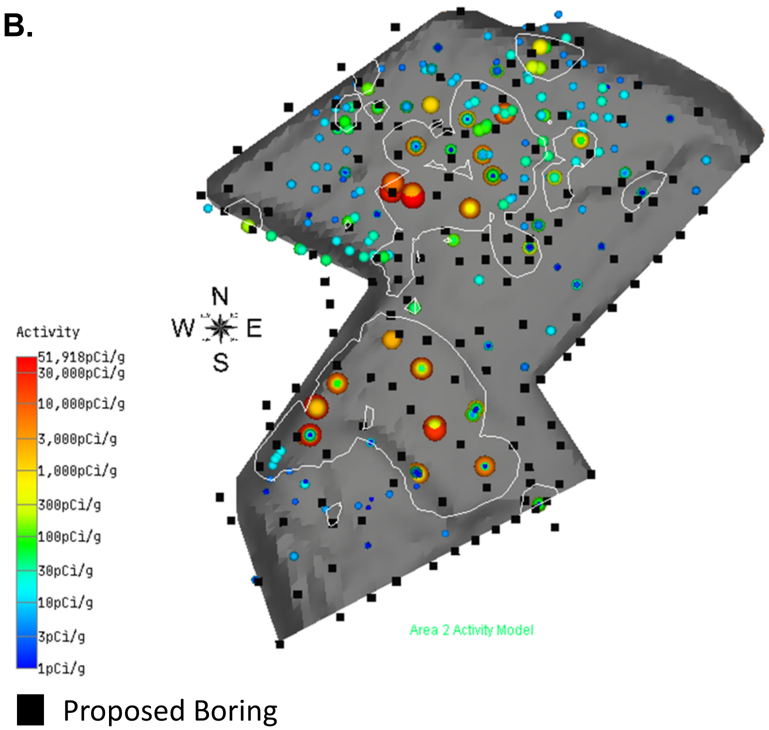
PARSONS

Syracuse, NY

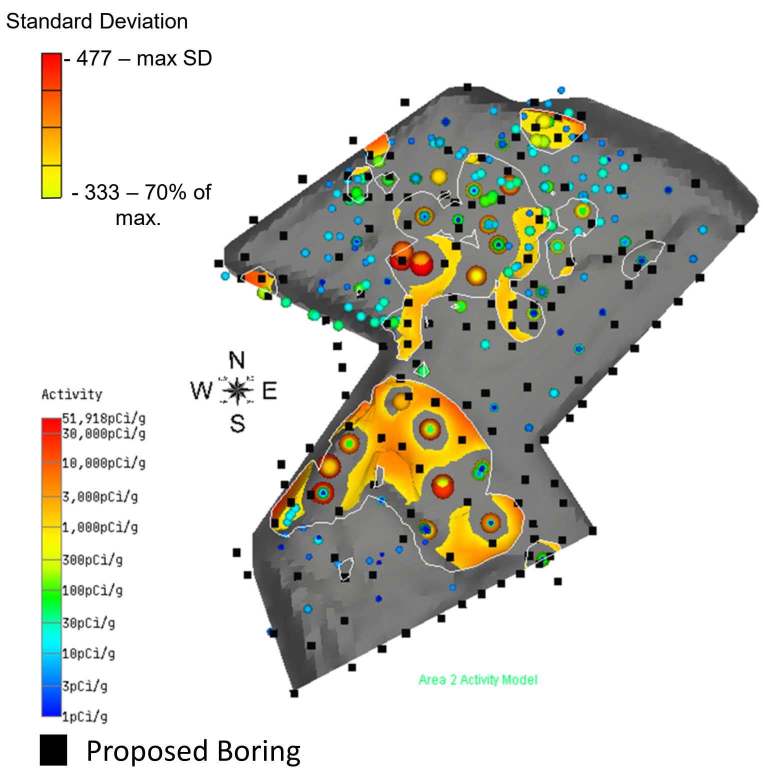
A.



B.



C.



Notes:

1. White outline shows RIM >52.9 pCi/g at 50% non-exceedance probability from 0-16 ft B2005GS.
2. Gray background shows elevation surface at 12 ft B2005GS within Area 2 boundary.

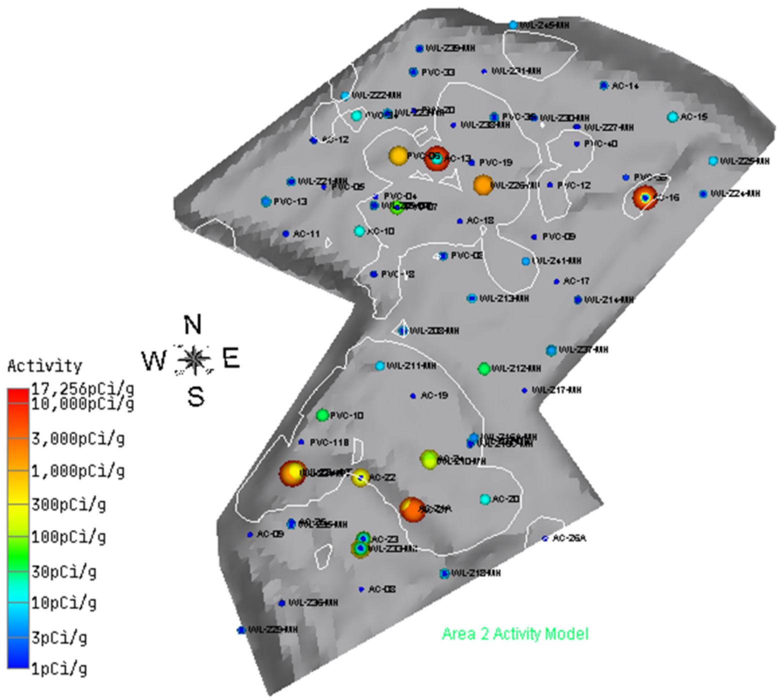
FIGURE ATTACHMENT E2-1c

Activity Model – Area 2
2005 GS – 12 ft B2005GS
Sample Activities, Proposed Boring Plan and Highest Standard Deviation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

