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U.S. Nuclear Regulatory Commission  
Division of Decommissioning, Uranium Recovery, and Waste Programs  
Material Decommissioning Branch  
TWFN Mail Stop T-8F5  
Rockville, MD 20852

**SUBJECT: FINAL REPORT—INDEPENDENT CONFIRMATORY SURVEY  
SUMMARY AND RESULTS FOR SURVEY UNITS LSA 10-03 AND  
LSA 10-04 AND SCAN SURVEY RESULTS FOR LSA 10-01 AND LSA 10-02  
FOR THE HEMATITE DECOMMISSIONING PROJECT,  
FESTUS, MISSOURI (RFTA NO. 14-003); DCN 5184-SR-05-0**

Dear Mr. Smith:

ORAU is pleased to provide the enclosed final report detailing the independent confirmatory survey activities of Survey Units LSA 10-03, LSA 10-04, and scan survey results for LSA 10-01 and LSA 10-02 at the Hematite Decommissioning Project in Festus, Missouri. This report provides the summary and results of activities performed by ORAU, under the Oak Ridge Institute for Science and Education (ORISE) contract, during the period of May 4–7, 2015. Comments on the June 2015 draft version of this report have been incorporated.

You may contact me via at 865.241.8793 or Erika Bailey at 865.576.6659 if you have any questions.

Sincerely,

Evan M. Harpenau  
Health Physicist  
ORAU

EMH:fs

Enclosure

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**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS  
FOR SURVEY UNITS LSA 10-03 AND LSA 10-04 AND  
SCAN SURVEY RESULTS FOR LSA 10-01 AND LSA 10-02  
FOR THE HEMATITE DECOMMISSIONING PROJECT,  
FESTUS, MISSOURI**

**FINAL REPORT**



Prepared by  
Evan M. Harpenau

**APRIL 2016**

Prepared for the  
U.S. Nuclear Regulatory Commission

Prepared by ORAU under the Oak Ridge Institute for Science and Education contract, number DE-AC05-06OR23100, with the U.S. Department of Energy under interagency agreement (NRC FIN No. F-1244) between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy.



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**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS  
FOR SURVEY UNITS LSA 10-03 AND LSA 10-04 AND  
SCAN SURVEY RESULTS FOR LSA 10-01 AND LSA 10-02  
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**EXECUTIVE SUMMARY**

The U.S. Nuclear Regulatory Commission (NRC) requested that ORAU, working under the Oak Ridge Institute for Science and Education (ORISE) contract, perform an independent confirmatory survey at the Hematite Decommissioning Project (HDP) in Festus, Missouri. Westinghouse Electric Company, LLC (WEC) is currently engaged in the decontamination and decommissioning of the approximate ten-acre Central Tract. This report focuses on confirmatory survey activities performed on land survey areas (LSAs) 10-03 and 10-04, as well as confirmatory gamma scan surveys of LSAs 10-01 and 10-02 in support of their release for unrestricted use.

The confirmatory survey activities included document reviews, gamma walkover surveys, soil sampling activities, and laboratory analysis of confirmatory soil samples. Field activities included gamma and beta radiation surveys and soil sampling during the period of May 4–7, 2015. Based on the findings of the confirmatory survey, ORAU is of the opinion that the licensee has adequately demonstrated that survey units LSA 10-03 and 10-04 meet the release criteria. ORAU was unable to fully assess the residual radiological status of LSAs 10-01 and 10-02 because the NRC's request was limited to performing confirmatory gamma scan surveys, but the walkover survey data show that gamma surface activity levels were within the background variance for the site.



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**INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS  
FOR SURVEY UNITS LSA 10-03 AND LSA 10-04 AND  
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## **1. INTRODUCTION**

Westinghouse Electric Company, LLC (WEC) is in the process of removing radiologically contaminated materials from a former nuclear fuel fabrication facility near Festus, Missouri now known as the Hematite Decommissioning Project (HDP). From its inception in 1956 through 1974, the facility was used primarily in support of government contracts that required the production of highly enriched uranium products. From 1974 through plant closure in 2001, the focus changed from government contracts to commercial fuel production. Specifically, operations included the conversion of uranium hexafluoride gas of various uranium enrichments to uranium oxide, uranium carbide, uranium dioxide pellets, and uranium metal. Secondary operations included research and development and uranium scrap recovery processes.

The site is located in Jefferson County, Missouri, less than four miles west of the town of Festus, Missouri, and 35 miles south of the city of St. Louis. It is surrounded by forest, agricultural lands, and low-density residential housing (Figure A-1). The entire site consists of approximately 228 acres; however, the impacted portion of the site—referred to as the central tract—includes approximately 19 acres.

The U.S. Nuclear Regulatory Commission (NRC) is responsible for oversight of permitted license activities that are currently being conducted at the HDP. The NRC requested that ORAU, under the Oak Ridge Institute for Science and Education (ORISE) contract, perform confirmatory surveys of final status survey (FSS) units land survey areas (LSAs) 10-03 and 10-04. While on site, the NRC also requested that ORAU perform gamma scan surveys of LSAs 10-01 and 10-02 if time permitted. The primary focus of confirmatory activities during the May trip was on survey units (SUs) LSAs 10-03 and 10-04, which are located in the North Burial Pit Area. The burial pits had been used for radioactive and chemical waste disposal during the operational lifetime of the Hematite Fuel Fabrication Facility (WEC 2015a and 2015b) (Figure A-2). Confirmatory activities included

document reviews and the collection of independent survey data for the NRC's use in the assessment of the adequacy of the licensee's FSS process.

## 2. APPLICABLE SITE GUIDELINES

The primary radionuclides of concern (ROCs) at the HDP were technetium-99 (Tc-99), thorium-232 (Th-232), uranium-234 (U-234), U-235, and U-238. Radium-226 (Ra-226) is also considered to be a ROC within the Burial Pit Area (WEC 2011). The balance of ROCs, neptunium-237(Np-237), plutonium-239/240 (Pu-239/240), and americium-241 (Am-241), are considered to be insignificant based on the aggregate dose of these radionuclides being less than 10% of the total effective dose equivalent (TEDE) for each conceptual site model (CSM). However, their dose contributions have been accounted for in the adjusted derived concentration guideline levels (DCGL<sub>w</sub>s) accordingly (WEC 2011). A DCGL<sub>w</sub> is a radionuclide-specific activity concentration corresponding to a release criterion based on the spatial distribution of a contaminant as derived for the nonparametric statistical test.

Each radionuclide-specific DCGL<sub>w</sub> represents the concentration above background of a residual radionuclide that would result in a radiological dose of 25 millirem per year (mrem/yr) to the average member of the critical group (WEC 2013). For conservatism, the licensee has opted to compare the DCGL<sub>w</sub>s to gross soil concentrations with the exception of Ra-226 and Th-232. For consistency, ORAU's analytical data are presented and assessed in the same manner. Because each of the individual DCGL<sub>w</sub> represents 25 mrem/yr, the sum-of-the-fractions (SOF) approach is used to demonstrate compliance with the dose limit. SOF calculations are performed as follows:

$$\text{SOF}_{\text{TOTAL}} = \sum_{j=0}^n \text{SOF}_j = \sum_{j=0}^n \frac{C_j}{\text{DCGL}_{w,j}}$$

Where  $C_j$  is the concentration of ROC "j," and  $\text{DCGL}_{w,j}$  is the DCGL<sub>w</sub> for ROC "j." Note that gross concentrations are considered here for conservatism. The analytical results were evaluated and compared to the applicable Uniform Stratum DCGL (Uniform DCGL<sub>w</sub>) presented in Table 2.1.

