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January 14, 2014

John J. Hayes, Project Manager
U.S. Nuclear Regulatory Commission
Materials Decommissioning Branch
Division of Waste Management and Environmental Protection
TWFN Mail Stop T-8F5
Rockville, MD 20852

SUBJECT: FINAL REPORT FOR INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR SURVEY UNITS LSA 05-01, LSA 05-02 AND LSA 05-03 FOR THE HEMATITE DECOMMISSIONING PROJECT, FESTUS, MISSOURI DCN: 5184-SR-03-0 (RFTA 12-012; DOCKET NO. 70-036)

Dear Mr. Hayes:

Enclosed is the final report for independent confirmatory survey activities of Final Status Survey (FSS) Survey Units LSA 05-01, LSA 05-02, and LSA 05-03 at the Hematite Decommissioning Project in Festus, Missouri. The information contained in the report provides information and results of activities performed by Oak Ridge Associated Universities, under the Oak Ridge Institute for Science and Education contract, during the inspections conducted by the U.S. Nuclear Regulatory Commission from June 3 through November 13, 2013. Comments on the draft report, submitted on December 17, 2013, were incorporated into the final report.

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

Sincerely,

Wade C. Adams

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Health Physicist/Project Manager
Independent Environmental Assessment
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WCA:fs

Enclosure

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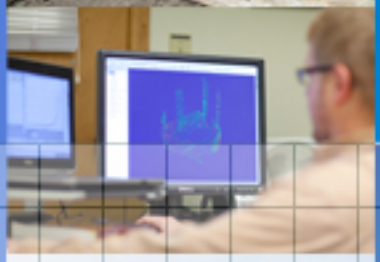

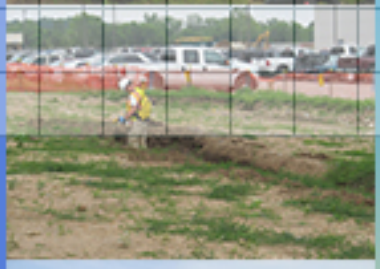

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Prepared for the
U.S. Nuclear Regulatory Commission

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Prepared for the
U.S. Nuclear Regulatory Commission

FINAL REPORT

JANUARY 2014

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ORAU

FINAL REPORT FOR INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR LSA 05-01, LSA 05-02, AND LSA 05-03 AT THE HEMATITE DECOMMISSIONING PROJECT, FESTUS, MISSOURI

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FINAL REPORT

JANUARY 2014

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ACRONYMS

cpm	counts per minute
CSM	conceptual site model
$DCGL_W$	radionuclide-specific derived concentration guideline level
DP	decommissioning plan
dpm/100 cm^2	disintegrations per minute per one hundred square centimeters
ECC	Environmental Chemical Corporation
EMC	elevated measurement comparison
EPA	U.S. Environmental Protection Agency
FSS	final status survey
FSSP	final status survey plan
GPS	global positioning system
HDP	Hematite Decommissioning Project
IEAV	Independent Environmental Assessment and Verification
LSA	Land Survey Area
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
mrem/yr	millirem per year
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram
ROC	radionuclide of concern
RSS	ranked set sampling
SOF	sum of fractions
SU	survey unit
TAP	total absorption peak
TEDE	total effective dose equivalent
VSP	Visual Sample Plan
WEC	Westinghouse Electric Company, LLC

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1. INTRODUCTION

The Westinghouse Electric Company, LLC (WEC) former fuel cycle facility near Festus, Missouri operated from 1956 to 2001 manufacturing uranium for use as nuclear fuel. The site ceased operational activities in September 2001. WEC is decommissioning the facility 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 the 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 facility's central land area and the site creek were impacted by the fuel fabrication activities.