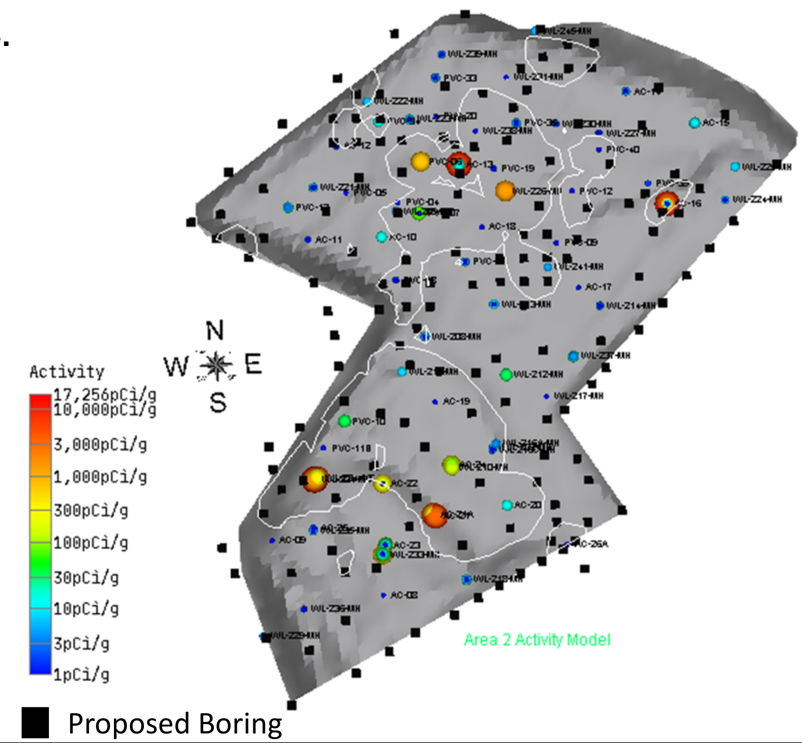
PARSONS

Syracuse, NY

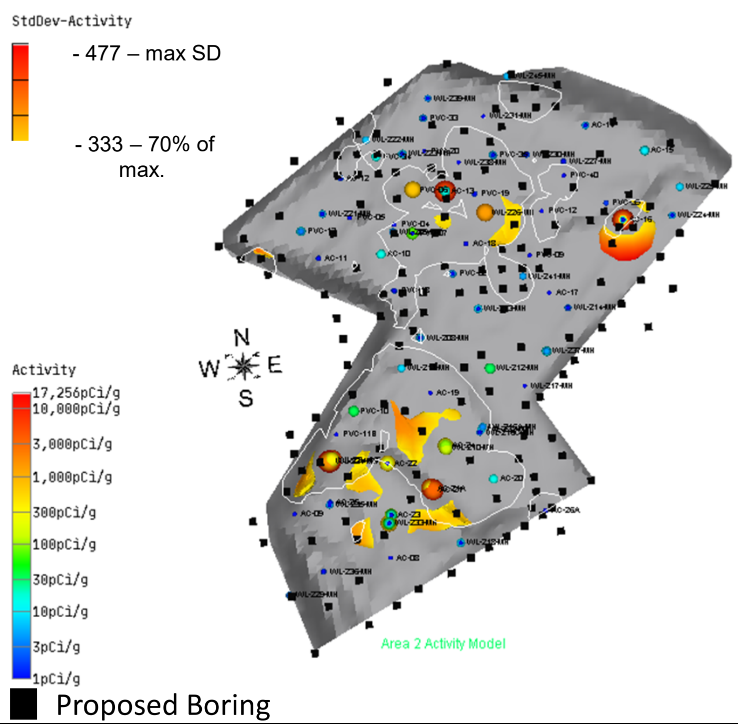
A.



B.



C.



Notes:

1. White outline shows RIM >52.9 pCi/g at 50% non-exceedance probability from 0-16 ft B2005GS.
2. Gray background shows elevation surface at 20 ft B2005GS within Area 2 boundary.

FIGURE ATTACHMENT E2-1d

Activity Model – Area 2
12 – 20 ft B2005GS
Sample Activities, Proposed Boring Plan and Highest Standard Deviation
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY

ATTACHMENT E-3 - USEPA TYPE I AND II ERROR RATE PERCENTAGES FOR STANDARD DEVIATION TO WARRANT SAMPLING CRITERIA

Decision Error Rates

Hayley Brittingham and Leslie Gains-Germain

5/25/2020

Hypothesis Tests

Case I, less than 0.5

Predicted probabilities are less than 0.5, predicting non-RIM material, generally outside of the current RIM shell.

$H_0 : \mu \geq 0.5$ Material is RIM

$H_A : \mu < 0.5$ Material is NOT RIM

- Type I Error: Reject the null when the null is true. Material is classified as NOT RIM (and left in place) when it truly is RIM. Misses RIM material.
- Type II Error: Fail to reject the null when the alternative is true. MATERIAL is classified as RIM when truly it is NOT RIM (and excavating more material than is really necessary). Overexcavates.

Case II, greater than 0.5

Predicted probabilities are greater than 0.5, predicting RIM material, generally inside the current RIM shell.

$H_0 : \mu \leq 0.5$ Material is NOT RIM

$H_A : \mu > 0.5$ Material is RIM

- Type I Error: Reject the null when the null is true. MATERIAL is classified as RIM when truly it is NOT RIM (and excavating more material than is really necessary). Overexcavates.
- Type II Error: Fail to reject the null when the alternative is true. Material is classified as NOT RIM (and left in place) when it truly is RIM. Misses RIM material.

Current Table

The current table how tandard deviation needed to achieve 5% Type I error and 50% Type II error, applicable to area out ide the RIM hell (probability of RIM 0 5)

Probability of RIM	SD to warrant sampling	Type I Error	Type II Error
0.45	0.03	0.05	0.5
0.40	0.06	0.05	0.5
0.30	0.12	0.05	0.5
0 20	0 18	0 05	0 5
0.10	0.24	0.05	0.5

Hypothesis Tests

Case 1: less than 0.5

Predicted probabilities are less than 0.5, predicting non-RIM material, generally outside of the current RIM shell.

$H_0 : \mu \geq 0.5$ Material is RIM

$H_A : \mu < 0.5$ Material is NOT RIM

The meaning of the error rates for this hypothesis test (outlined in EPA comment #17) are:

- Type I Error: Reject the null when the null is true. Material is classified as NOT RIM (and left in place) when it truly is RIM. Misses RIM material. Known as false compliance.
- Type II Error: Fail to reject the null when the alternative is true. Material is classified as RIM when truly it is NOT RIM and excavating more material than is really necessary, causing overexcavation. Known as false exceedance.

Case 2: greater than 0.5

Predicted probabilities are greater than 0.5, predicting RIM material, generally inside the current RIM shell.

In this case the null and alternative hypotheses are switched. We are still looking for evidence that our classification of RIM was correct, but this time that means evidence that the material is RIM rather than not.

$H_0 : \mu \leq 0.5$ Material is NOT RIM

$H_A : \mu > 0.5$ Material is RIM

- Type I Error: Reject the null when the null is true. Material is classified as RIM when truly it is NOT RIM and excavating more material than is really necessary, causing overexcavation. Known as false exceedance.
- Type II Error: Fail to reject the null when the alternative is true. Material is classified as NOT RIM (and left in place) when it truly is RIM. Misses RIM Known as false compliance.