Table 2.1. Adjusted Site-specific Soil DCGL<sub>ws</sub> by CSM<sup>a</sup>

Radionuclide	DCGL <sub>w</sub> By Conceptual Site Model (pCi/g)				
	Shallow Stratum	Root Stratum	Deep Stratum	Excavation Scenario	Uniform Stratum
Uranium-234	508.5	235.6	2,890	872.4	195.4
Uranium-235+D <sup>b</sup>	102.3	64.1	3,034	208.1	51.6
Uranium-238+D <sup>b</sup>	297.6	183.3	3,028	551.1	168.8
Technetium-99	151.0	30.1	98,649	74.0	25.1
Thorium-232+C <sup>c</sup>	4.7	2.0	9,279	5.2	2.0
Radium-226+C <sup>c</sup>	5.0	2.1	13,029	5.4	1.9

CSM = conceptual site model

<sup>a</sup>Table populated from WEC 2013 Table 14-4.

<sup>b</sup>+D indicates the DCGL<sub>w</sub> includes short-lived (half-life ≤6 mo.) decay products.

<sup>c</sup>+C indicates the DCGL<sub>w</sub> includes all radionuclides in the associated decay chain.

### 3. PROCEDURES

The confirmatory survey activities were conducted May 4–7, 2015, in accordance with a project-specific confirmatory survey plan approved by the NRC, the *ORAU Radiological and Environmental Survey Procedures Manual*, the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual*, and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2013, 2015a, 2015b, and 2014c).

ORAU performed high-density gamma radiation scans of the accessible soil surfaces within each SU. High-density walkover scans were performed in 1-meter intervals using Ludlum Model 44-10 sodium iodide (NaI) detectors coupled to Ludlum Model 2221 ratemeter-scalers with an audible indicator. The ratemeter-scalers were also coupled to global positioning systems (GPS) that enabled real-time gamma count rate and spatial data capture. Figures A-3 through A-6 show the spatially-oriented gamma walkover surveys for SUs LSA 10-01, 10-02, 10-03, and 10-04, respectively.

A ranked set sampling (RSS) design was used to estimate the mean radionuclide concentration in the SUs identified in the primary request (EPA 2002). The number of locations to evaluate and sample within each SU were calculated by using the contractor's FSS data and Visual Sample Plan software, version 7.3 (WEC 2015a and 2015b). As a result of the sample planning inputs, 18 ranking locations

were evaluated in both LSA 10-03 and 10-04. Following completion of walkover surveys, the RSS locations were laid out as illustrated in Figures A-7 and A-8. A one-minute static gamma measurement was made with the NaI detector at each ranking location. The surface measurements were then ranked, which resulted in the selection of 6 locations per SU for sampling. The 6 sample locations are presented in Figures A-9 and A-10 for LSA 10-03 and LSA 10-04, respectively. Additionally, due to the depth of the excavations after soil remediation, the perimeters of the SUs incorporated a benching to the sidewalls which, in turn, increased the surface area within each respective SU. Four additional randomly generated sidewall samples were collected from each of the SUs to account for the increased surface area created by the benched sidewalls (see Figures A-9 and A-10). Furthermore, one judgmental sample was collected from a sidewall location where post-sample surveys suggested the possibility of residual contamination.

Soil samples were returned to the ORAU/ORISE Radiological and Environmental Analytical Laboratory in Oak Ridge, Tennessee for laboratory analysis. Sample analyses were performed in accordance with the laboratory procedures manual (ORAU 2015b). Samples were analyzed by solid-state gamma spectroscopy for gamma-emitting ROCs. Tc-99 was quantified by radiochemical separation using extraction chromatography and counted by liquid scintillation. Analytical results were reported in units of picocuries per gram (pCi/g). Even though the gamma spectroscopy results identified enriched uranium at low levels (<5%) in several samples, the concentrations with respect to the U-235 DCGL<sub>w</sub> did not warrant alpha spectroscopic analysis. The U-234 concentrations were calculated using the ORAU U-238/U-235 analytical concentration ratios and then interpolating those data with Table 14-5 of the HDP decommissioning plan (WEC 2009) to calculate the U-234/U-235 ratio. The U-234/U-235 ratio was then multiplied by the U-235 concentration, resulting in an inferred U-234 concentration (Table B-1).

#### **4. RESULTS**

Gamma walkover scans of LSAs 10-01, 10-02, and 10-03 did not detect any areas with elevated direct gamma radiation in excess of the background count variability. Overall instrument response for these SUs ranged from less than 9,000 to 14,400 cpm with a mean count rate of approximately 11,000 cpm. Gamma radiation scan data for these SUs are shown in Figures A-3, A-4, and A-5. The walkover surveys in LSA 10-04 exhibited a count rate that increased as the survey progressed towards the southern and western edges of the SU. Overall instrument response in this SU ranged



from less than 9,000 to 17,500 cpm with a mean count rate also around 11,000 cpm (Figure A-6). A majority of the observed instrument responses for LSA 10-04 were also within the background count variability for all areas of the SU with the exception of the southern and western perimeters where count rates exceeded 15,300 cpm. The background count variability relates to data that is within  $\pm 3\sigma$  (sigma) of the mean as long as the mean is consistent with the predetermined background for the site while also considering surface geometry can cause a shift in background levels.

In addition to the random sample that was collected in the area of the highest observed count rate, ORAU collected a judgmental sample that spanned from the 6–24 inch depth below the surface. The judgmental sample location for the confirmatory survey is identified as 5184S0099 in Figure A-10. Review of the analytical results for the licensee’s corresponding investigation sample showed statistical agreement with sample 5184S0099 such that residual concentrations of the ROCs were below the Uniform Stratum DCGL<sub>ws</sub> and their subsequent SOF was less than unity.

A comprehensive summary of ORAU/ORISE Radiological and Environmental Analytical Laboratory sample results for site-related ROCs (excluding Pu-239/240, Am-241, and Np-237) is provided in Table B-2. Table 4.1 summarizes the ROC concentrations reported in Table B-2.

**Table 4.1. ORAU ROC Concentration Range Summary in pCi/g**

ROC	Gross Soil Activity Concentration Range		
U-234 <sup>a</sup>	1.49	to	69.72
U-235	0.08	to	3.85
U-238	0.97	to	14.7
Tc-99	-0.10	to	10.51
Th-232	0.60	to	1.55
Ra-226	0.62	to	1.07

<sup>a</sup>U-234 concentrations are calculated by determining the gamma spectroscopy U-238/U-235 ratio, then using Table 14-5 from the DP to determine the U-234/U-235 ratio (using interpolation) and hence the enrichment percentage. The U-235 value is then multiplied by the U-234/U-235 ratio to determine the U-234 concentration result. The U-234 error was propagated by assuming the U-234/U-235 ratio did not have an error.



The analytical results were evaluated and compared to the applicable Uniform DCGL<sub>w</sub> presented in Table 2.1. Comparisons to the Uniform DCGL<sub>w</sub>s were made using gross concentrations—i.e., the concentrations were not adjusted for soil background—with the exception of Ra-226 and Th-232, which were corrected for background concentrations of 0.9 and 1.0 pCi/g, respectively (WEC 2012). The SOFs for each sample was then calculated to evaluate compliance with the 25 mrem/year release criteria. WEC’s analytical results and SOF averages were evaluated against the confirmatory sample results to determine if the radionuclide concentrations reported from FSS activities were consistent with the results of the confirmatory surveys for each SU. The average SOF values of the random samples reported by WEC and for ORAU confirmatory samples are presented in Table 4.2 for comparison. All of the ROC concentrations in confirmatory soil samples, including the judgmental samples, were below the individual Uniform Stratum DCGL<sub>w</sub>, and the SOF calculations were less than unity.

Table 4.2. SOF Statistical Comparison <sup>a</sup>				
SOF	LSA 10-03		LSA 10-04	
	ORAU	WEC <sup>b</sup>	ORAU	WEC <sup>b</sup>
<b>Average</b>	0.27	0.20	0.22	0.11
<b>Standard Deviation<sup>c</sup></b>	0.08	0.09	0.23	0.08
<b>Minimum</b>	0.17	0.09	0.04	0.02
<b>Maximum</b>	0.39	0.36	0.77	0.34

<sup>a</sup>Sum-of-fractions (SOF) calculated using the unity rule for each radionuclide-of-concern. Background concentrations for Ra-226 and Th-232 were subtracted prior to the calculation; negative values were listed as a zero value in calculations. Based on the WEC analyses, background concentrations are as follows: Th-232 is 1.0 pCi/g and Ra-226 is 0.9 pCi/g (WEC 2012).