If Type I and Type II Error Rates are Equal

15% Type I and Type II Error

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.05
0.3 or 0.7	0.10
0.2 or 0.8	0.14
0.1 or 0.9	0.19

20% Type I and Type II Error

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.06
0.3 or 0.7	0.12
0.2 or 0.8	0.18
0.1 or 0.9	0.24

25% Type I and Type II Error

Probability of RIM	SD to warrant sampling

30% Type I and Type II Error

Probability of RIM	SD to warrant sampling

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.07
0 3 or 0 7	0 15
0.2 or 0.8	0.22
0.1 or 0.9	0.30

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.10
0 3 or 0 7	0 19
0.2 or 0.8	0.29
0.1 or 0.9	0.38

35% Type I and Type II Error

Probability of RIM	SD to warrant sampling
0 4 or 0 6	0 11
0.3 or 0.7	0.22
0.2 or 0.8	0.33
0.1 or 0.9	0.44

40% Type I and Type II Error

Probability of RIM	SD to warrant sampling
0 4 or 0 6	0 13
0.3 or 0.7	0.26
0.2 or 0.8	0.39
0.1 or 0.9	0.51

If False Exceedance Rate is Greater than False Compliance

Controlling the fal e compliance rate (mi ing RIM) i protective of human health, while controlling the fal e e ceedance rate (e cavating more material than i really nece ary) i economically efficient

10% False Compliance and 15% False Exceedance

Probability of RIM	SD to warrant sampling
0 4 or 0 6	0 04
0.3 or 0.7	0.09
0.2 or 0.8	0.13
0.1 or 0.9	0.17

10% False Compliance and 20% False Exceedance

Probability of RIM	SD to warrant sampling
0 4 or 0 6	0 05
0.3 or 0.7	0.09
0.2 or 0.8	0.14
0.1 or 0.9	0.19

15% False Compliance and 20% False Exceedance

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.05
0.3 or 0.7	0.11

15% False Compliance and 25% False Exceedance

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.06
0.3 or 0.7	0.12

Probability of RIM	SD to warrant sampling
0.2 or 0.8	0.16
0.1 or 0.9	0.21

Probability of RIM	SD to warrant sampling
0.2 or 0.8	0.17
0.1 or 0.9	0.23

20% False Compliance and 25% False Exceedance

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.07
0.3 or 0.7	0.13
0.2 or 0.8	0.20
0.1 or 0.9	0.26

20% False Compliance and 30% False Exceedance

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.07
0.3 or 0.7	0.15
0.2 or 0.8	0.22
0.1 or 0.9	0.29

25% False Compliance and 30% False Exceedance

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.08
0.3 or 0.7	0.17
0.2 or 0.8	0.25
0.1 or 0.9	0.33

30% False Compliance and 35% False Exceedance

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.11
0.3 or 0.7	0.22
0.2 or 0.8	0.33
0.1 or 0.9	0.44

35% False Compliance and 40% False Exceedance

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.16
0.3 or 0.7	0.31
0.2 or 0.8	0.47
0.1 or 0.9	0.63

30% False Compliance and 40% False Exceedance

Probability of RIM	SD to warrant sampling
0.4 or 0.6	0.13
0.3 or 0.7	0.26
0.2 or 0.8	0.39
0.1 or 0.9	0.51

Additional Information regarding Standard Deviation Calculations

In order to increase confidence in the final RIM boundaries, borings/samples must be proposed in areas where the kriging standard deviation is relatively high, and the probability of RIM is close to 0.5. The specific standard deviation that would warrant additional sampling depends on the predicted probability of RIM at that location and can be calculated fairly easily assuming a one-sided, one-sample hypothesis test. To make this example more intuitive, the probabilities provided below are the probabilities of RIM being above the concentration threshold of 52.9 pCi/g. However, this can easily be converted to non-exceedance probabilities. This hypothesis test asks one of two questions depending on whether the predicted probability is above or below the RIM probability threshold of 0.5. The significant level of the test defines the type I error rate, or the probability that the null hypotheses will be rejected if it is in fact true. This specific hypothesis test is performed as:

$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}}$$

Where z is the test statistic, $\bar{x}$ is the predicted probability of exceeding the concentration threshold, μ_0 is 0.5, and $\sigma / \sqrt{n}$ is the standard error, in this case the kriging standard deviation.

Case (a). For predicted probabilities less than 0.5, the question is whether the RIM probability is truly less than 0.5. That is, the true probability *could be* greater than 0.5 after accounting for model uncertainty. The null and alternative hypotheses are defined as follows:

$H_0: \mu \geq 0.5$ Material is RIM
$H_A: \mu < 0.5$ Material is not RIM

In this case, the type I error rate is the false compliance rate, or the probability that material is classified as NOT RIM when truly it is RIM. The null hypothesis that a specific location is RIM ($\mu \geq 0.5$) is rejected if $z < z_\alpha$, which is 1.645 to achievea 5% type I error rate. Therefore, we conclude that a specific location, i, is not RIM if:

$$\frac{x_i - 0.5}{SD_i} < 1.645$$

Where x_i is the predicted probability of RIM at location i, and SD_i is the kriging standard deviation at location i.

The above rejection rules control for the type I error rates of the test, but a second equation must be considered to control for the type II error rate of the test. For Case (a), a type II error is equivalent to false exceedance, or classification of material as RIM when it is truly NOT RIM. For Case (b), a type II error is equivalent to false compliance, or classification of material as NOT RIM when it is truly RIM. The type II error rate is equal to one minus the power of the test (β), and the following equation is used to define the desired power for both Cases (a) and (b).

$$P(reject\ H_0|H_A) = \beta$$

For Case (a), a desired power of 0.8 and a rejection rule based on a type I error rate of 5% reduces the formula to the following.

$$P\left(\frac{x_i - 0.5}{SD_i} < -1.645\middle|H_A\right) = 0.8$$

Solving further,

$$P(x_i < -1.645SD_i + 0.5|H_A) = 0.8$$

Assuming the alternative is true (i.e., material is not RIM), we subtract the alternative mean (μ_A) from both sides of the equation and divide by the kriging standard deviation. This yields a z-score on the left-hand side of the equation.

$$P(z < \frac{-1.645SD_i + 0.5 - \mu_A}{SD_i}) = 0.8$$

Lastly, set the right-hand side of the equation to the 80th percentile of the standard normal distribution ($z_\beta = 0.842$) and solve for the standard deviation.

$$\frac{-1.645SD_i + 0.5 - \mu_A}{SD_i} = 0.842$$

The equation is solved assuming the alternative mean (μ_A) is equal to the predicted probability (x_i). The solution is

$$SD_i = \frac{0.5 - x_i}{z_\beta - z_\alpha}$$

Where $z_\alpha = -1.645$ for a type I error rate of 5% and $z_\beta = 0.842$ for a type II error rate of 20%. Note that for Case (a), z_α will always be negative and z_β will always be positive; for Case (b), z_α will always be positive and z_β will always be negative. This is due to the opposite signs in the rejection rule for Case (b) compared with Case (a).

As an example, around the 0.3 RIM shell, if the desired type I and type II error rates are both 20%, a standard deviation less than or equal to 0.12 $\left(\text{or } \frac{0.5-0.3}{0.842-(-0.842)}\right)$ is necessary to be confident at a 20% one-sided significance level that those locations are indeed not RIM. If the standard deviation is less than 0.12, additional sampling is unlikely to change the conclusion that those locations are not RIM. Given the same type I and type II error rates, the calculated standard deviations for Case (b) will be equivalent to those for Case (a) for the same absolutes difference between the predicted probabilities and 0.5.

Decision errors are always possible, acceptable false exceedance and false compliance rates for this effort should be defined based the remedial design objectives and the criteria in the RODA. Given the nature of the requirement in the RODA (minimize excavation volume through optimization), other type I and type II error rates may be considered. The standard deviations listed in the table below are required to achieve a 20% false exceedance and false compliance rate. Note that the values in the table below apply to both locations outside the current RIM shell with predicted probabilities less than 0.5, and to locations inside the RIM shell with predicted probabilities greater than 0.5. Sampling in both regions must be considered to also protect against both failure to excavate RIM material incorrectly identified as NOT RIM and over-excavation of material incorrectly identified as RIM. EPA has provided standard deviations for additional false exceedance and false compliance rates.

Standard deviations needed to achieve equal false compliance and false exceedance rates of 20%.

Probability of RIM	*SD to warrant sampling*
0.4 or 0.6	*0.06*
0.3 or 0.7	*0.12*
0.2 or 0.8	*0.18*
0.1 or 0.9	*0.24*
0.4 or 0.6	*0.06*

Ideally, a simulation study would be conducted to ensure the proposed borings could meet the desired reduction in standard deviation. Due to the complex nature of the geostatistical model behind the Contamination Concern Map (CCM), simulation is the only known way to estimate the potential reduction in standard deviation resulting from the proposed sampling locations prior to the design investigation and sample collection.

APPENDIX F DESIGN INVESTIGATION BORING PLACEMENT SUMMARY

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LIST OF ACRONYMS

ACRONYM	Definition
B2005GS	Below 2005 Ground Surface
CDF	Cumulative Distribution Function
DI	Design Investigation
DIO	Design Investigation Objectives
DIWP	Design Investigation Work Plan
FSP	Field Sampling Plan
GSMO	Geostatistical Model Objective
IVM	Indicator Variability Metric
OU	Operable Unit
pCi/g	picoCurie/gram
PEP	Preliminary Excavation Plan
RA	Remedial Action
RIM	Radiologically Impacted Material
RODA	Record of Decision Amendment
SDWS	Standard Deviation to Warrant Sampling
SOW	Scope of Work
UMTRCA	Uranium Mill Tailings Radiation Control Act
USEPA	U.S. Environmental Protection Agency

1.0 DESIGN INVESTIGATION SITE BORING PLAN

The objective of the Design Investigation Work Plan (DIWP) is to collect data needed to support the design and implementation of the selected remedy as defined in the Record Of Decision Amendment (RODA) (USEPA 2018). This Appendix to the DIWP provides additional details about the rationale and the tools used in determining the location of borings. In Section 1, the Design Investigation Objectives, Geostatistical Modeling Objectives (GSMOs) are outlined, and detailed steps taken to identify additional boring locations. Furthermore, in Sections 2 and 3 the borings are grouped relative to specific objectives and to the evaluations that were identified as part of the development of the DIWP.

1.1 Objectives

Design Investigation Objectives (DIOs) were developed based on guidance from Section 3.6 of the Scope of Work to describe specific data collection goals for the design investigation (DI). A comprehensive Field Sampling Plan (FSP) has been developed with a substantial focus on subsurface sample collection through the advancement of soil borings in Areas 1 and 2. The boring plan rationale described herein applies to interior Radiologically Impacted Material (RIM) borings and does not include perimeter borings associated with DIO #1. Interior RIM boring locations have been proposed to address two specific DIOs:

- DIO #2: Further characterize locations with RIM greater than 52.9 picoCurie/gram (pCi/g) to design an optimized excavation that meets the RODA requirements
- DIO #3: Further characterize RIM between 7.9 pCi/g and 52.9 pCi/g in order to identify the extent of RIM greater than 7.9 pCi/g for the purpose confirming the OU-1 boundary and designing and specifying the extent of the Uranium Mill Tailings Radiation Control Act (UMTRCA) cap

The data needs of the subsurface RIM investigation as they relate to DIO #2 and #3 were further categorized into Geostatistical Modeling Objectives (GSMOs). Specifically, these are:

- GSMO #1: increase data density between radium, thorium, and gamma
- GSMO #2: Improve Boring/Sample Spacing and Geometry
- GSMO #3: Further Define Activities and Extent of RIM

GSMO #1 is related to sample collection and based on gamma counts with little to no relationship of spatial location, therefore it is not discussed in this Appendix.

GSMO #2 serves to highlight data needs directly related to improving data density and distribution within the geostatistical model to predict areas of RIM with a 50% probability of exceeding 52.9 pCi/g. Areas for boring placement were selected using the following tools and objectives, which are further detailed in DIWP Appendix E.

<u>Qualitative review of standard deviation and RIM > 52.9 pCi/g</u>
First, the current model predictions of Standard Deviation to Warrant Sampling (SDWS) and probability of exceeding 52.9 pCi/g were mapped and reviewed for areas of relatively higher standard deviation (SD). Regions of the highest SD were targeted for additional borings. Next, the model was rerun with inclusion of proposed borings as artificial data. Results of the current model alongside the proposed model with artificial data were graphically compared (see Appendix E) to discern if the areas of highest SD were being targeted.

<u>SDWS</u>
The SDWS metric was employed in Area 2 as discussed with USEPA.

Indicator Variability Metric (IVM)

An Indicator Variability Metric (IVM) was developed to mathematically combine the estimated indicator values (i.e. non-exceedance probability) with the SD. This process "weights," (places more emphasis on) areas where both non-exceedance probability (NEP) approaches 0.5 and where SD is relatively higher. Therefore, this metric highlights the intersection of areas both near the threshold of interest (0.5 NEP) and where the uncertainty is highest. Results of this exploratory analysis were used to ensure that both the qualitative review and the SDWS correctly identified areas of model uncertainty for boring placement. IVM was not used as a primary driver of boring placement.