<sup>b</sup>WEC values calculated from WEC offsite summary data with ingrowth (WEC 2015c and 2015d)

<sup>c</sup>95% confidence interval

## 5. CONCLUSION

At NRC’s request, ORAU completed confirmatory surveys of two FSS survey units and performed gamma scans of two additional units at the Hematite Decommissioning Project during the period of May 4–7, 2015. The survey activities included document reviews, gamma walkover surveys, soil sampling activities, and laboratory analysis of confirmatory soil samples. All final confirmatory survey ROC concentrations from the LSA 10-03 and LSA 10-04 soil samples were below the individual Uniform Stratum DCGL<sub>w</sub> limits and also satisfied the SOF DCGL<sub>w</sub> criteria. The average



SOF concentrations between the ORAU and WEC sample populations for both SUs were in statistical agreement.

In addition, ORAU reviewed the licensee's MARSSIM-based elevated measurement comparison DCGL (DCGL<sub>EMC</sub>) for biased sample L10-04-13-B-E-B-00. Overall, ORAU did not find any issues in the methodology used for the calculation to dispute the licensee's determination. However, the following observations were made during review of their explanatory documentation. First, it was unclear to the reviewer as to how the licensee determined the 30 m<sup>2</sup> area factor to be sufficient in the DCGL<sub>EMC</sub> calculation. Second, the column headers in the table below Step 4.e. of document *Appendix G-2: Final Status Investigations for Soil Survey Units* appear to be out of sequence with the sample concentrations listed below them (WEC 2015e). Cross referencing was performed utilizing the LSA10-04 FSS Data Evaluation document (WEC 2015f). Third, the licensee's approach of including the fractional dose contributions of the re-use backfill material and ground water individually may have been overly conservative when determining whether a survey unit satisfies the DCGL<sub>EMC</sub>. ORAU does not have any documentation to support any explanation or resolution the licensee may have for these observations.

Based on the findings of the confirmatory survey, ORAU is of the opinion that the licensee has adequately demonstrated that survey units LSA 10-03 and 10-04 meet the release criteria. Though ORAU was unable to fully assess the residual radiological status of LSAs 10-01 and 10-02, the walkover survey data show that gamma surface activity levels were within the background variance for the site.



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## 5. REFERENCES

EPA 2002. *Guidance on Choosing a Sampling Design for Environmental Data Collection*. EPA QA/G-5S. U.S. Environmental Protection Agency Washington, DC. December.

ORAU 2013. *Final—Project-Specific Plan for Independent Confirmatory Survey Activities for the Hematite Decommissioning Project, Festus, Missouri*. 5184-PL-02-0. Oak Ridge Institute for Science and Education, managed by Oak Ridge Associated Universities. Oak Ridge, Tennessee. March 20.

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ORAU 2015c. *ORAU Environmental Services and Radiation Training Quality Program Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. August 7.

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WEC 2013 *Hematite Decommissioning Plan Chapter 14: HEM 13-10*; Revision 1.2. Westinghouse Electric Company, LLC. Festus, Missouri. February 12.

WEC 2015a. *Final Status Survey Sampling Plan Development Checklist for Soil Survey Units: LSA 10-03*. Hematite Decommissioning Project Technical Report. HDP-INST-FSS-10-06; Revision 1. Westinghouse Electric Company, LLC. Festus, Missouri. January.

WEC 2015b. *Final Status Survey Sampling Plan Development Checklist for Soil Survey Units: LSA 10-04*. Hematite Decommissioning Project Technical Report. HDP-INST-FSS-LSA10-07; Revision 1. Westinghouse Electric Company, LLC. Festus, Missouri. January.

WEC 2015c. *LSA 10-03 FSSDE WorksheetUniform*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. April 10.

WEC 2015d. *LSA 10-04 FSSDE WorksheetUniform*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. April 10.

WEC 2015e. *Appendix G-2: Final Status Investigations for Soil Survey Units*. Hematite Decommissioning Project Procedure. HDP-PR-FSS-721, Rev 5: Final Status Survey Data Evaluation. Westinghouse Electric Company, LLC. Festus, Missouri. September.



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WEC 2015f. *LSA 10-04 FSS Data Evaluation*. Microsoft Excel Workbook. Westinghouse Electric Company, LLC. Festus, Missouri. September.