GSMO #3 identifies data needs related to areas of the site where additional data are required to refine total activity calculations and optimize the proposed excavation (additional discussion in DIWP main text), specifically:

- Areas where current estimates suggest that thorium is greater than 52.9 pCi/g and radium is less than 52.9 pCi/g
- Along the currently estimated 52.9 pCi/g boundary
- Isolated pockets where RIM greater than 52.9 pCi/g is shallower than 12 feet below 2005 ground surface (B2005GS), as identified in the PEP Figures 13 and 14

Additional discussion of GSMO #3 is presented in the body of the DIWP report.

1.2 Detailed Stepwise Process

While the processes identified above summarize the evaluation related to specific DIOs and GSMOs, the following sequence describes the detailed step-by-step approach used to identify boring locations. This process began with qualitative comparisons and became more quantitative with the development and use of SDWS as a statistically based determination of the number of borings and locations necessary to meet the DIWP objectives.

1. Spatial areas were identified where the model estimated RIM >52.9 pCi/g and there were no borings already located in these areas. In other words, regions of predicted RIM >52.9 pCi/g that were not substantiated by hard or soft data were identified. Proposed borings were added to these areas.
2. Areas where thorium was estimated above 52.9 pCi/g, and radium was below 52.9 pCi/g were identified. Additional borings were added in these areas, if not coincident with proposed borings already added.
3. Additional borings were added in where:
   - The RIM shell geometry was complex, with irregular and/or lenticular shapes that were sometimes vertically separated by estimated material <52.9 pCi/g
   - Areas that were predicted to contain high activities
   - Areas of RIM that were based on model estimates without previous borings
4. The standard deviation field was mapped to graphically determine areas of highest error, while considering RIM activities. Additional borings were added in these areas, if not coincident with other proposed borings.
5. Areas of estimated activity between 7.9 and 52.9 pCi/g were identified and proposed borings were located where no borings had been previously drilled.
6. Overland gamma survey results from the original Remedial Investigation (Engineering Management Support Inc. 2000) were compared to previous and proposed borings to ensure these areas were accounted for. Because these overland gamma data could not be incorporated into the geostatistical model, there were some discrepancies between the modelled extent of RIM and areas of elevated overland gamma results from this survey. As such, borings were added to areas that did not overlap with other proposed additional borings. In other words, the overland gamma results from the original RI were compared with the proposed

borings defined above, and if there were areas (of reasonable size) of overland gamma with no borings, additional proposed borings were added.

7. Comparison of existing and proposed borings (above) with a 2,000-square-meter grid; if there were any grid cells without a boring an additional proposed boring was added to that grid cell center. The use of the 2,000-square-meter grid was chosen both as a qualitative reference point and as a mechanism for “infilling” areas without borings.
8. The SDWS tool was used for highlighting regions to target for sampling based on standard deviation and RIM NEP, as developed by the USEPA in response to Comment #17 of the USEPA’s Comments on 3/30/2020 Design Investigation Work Plan.
9. The IVM, which combines standard deviation and indicators with a weighted function that identifies areas of highest SD and RIM near 52.9 pCi/g, was used as a graphical comparison to other evaluation methods as discussed above.
10. Recommendations from USEPA, including Figures 17 and 18 from the RODA (USEPA 2018).

The above sequence of analyses represents a combination of graphical, analytical, and statistical methods used to support the identification of sufficient locations without excessive redundancy, thereby resulting in a resource-effective design investigation.

Figure F.1 (Area 1) and **Figure F.2** (Area 2) were incorporated into this Appendix to provide a visual aid showing borings arranged by criteria in a layered PDF. Individual layers can be turned “on” and “off” to provide an interactive view, and thus deeper understanding, of how the boring program was designed and optimized to fulfill the DIOs and GSMOs in Areas 1 and 2. **Figures F.1** and **F.2** display the same information included in the DIWP, but were separated by radiological area and organized into a layered PDF format for ease of comparison.

2.0 AREA 1 PROPOSED BORINGS

Table F.1 provides a summary of borings proposed within Area 1 that were placed to address areas requiring additional data collection identified using the tools and site areas listed in Section 1. **Figure F.1** shows the proposed borings in Area 1 and includes layers for IVM, Intermediate Cumulative Distribution Function (CDF), Final CDF, as well as areas of deeper RIM and isolated pockets of RIM, which are also discussed in the body of the DIWP report. Areas of thorium-driven RIM are not explicitly called out in these figures, but estimated lateral and vertical distribution of RIM extent in areas where RIM is thought to consist of combined thorium activities greater than 52.9 pCi/g and combined radium activities less than 52.9 pCi/g are included in Section 3.2.2.1 of the DIWP and detailed in Appendix E.

TABLE F-1 AREA 1 BORING PLACEMENT

Placement Metric	Proposed Borings
CDF	A1-SB056, A1-SB057, A1-TH082, A1-TH084, A1-TH085, A1-TH086
Thorium-driven (systematic spacing)	A1-TH081, A1-TH082, A1-TH084, A1-TH085, A1-TH086, A1-TH087, A1-TH088, A1-TH089, A1-TH090
Isolated Pockets	A1-SB056, A1-SB060, A1-SB061, A1-SB062, A1-SB064, A1-SB065, A1-TH082, A1-TH084, A1-TH085, A1-TH086, A1-TH087, A1-TH088, A1-TH089, A1-SB128, A1-SB141, A1-SB145, A1-SB147
Deeper RIM (12-20 feet B2005GS) (1)	A1-SB053, A1-SB054, A1-SB060, A1-SB061, A1-SB063, A1-SB069, A1-SB070, A1-SB070-DUP, A1-TH084, A1-TH085, A1-TH087, A1-TH088, A1-TH089
52.9 pCi/g Boundary	A1-SB052, A1-SB053, A1-SB054, A1-SB055, A1-SB056, A1-SB057, A1-SB061, A1-SB062, A1-SB063, A1-SB064, A1-SB065, A1-SB068, A1-SB068-DUP, A1-SB069, A1-SB071, A1-SB072, A1-SB073, A1-SB074, A1-SB075, A1-TH081, A1-TH082, A1-TH085, A1-TH086, A1-TH090, A1-SB128, A1-SB140, A1-SB141, A1-SB144, A1-SB145
RIM between 7.9 and 52.9 pCi/g	A1-SB058, A1-SB059, A1-SB062, A1-SB064, A1-SB066, A1-SB067, A1-SB076, A1-SB083, A1-SB128, A1-SB129, A1-SB141, A1-SB142, A1-SB143, A1-SB144, A1-SB145

Notes:

(1) The 13 borings listed in **Table F.1** with the purpose of defining deeper RIM were placed in specific areas where the excavation is expected to be optimized to include deeper RIM removal. However, all interior RIM borings will be installed to 20 feet B2005GS with continuous core scanning and downhole gamma logging. Therefore all interior RIM borings will aid in the delineation of RIM greater than 52.9 pCi/g from 12 to 20 feet B2005GS.

3.0 AREA 2 PROPOSED BORINGS

Table F.2 provides a summary of borings proposed within Area 2 that were placed to address areas requiring additional data collection identified using the tools and site areas listed in Section 1. Figure F.2 shows the proposed borings in Area 2 and includes layers for IVM, Intermediate CDF, Final CDF, as well as areas of deeper RIM and isolated pockets of RIM as discussed in the body of the DIWP report.

TABLE F.2 AREA 2 BORING PLACEMENT

Placement Metric	Proposed Borings
CDF	A2-SB001, A2-SB006, A2-SB007, A2-SB009, A2-SB018, A2-SB021, A2-SB022, A2-SB025, A2-SB026, A2-SB030, A2-SB034, A2-SB036, A2-SB037, A2-SB043, A2-SB045, A2-SB078, A2-TH091, A2-TH092, A2-TH096, A2-TH099, A2-TH101, A2-TH105, A2-TH111, A2-TH112, A2-TH114, A2-TH115, A2-TH118, A2-TH120, A2-TH121, A2-SB136, A2-SB137
Thorium-driven (systematic spacing)	A2-TH091, A2-TH092, A2-TH094, A2-TH095, A2-TH096, A2-TH097, A2-TH098, A2-TH099, A2-TH100, A2-TH101, A2-TH102, A2-TH104, A2-TH105, A2-TH106, A2-TH107, A2-TH108, A2-TH109, A2-TH110, A2-TH111, A2-TH112, A2-TH113, A2-TH114, A2-TH115, A2-TH116, A2-TH117, A2-TH118, A2-TH119, A2-TH120, A2-TH121, A2-TH122, A2-TH123, A2-TH124, A2-TH125, A2-TH126, A2-TH127
Isolated Pockets	A2-SB006, A2-SB007, A2-SB009, A2-SB019, A2-SB022, A2-SB023, A2-SB024, A2-SB039, A2-SB040, A2-SB041, A2-SB042, A2-SB078, A2-TH091, A2-TH092, A2-TH096, A2-TH100, A2-TH101, A2-TH102, A2-TH105, A2-TH106, A2-TH107, A2-TH108, A2-TH109, A2-TH110, A2-TH111, A2-TH112, A2-TH113, A2-TH114, A2-TH115, A2-TH116, A2-TH117, A2-TH118, A2-TH119, A2-TH120, A2-TH121, A2-TH122, A2-TH123, A2-TH124, A2-TH125, A2-TH126, A2-TH127, A2-SB132, A2-SB137, A2-SB154
Deeper RIM (12-20 feet B2005GS) (1)	A2-SB002, A2-SB003, A2-SB005, A2-SB007, A2-SB013, A2-SB017, A2-SB031, A2-SB032, A2-SB033, A2-SB034, A2-SB036, A2-SB038, A2-SB039, A2-SB051
52.9 pCi/g Boundary	A2-SB001, A2-SB002, A2-SB003, A2-SB004, A2-SB005, A2-SB006, A2-SB012, A2-SB014, A2-SB015, A2-SB016, A2-SB017, A2-SB019, A2-SB022, A2-SB023, A2-SB024, A2-SB026, A2-SB028, A2-SB030, A2-SB031, A2-SB032, A2-SB033, A2-SB034, A2-SB036, A2-SB037, A2-SB039, A2-SB040, A2-SB041, A2-SB042, A2-SB043, A2-SB045, A2-SB046, A2-SB047, A2-SB079, A2-TH095, A2-TH096, A2-TH097, A2-TH098, A2-TH099, A2-TH100, A2-TH101, A2-TH102, A2-TH104, A2-TH107, A2-TH110, A2-TH111, A2-TH112, A2-TH113, A2-TH114, A2-TH115, A2-TH116, A2-TH117, A2-TH118, A2-TH119, A2-TH120, A2-TH121, A2-TH122, A2-TH123, A2-TH124, A2-TH125, A2-TH126, A2-TH127, A2-SB130, A2-SB132, A2-SB134, A2-SB135, A2-SB136, A2-SB137, A2-SB138, A2-SB146
RIM between 7.9 and 52.9 pCi/g	A2-SB001, A2-SB008, A2-SB013, A2-SB016, A2-SB027, A2-SB029, A2-SB044, A2-SB046, A2-SB048, A2-SB050, A2-SB077, A2-SB079, A2-SB080, A2-SB093, A2-SB103, A2-SB131, A2-SB135, A2-SB139, A2-SB147, A2-SB148, A2-SB149, A2-SB154

Placement Metric	Proposed Borings
SDWS (boring located with other metrics that also intersect areas of elevated SDWS)	A2-SB002, A2-SB003, A2-SB004, A2-SB005, A2-SB006, A2-SB007, A2-SB008, A2-SB009, A2-SB010, A2-SB011, A2-SB012, A2-SB013, A2-SB014, A2-SB015, A2-SB016, A2-SB017, A2-SB018, A2-SB019, A2-SB020, A2-SB021, A2-SB022, A2-SB023, A2-SB024, A2-SB025, A2-SB026, A2-SB027, A2-SB028, A2-SB029, A2-SB030, A2-SB031, A2-SB032, A2-SB033, A2-SB034, A2-SB035, A2-SB036, A2-SB037, A2-SB038, A2-SB039, A2-SB040, A2-SB041, A2-SB042, A2-SB043, A2-SB044, A2-SB045, A2-SB046, A2-SB047, A2-SB048, A2-SB049, A2-SB050, A2-SB051, A2-SB077, A2-SB078, A2-SB079, A2-SB080, A2-SB093, A2-SB103, A2-SB130, A2-SB131, A2-SB132, A2-SB133, A2-SB134, A2-SB135, A2-SB136, A2-SB137, A2-SB138, A2-SB139, A2-SB146, A2-SB154, A2-SB156, A2-SB157, A2-TH091, A2-TH092, A2-TH094, A2-TH095, A2-TH096, A2-TH097, A2-TH098, A2-TH099, A2-TH100, A2-TH101, A2-TH102, A2-TH104, A2-TH105, A2-TH106, A2-TH107, A2-TH108, A2-TH109, A2-TH110, A2-TH111, A2-TH112, A2-TH113, A2-TH114, A2-TH115, A2-TH116, A2-TH117, A2-TH118, A2-TH119, A2-TH120, A2-TH121, A2-TH122, A2-TH123, A2-TH124, A2-TH125, A2-TH126, A2-SB156, A2-SB157

Notes:

(1) The 14 borings listed in **Table F.2** with the purpose of defining deeper RIM were placed in specific areas where the excavation is expected to be optimized to include deeper RIM removal. However, all interior RIM borings will be installed to 20 feet B2005GS with continuous core scanning and downhole gamma logging. Therefore all interior RIM borings will aid in the delineation of RIM greater than 52.9 pCi/g 12-20 feet B2005GS.