**ATTACHMENT A**  
**FIGURES**



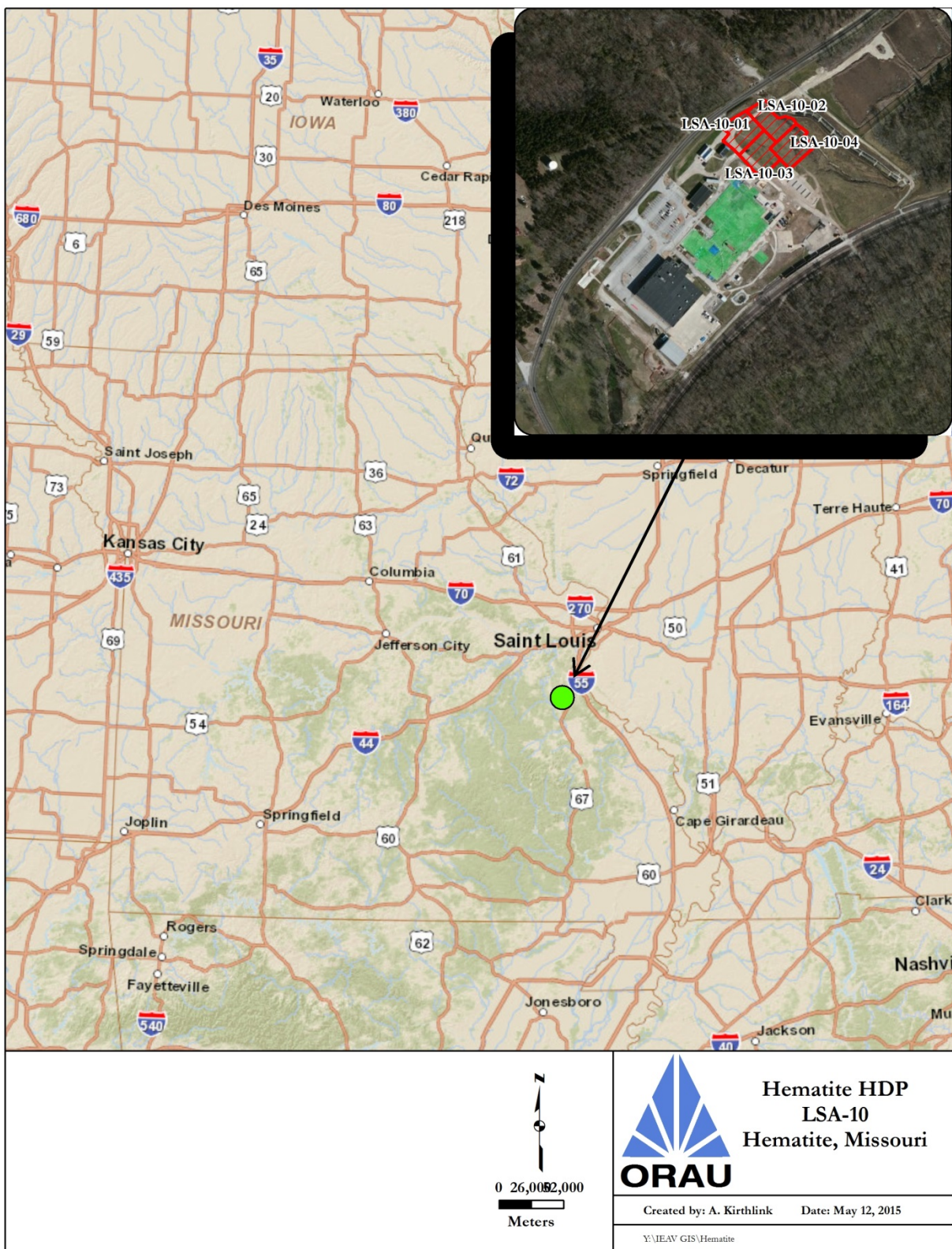


Figure A-1. Location of Hematite Decommissioning Project, Festus, Missouri



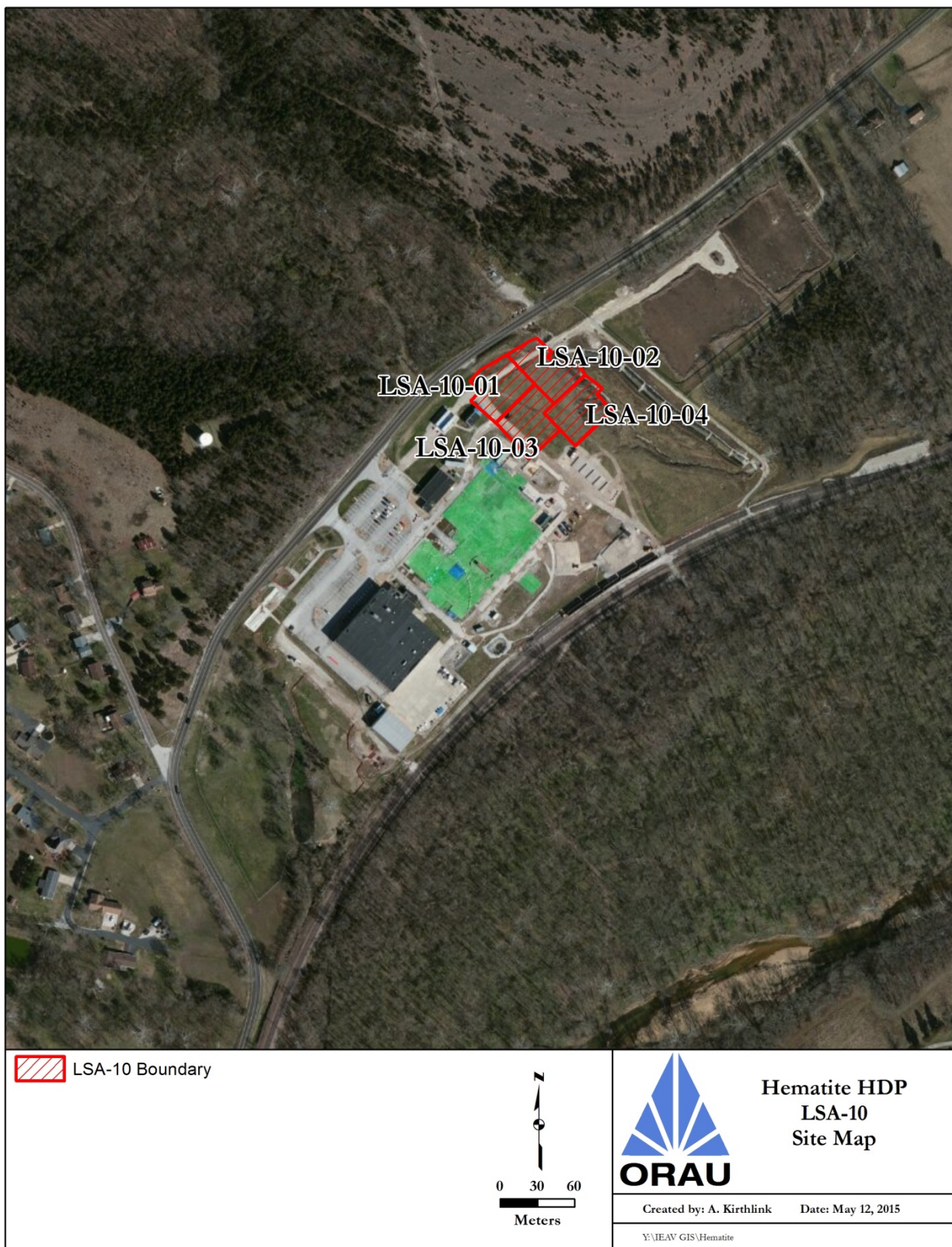


Figure A-2. Plot Plan of LSA 10-03 and LSA 10-04 at the Hematite Decommissioning Project



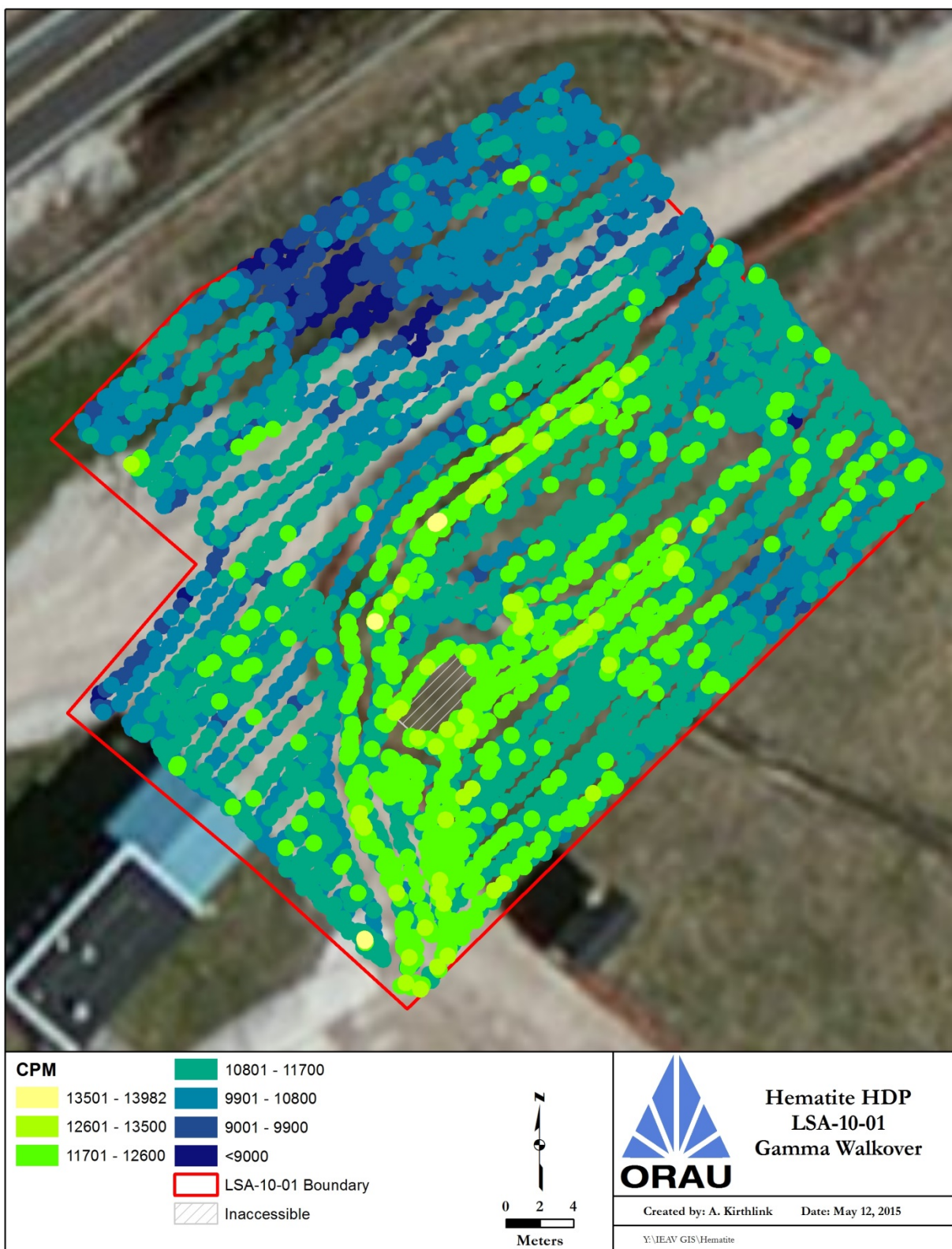


Figure A-3. LSA 10-01—Gamma Walkover Scans

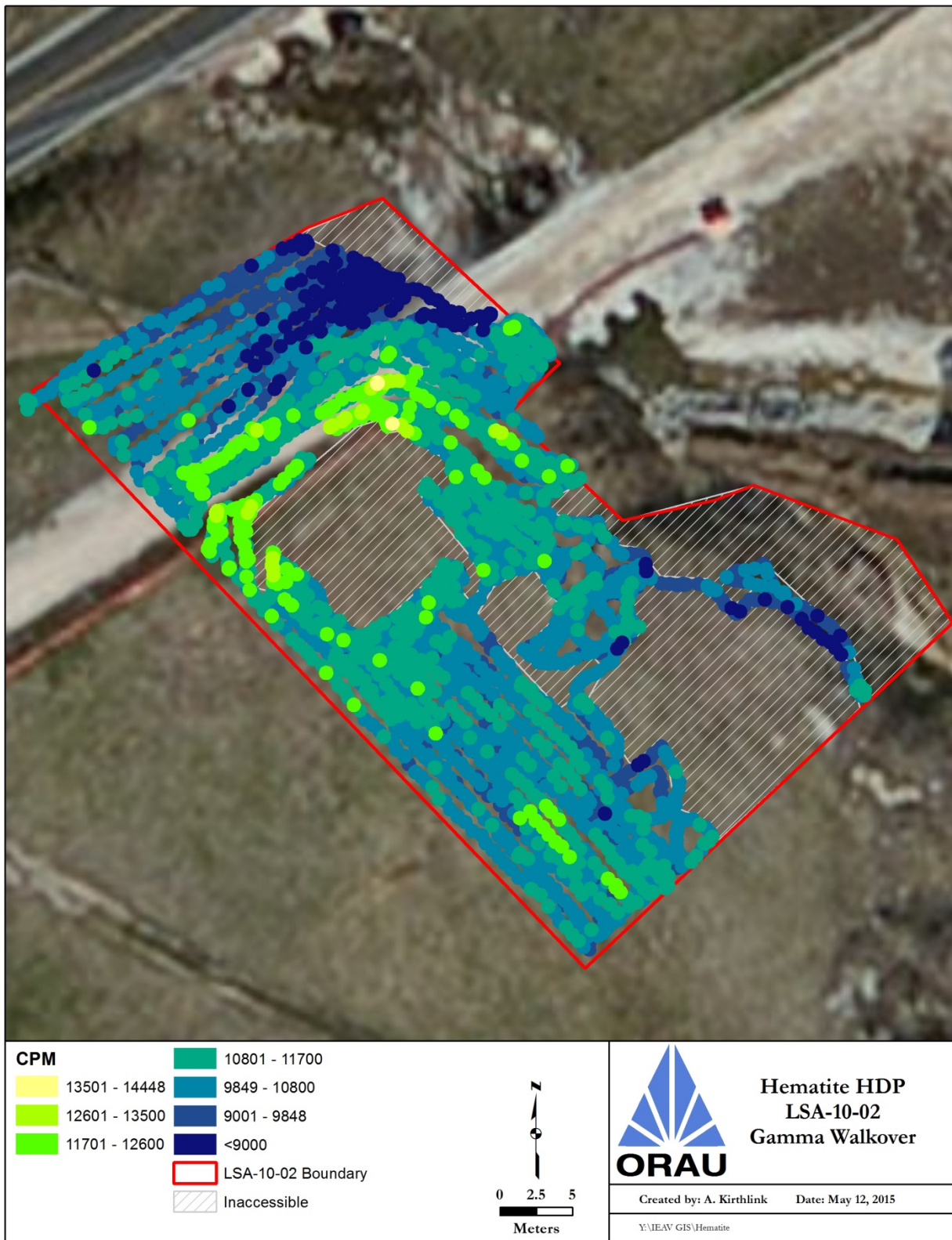


Figure A-4. LSA 10-02—Gamma Walkover Scans



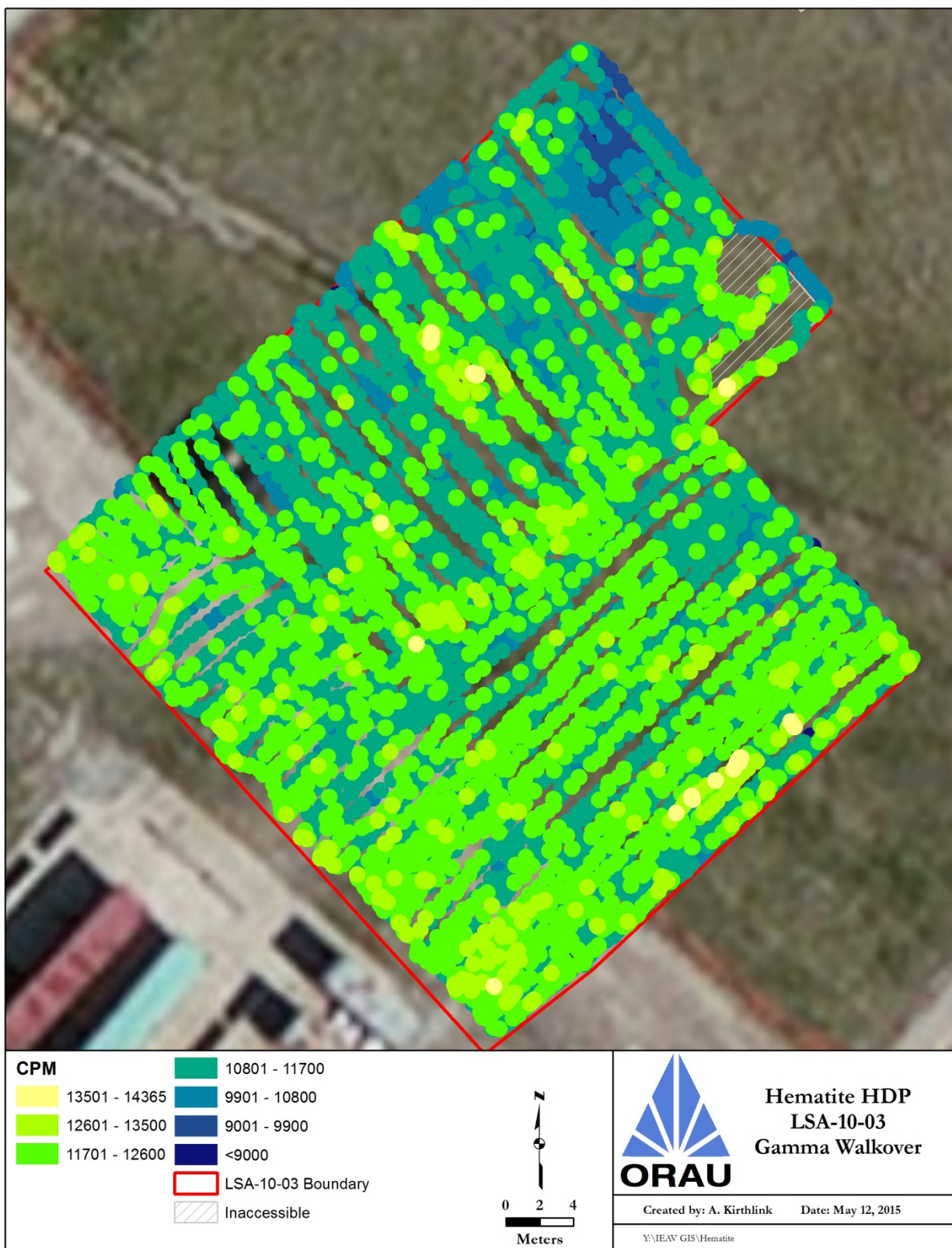


Figure A-5. LSA 10-03—Gamma Walkover Scans

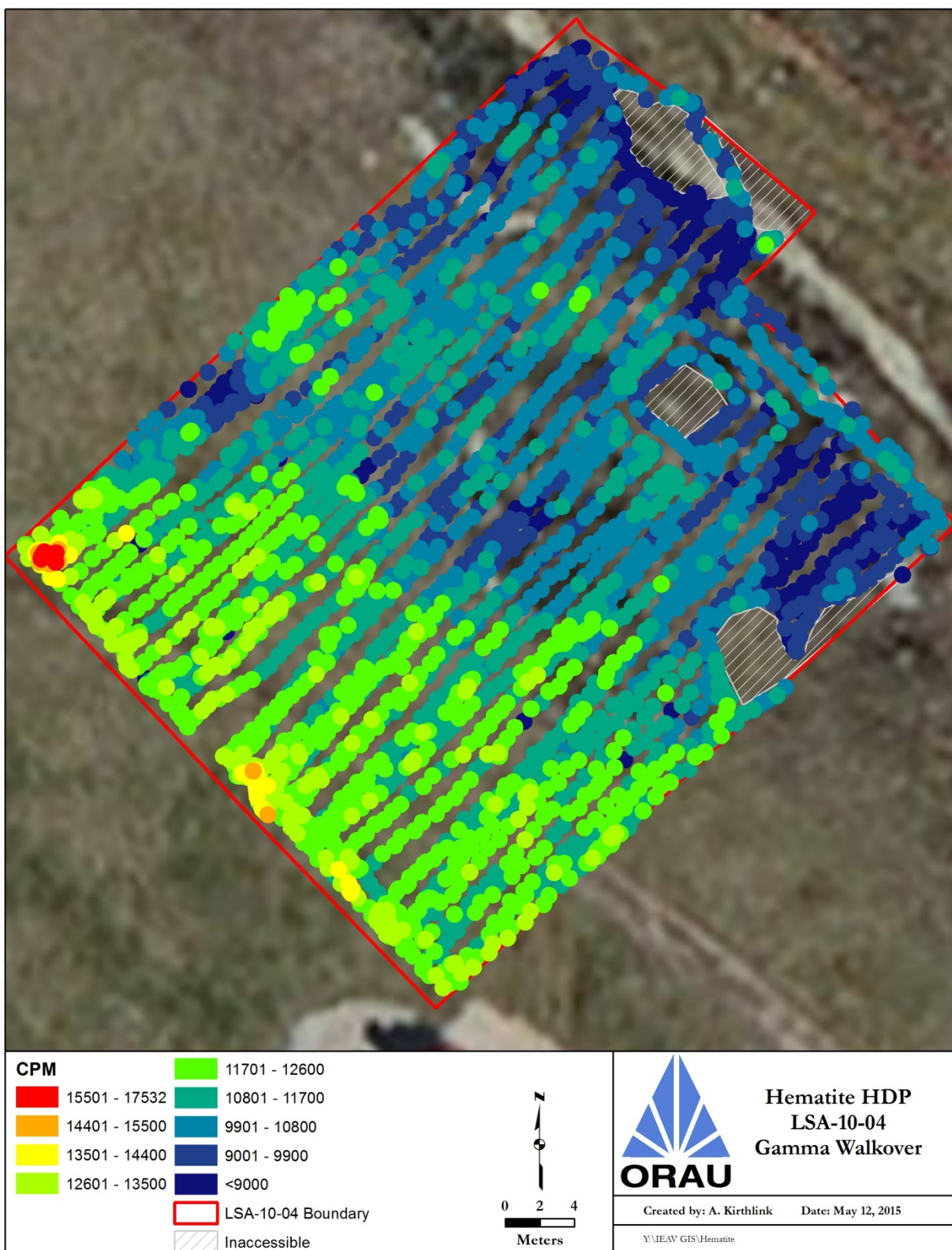