4.0 SUMMARY

Table F.3 provides a summary of borings proposed in areas identified for data collection through IVM, CDF, and SDWS comparison tools, and as dictated through the DIOs and GSMOs. The following table shows the number of borings proposed to address each category. However, the majority of proposed boring locations satisfy two or more of the data needs identified in the "Placement Metric" column of the table, as illustrated through comparison of boring "Total (with redundancy)" versus boring "Total (optimized)" for both Areas 1 and 2. Laboratory analytical sample counts were calculated using the sampling approach detailed in the Field Sampling Plan for general Interior RIM and Thorium-focused boring types ("SB" and "TH" prefixes, respectively).

TABLE F.3 BORING PROGRAM SUMMARY

Placement Metric	Boring Count Area 1	Boring Count Area 2
CDF	6	31
Thorium-driven (systematic spacing)	9	35
Isolated Pockets	17	44
Deeper RIM (12-20 feet B2005GS)	13	14
52.9 pCi/g Boundary	29	69
RIM between 7.9 and 52.9 pCi/g	15	22
SDWS	0	106
Total (with redundancy)	89	321
Total (optimized)	45	111

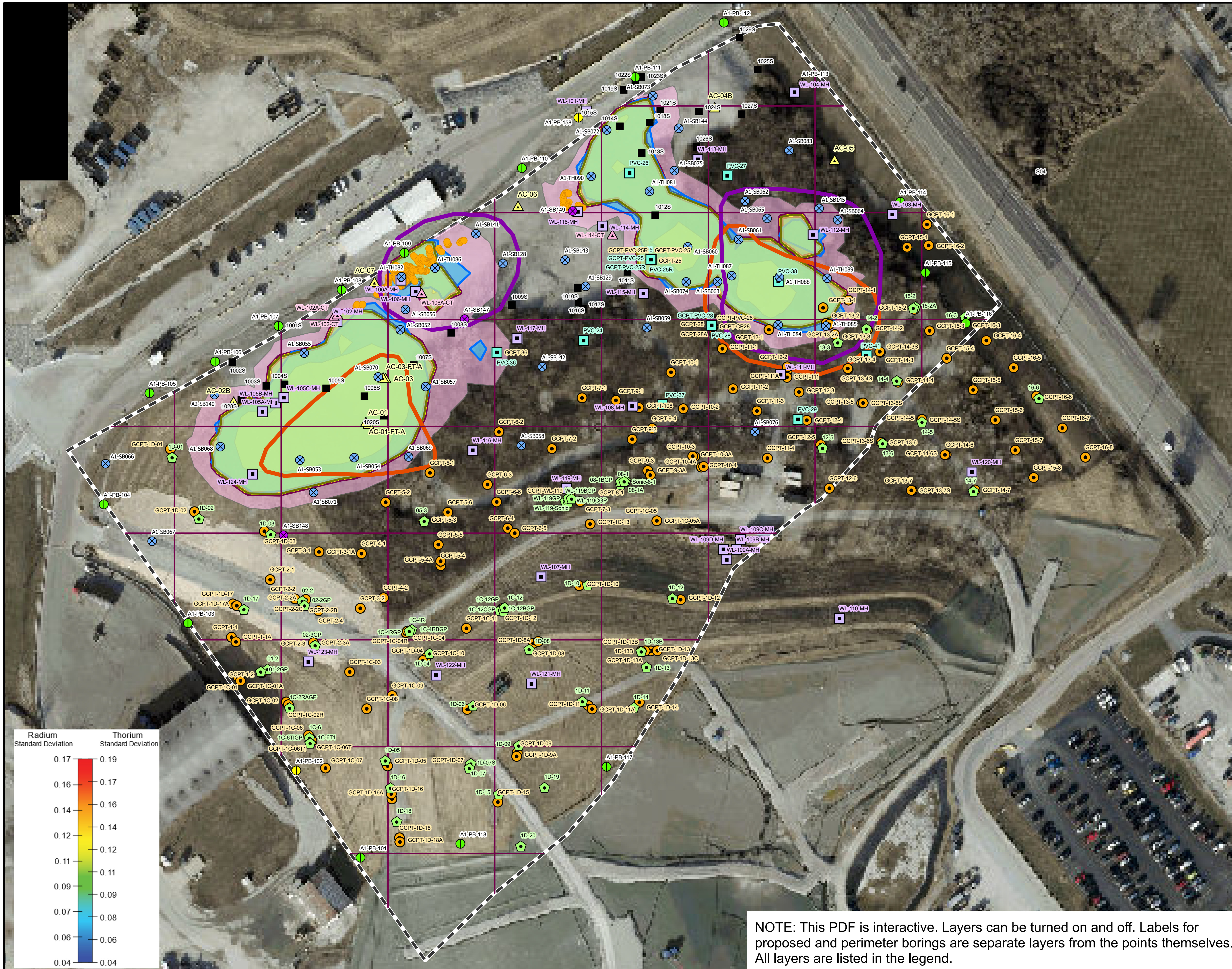
Optimization, as it refers to the boring and sampling plan, results in a single boring fulfilling multiple purposes. Gridded borings in thorium-driven areas, for example, generally also satisfy needs related to delineating isolated pockets of RIM. Borings are proposed strategically to minimize redundancy to the extent practical. The "Total (with redundancy)" values in **Table F.3** demonstrate boring/sample counts that would be required if each placement metric was assigned a single dedicated boring, while the "Total (optimized)" borings represent the proposed boring and sampling plan.

5.0 REFERENCES

Engineering Management Support Inc. 2000. Remedial Investigation Report, West Lake Landfill, Operable Unit 1.

USEPA. 2018. *Record of Decision Amendment, West Lake Landfill Site, Bridgeton, Missouri, Operable Unit 1.* Sep 2018, U.S. Environmental Protection Agency.

FIGURES



NOTE: This PDF is interactive. Layers can be turned on and off. Labels for proposed and perimeter borings are separate layers from the points themselves. All layers are listed in the legend.