Figure A-6. LSA 10-04—Gamma Walkover Scans



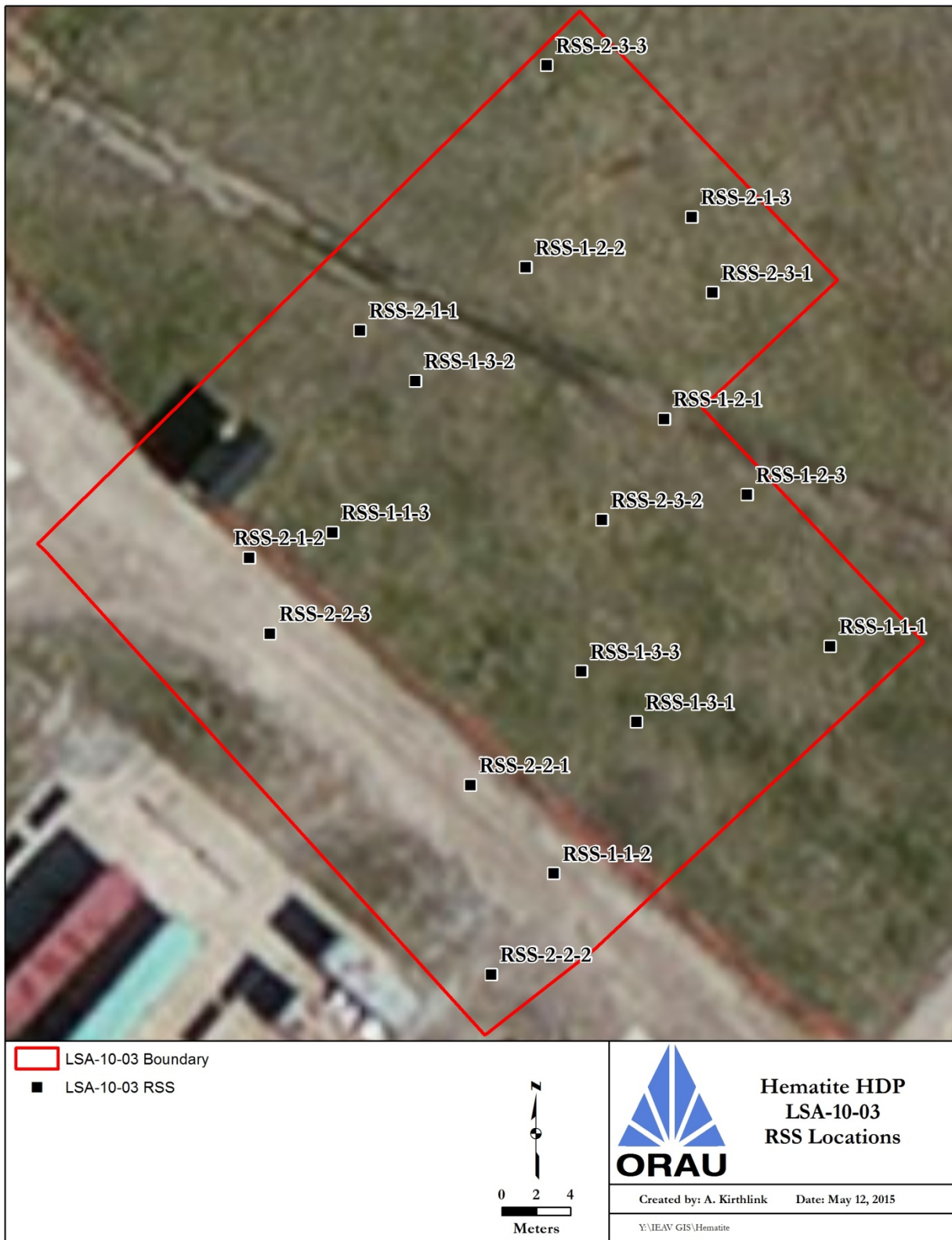


Figure A-7. LSA 10-03—Ranked Set Sampling Measurement Locations

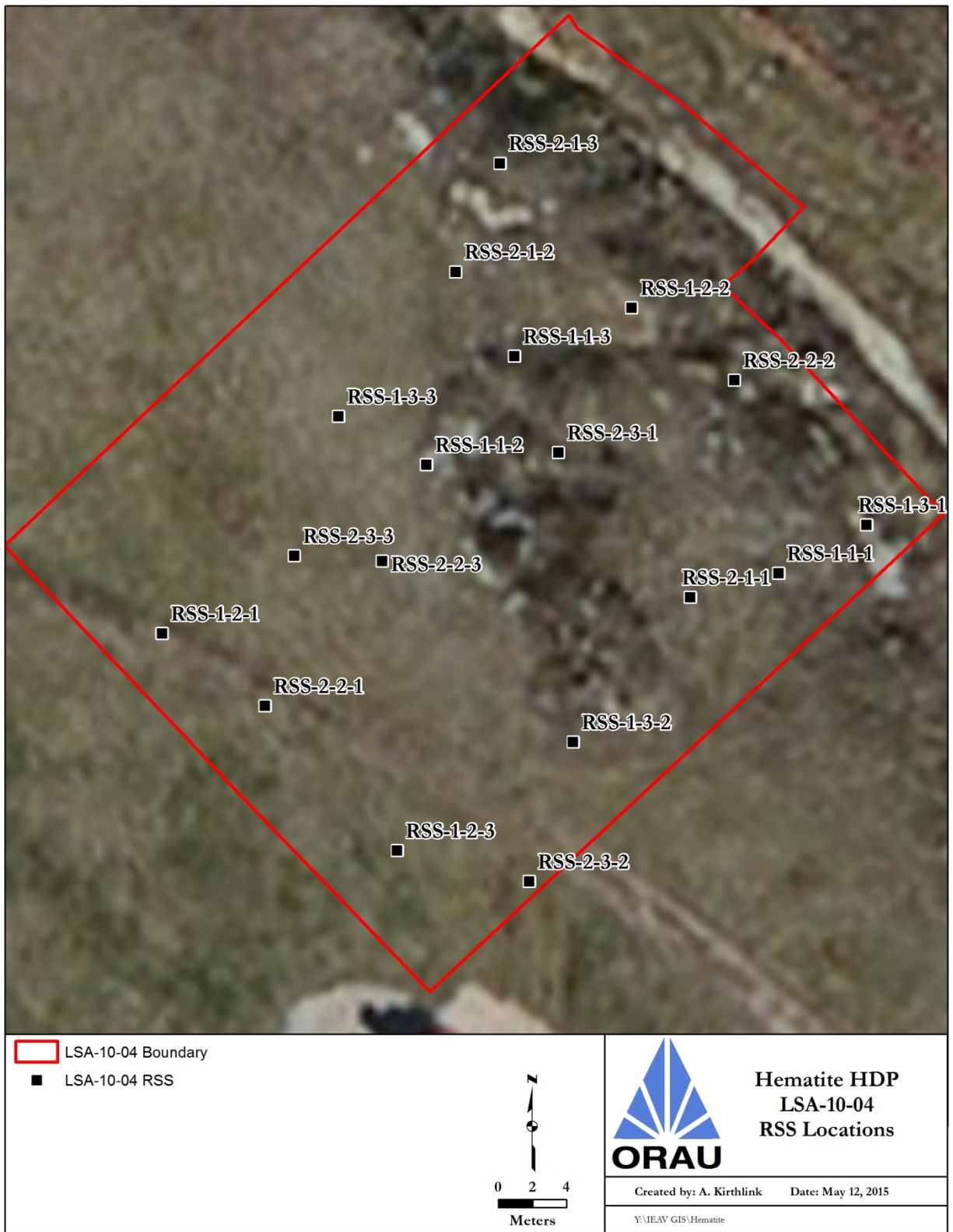
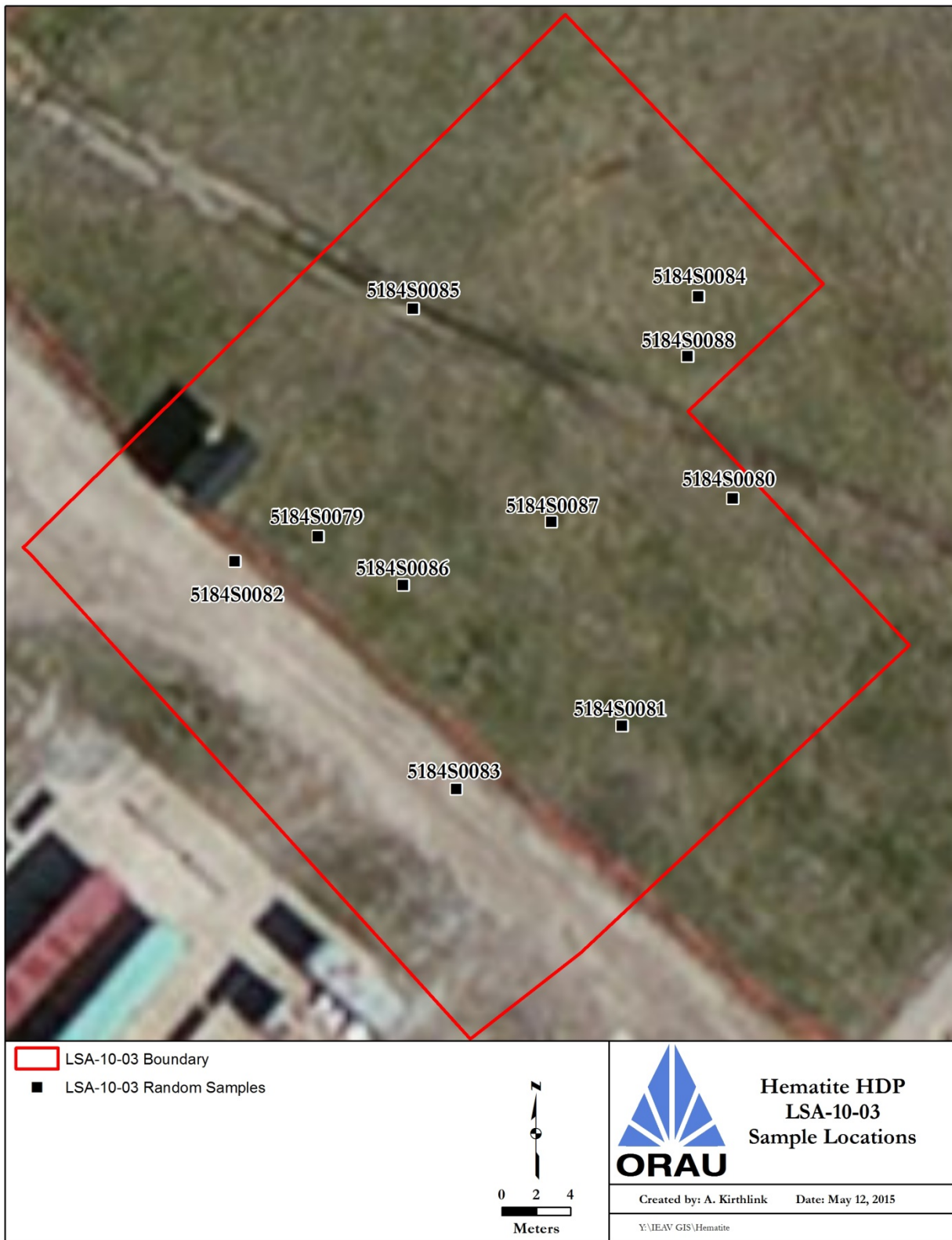


Figure A-8. LSA 10-04—Ranked Set Sampling Measurement Locations



**Figure A-9. LSA 10-03—Soil Sampling Locations**





Figure A-10. LSA 10-04—Soil Sampling Locations

**ATTACHMENT B**  
**DATA TABLES**

**Table B-1. U-234 Calculations from U-238 and U-235 for LSA-10-03, and 10-04 Soil Samples  
Hematite Decommissioning Project  
Festus, Missouri**

Sample	U-238 (pCi/g)	U-235 (pCi/g)	U-238/U-235	U-234/U-235 <sup>a</sup>	Enrichment (% U-235) <sup>b</sup>	U-234 (pCi/g)
	Result	Result	Ratio	Ratio		Result
5184S0079	1.83 ± 0.88 <sup>c</sup>	0.20 ± 0.09	9.24	18.79	1.7	3.72 ± 2.42 <sup>d</sup>
5184S0080	0.97 ± 0.45	0.08 ± 0.09	12.60	19.36	1.2	1.49 ± 1.86
5184S0081	1.54 ± 0.57	0.16 ± 0.10	9.63	18.85	1.6	3.02 ± 2.14
5184S0082	1.23 ± 0.81	0.31 ± 0.11	3.97	18.12	3.8	5.62 ± 4.20
5184S0083	1.40 ± 0.54	0.08 ± 0.13	17.50	20.24	0.9	1.62 ± 2.70
5184S0084	1.76 ± 0.80	0.13 ± 0.12	13.54	19.52	1.1	2.54 ± 2.61
5184S0085	2.41 ± 0.84	0.31 ± 0.10	7.77	18.55	2	5.75 ± 2.73
5184S0086	6.6 ± 1.5	1.38 ± 0.15	4.78	18.18	3.1	25.08 ± 6.32
5184S0087	1.72 ± 0.53	0.22 ± 0.09	7.68	18.54	2	4.15 ± 2.06
5184S0088	2.19 ± 0.88	0.13 ± 0.12	16.85	19.81	1	2.58 ± 2.59
5184S0089	1.56 ± 0.49	0.15 ± 0.06	10.76	19.04	1.4	2.76 ± 1.48
5184S0090	1.59 ± 0.69	0.13 ± 0.09	12.42	19.33	1.2	2.47 ± 2.04
5184S0091	2.16 ± 0.86	0.13 ± 0.10	16.24	20.01	1.	2.66 ± 2.19
5184S0092	2.30 ± 0.65	0.40 ± 0.10	5.75	18.28	2.6	7.31 ± 2.76
5184S0093	1.17 ± 0.75	0.09 ± 0.10	12.58	19.35	1.2	1.80 ± 2.20
5184S0094	2.18 ± 0.88	0.25 ± 0.10	8.86	18.73	1.7	4.61 ± 2.57
5184S0095	14.7 ± 3.3	3.85 ± 0.30	3.82	18.11	3.9	69.72 ± 16.57
5184S0096	1.34 ± 0.81	0.09 ± 0.10	15.58	19.88	1.	1.71 ± 2.22
5184S0097	3.83 ± 0.97	0.39 ± 0.10	9.82	18.88	1.6	7.36 ± 2.65
5184S0098	2.29 ± 0.62	0.19 ± 0.08	12.12	19.27	1.3	3.64 ± 1.88
5184S0099	7.9 ± 1.9	2.42 ± 0.21	3.26	18.10	4.5	43.81 ± 11.20

<sup>a</sup>U-234 concentrations are calculated by determining the gamma spectroscopy U-238/U-235 ratio, then using Table 14-5 from the DP to determine the U-234/U-235 ratio (using interpolation) and hence the enrichment percentage. The U-235 value is then multiplied by the U-234/U-235 ratio to determine the U-234 concentration result. The U-234 error was propagated by assuming the U-234/U-235 ratio did not have an error.

<sup>b</sup>From Table 14-5 "Radioactivity and Isotopic Ratios Relative to Enrichment" in the Hematite DP Rev 1.2.

<sup>c</sup>Two sigma uncertainty is presented.

<sup>d</sup>Though calculations were performed for "enrichments" less than 0.7 percent, those calculated values are subject to significant error due to limitations of the original empirically-derived formulas. Additional calculations should be performed if the weight percent of U-235 is less than 0.7 percent.

**Table B-2. Radionuclide Concentrations in LSA 10-03 and 10-04 Soil Samples**  
**Hematite Decommissioning Project**  
**Festus, Missouri**

Sample ID	Sample Coordinates (ft)		Radionuclide Concentration (pCi/g) <sup>a</sup>						SOF <sup>c</sup>
	East	North	Tc-99	Ra-226	Th-232	U-234 <sup>b</sup>	U-235	U-238	
Uniform Stratum DCGL <sub>W</sub> <sup>d</sup>			25.1	1.9	2.0	195.4	51.6	168.8	<1
LSA 10-03 <sup>e</sup>									
5184S0079	827324	865212	0.01	0.86	1.40	3.72	0.20	1.83	0.23
5184S0080	827404	865220	-0.02	0.85	1.52	1.49	0.08	0.97	0.27
5184S0081	827382	865176	0.20	0.97	1.19	3.02	0.16	1.54	0.17
5184S0082	827308	865208	0.12	1.04	1.32	5.62	0.31	1.23	0.28
5184S0083	827351	865164	0.24	0.88	1.29	1.62	0.08	1.40	0.17
5184S0084	827397	865258	0.64	0.97	1.48	2.54	0.13	1.76	0.33
LSA 10-03 Sidewall Samples <sup>e</sup>									
5184S0085	827342	865256	0.09	0.89	1.48	5.75	0.31	2.41	0.29
5184S0086	827340	865203	0.28	1.05	1.18	25.08	1.38	6.6	0.37
5184S0087	827368	865215	-0.09	0.95	1.30	4.15	0.22	1.72	0.21
5184S0088	827395	865247	-0.02	1.07	1.55	2.58	0.13	2.19	0.39
LSA 10-04 <sup>f</sup>									
5184S0089	827544	865231	10.51	0.62	0.80	2.76	0.15	1.56	0.44
5184S0090	827425	865219	-0.06	0.88	1.08	2.47	0.13	1.59	0.06
5184S0091	827505	865198	1.73	0.93	1.10	2.66	0.13	2.16	0.16
5184S0092	827482	865289	0.80	0.84	0.96	7.31	0.40	2.30	0.09
5184S0093	827468	865233	0.36	0.92	0.99	1.80	0.09	1.17	0.04
5184S0094	827496	865172	3.10	0.98	1.18	4.61	0.25	2.18	0.29
LSA 10-04 Sidewall Samples <sup>f</sup>									
5184S0095	827403	865235	-0.10	1.00	1.40	69.72	3.85	14.7	0.77
5184S0096	827442	865217	0.07	0.97	1.13	1.71	0.09	1.34	0.12
5184S0097	827438	865259	0.00	0.67	0.60	7.36	0.39	3.83	0.07
5184S0098	827480	865308	1.82	0.81	1.14	3.64	0.19	2.29	0.18
LSA 10-04 Judgmental Samples <sup>f</sup>									
5184S0099	827403	865235	0.02	0.88	1.49	43.81	2.42	7.9	0.56

Footnotes on next page

<sup>a</sup>These values are gross concentrations; background concentrations have not been subtracted.

<sup>b</sup>U-234 concentrations and uncertainties calculated from the U-238/U-235 ratios and using Table 14-5 in the Hematite DP, Rev. 1.2. Full details of calculations are provided in Table B-1.

<sup>c</sup>Sum-of-fractions (SOF) calculated using the unity rule for each radionuclide-of-concern (ROC). Background concentrations for Ra-226 and Th-232 were subtracted prior to the calculation; negative values were listed as a zero value in calculations. Based on the HDP FSS Data for Reuse Stockpile 2, background concentrations are as follows: Th-232 is 1.0 pCi/g and Ra-226 is 0.9 pCi/g (WEC 2012).

<sup>d</sup>DCGL<sub>W</sub> values are from the Uniform Stratum column in Table 2.1.

<sup>e</sup>Refer to Figure A.9.

<sup>f</sup>Refer to Figure A.10.