Proposed Borings

- Enclosure A Borings
- USEPA Perimeter Borings
- USEPA Proposed Interior Borings
- Proposed Interior Borings
- Perimeter Borings

Historical Data

- Additional Characterization Data
- Phase1 Data (no GCPT)
- Cotter Data
- McLaren/Hart Data
- NRC Data
- GCPT Locations
- Surface Samples
- Grid
- Isolated Pockets
- Deeper RIM
- Standard Deviation Warrant to Sample (see color scale on map)

Overland Gamma Survey

- Overland Gamma Survey >1000 μR/hr
- Overland Gamma Survey 250-1000 μR/hr
- Overland Gamma Survey 40-250 μR/hr

Final vs. Intermediate Cumulative Distribution Functions (CDFs)

- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS (Final CDF, 50% Probability)
- Intermediate CDF - Maximum extent of RIM >52.9 pCi/g 0-16 ft B2005GS

Indicator Variability Metric (IVM)

- Maximum extent of RIM >52.9 pCi/g 0-16 ft B2005GS

25%, 50%, 75% Probabilities

- 75% probability of being RIM >52.9pCi/g
- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- 25% probability of being RIM >52.9pCi/g
- OU-1 Area Boundary

0 55 110 220 Feet

N

Figure F-1

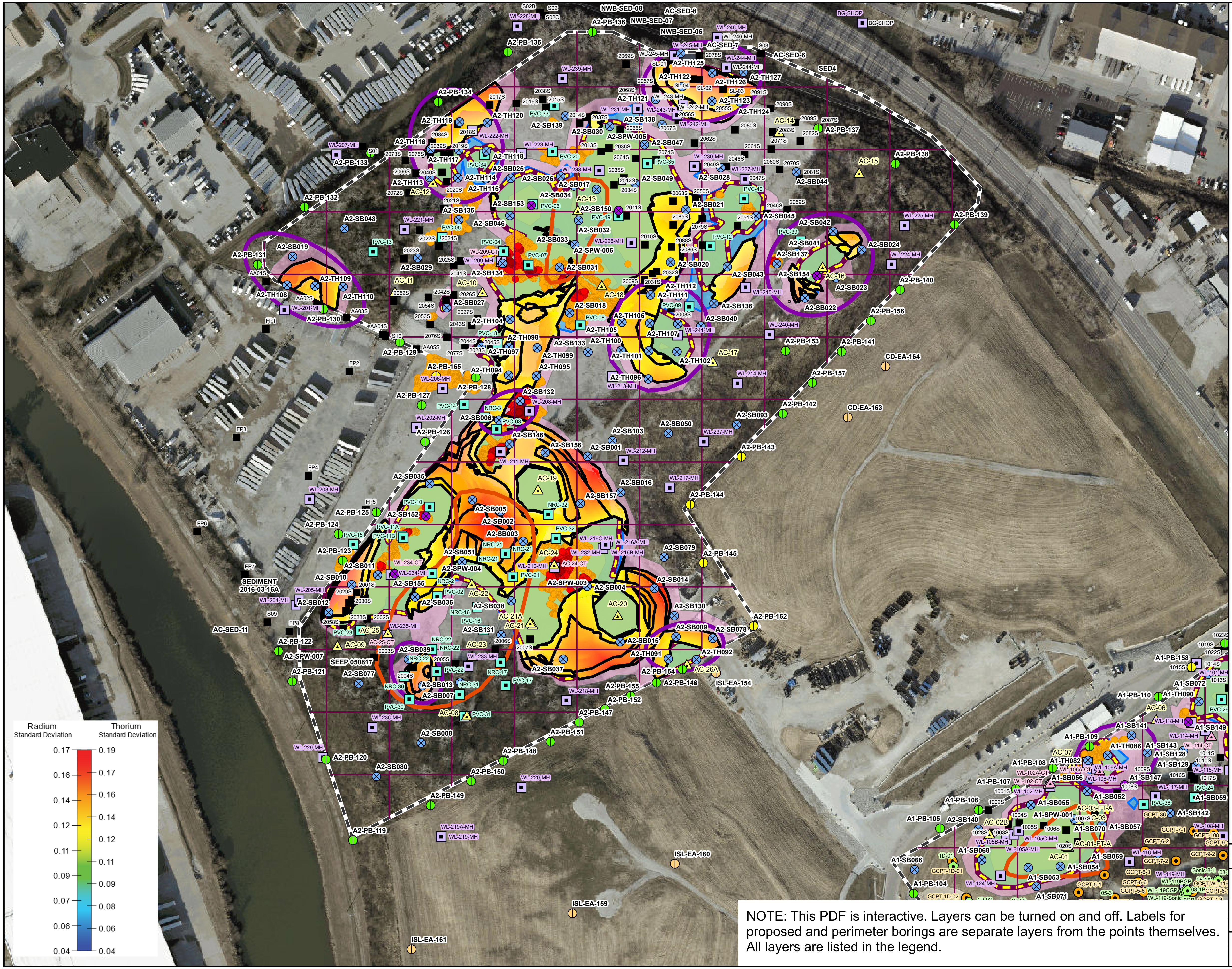
Area 1
Proposed Borings (Layered)

PARSONS
301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-451-9560

Plotted By: CS

Plot Date: 9/11/2020

Document Path: C:\Users\p002737e\Documents\West Lake\ArcMap Data\DIWP Figures\West Lake Package.aprx



Proposed Borings
- Enclosure A Borings
- USEPA Proposed Interior Borings
- USEPA Proposed Perimeter Borings
- Proposed Interior Borings
- Proposed Perimeter Borings

Historical Data
- Additional Characterization Data
- Phase1 Data (no GCPT)
- Cotter Data
- McLaren/Hart Data
- NRC Data
- GCPT Locations
- Surface Samples
- Grid
- Isolated Pockets
- Deeper RIM
- Standard Deviation Warrant to Sample (see color scale on map)

Overland Gamma Survey
- Overland Gamma Survey >1000 µR/hr
- Overland Gamma Survey 250-1000 µR/hr
- Overland Gamma Survey 40-250 µR/hr
- Maximum extent of RIM >52.9 pCi/g 0-16 ft B2005GS

Final vs. Intermediate Cumulative Distribution Functions (CDFs)
- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS (Final CDF, 50% Probability)
- Intermediate CDF - Maximum extent of RIM >52.9 pCi/g 0-16 ft B2005GS

25%, 50%, 75% Probabilities
- 75% probability of being RIM >52.9pCi/g
- Maximum Extent of RIM >52.9 pCi/g 0-16 ft B2005GS
- 25% probability of being RIM >52.9pCi/g
- OU-1 Area Boundary

0 100 200 400 Feet N

Figure F-2

Area 2
Proposed Borings (Layered)

PARSONS
301 PLAINFIELD ROAD, SUITE 350, SYRACUSE, NY 13212 • 315-451-9560

Plotted By: CS
Plot Date: 10/9/2020

Document Path: C:\Users\p003308E\Documents\ArcGIS\Packages\West Lake Layered PDF Package Oct8_4c42cf\p20\West Lake Package.aprx