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 opted to perform independent (third party) confirmatory evaluations of various site activities to assess the radiological conditions at the site. This included independent reviews of the licensee's documents, survey data, and analytical results to ensure that site documentation accurately and adequately described the conditions at the site; that procedures were sufficiently robust to meet the requirements for assessing and documenting final radiological status; and that the implementation of plans and procedures was successful. The confirmatory evaluation also included conducting on-site evaluations of the licensee's field activities (i.e., in-process inspections), and generating independent radiological data to evaluate the adequacy and accuracy of the final conclusions.

At NRC's request, the Independent Environmental Assessment and Verification (IEAV) Program of Oak Ridge Associated Universities (ORAU) was responsible for independent confirmatory activities at HDP. ORAU performed this task under the Oak Ridge Institute for Science and Education (ORISE) contract.

2. SITE DESCRIPTION

The Hematite facility 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 (Fig. A-1). The site is surrounded by forest, agricultural lands, and low-density residential housing. The entire site consists of approximately 228 acres; however, the impacted portion of the site—referred to as the central tract—only includes approximately 19 acres. The central tract of the site is bounded by State Road P to the north, the northeast site creek to the east, Union-Pacific railroad tracks to the south, and the site creek/pond to the west (Fig. A-2).

Land Survey Area 05 (LSA 05) is the Barns and Open Land Area adjacent to State Road P. This area previously contained the Tile Barn and Wood Barn Area and the Cistern Burn Pit Area (Fig. A-2).

3. OBJECTIVES

The objective of the confirmatory surveys was to provide independent contractor field data reviews, and to generate independent radiological data for NRC's use in evaluating the accuracy and adequacy of the licensee's procedures. More specifically, the objective for these survey activities was to perform confirmatory surveys in areas where WEC, the licensee, and Environmental Chemical Corporation (ECC), the decommissioning contractor, had completed final status survey (FSS) activities. To achieve this objective, ORAU performed document reviews and onsite in-process confirmatory inspections and surveys. The WEC split soil sample results were also provided to ORAU to assess the licensee's analytical capabilities.

4. DOCUMENT REVIEW

Prior to on-site activities, ORAU was provided the *Hematite Decommissioning Plan* (DP) (WEC 2009), supplemental data from HEM-11-96 which resolved NRC questions regarding the DP (WEC 2011), and the NRC's Safety Evaluation Report approving WEC's DP (NRC 2011). These documents were reviewed and used to develop a project-specific plan. Also prior to and upon arrival at the site, WEC provided preliminary FSS data and instructions applicable to the confirmatory survey objectives for ORAU to review. The data from the FSS data packages were used in planning the ORAU survey

strategy and to determine the number of samples required for each confirmatory survey area. Table 4.1 summarizes the specific procedures reviewed by ORAU.

Table 4.1. Procedural Review Summary

Procedure/Report/ Instruction Number	Title	Revision[a]
DO-08-004	Hematite Decommissioning Plan (includes Final Status Survey Plan)	0.0
HDP-PR-FSS-701	Final Status Survey Plan Development	2
HDP-PR-FSS-701, Appendix P-3	Final Status Survey Plan Development; Appendix P-3 FSS Sample Instructions: LSA 05-02	2
HDP-INST-FSS-LSA05-01	Final Status Survey Plan and Instructions for Survey Area & Unit LSA 05-01	3
HDP-INST-FSS-LSA05-02	Final Status Survey Plan and Instructions for Survey Area & Unit LSA 05-02	1
HDP-INST-FSS-LSA05-03	Final Status Survey Plan and Instructions for Survey Area & Unit LSA 05-03	0

[a]References WEC 2009, 2013a, b, c, d, and e

In addition to reviewing the DP, final status survey plan (FSSP) and the LSA 05 FSSPs, ORAU took into account guidance from the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC 2000).

5. APPLICABLE SITE GUIDELINES

5.1 RADIONUCLIDES OF CONCERN

Based on past site investigations, the primary radionuclides of concern (ROCs) at the HDP are technetium-99 (Tc-99), thorium-232 (Th-232), uranium-234 (U-234), uranium-235 (U-235), uranium-238 (U-238), americium-241 (Am-241), neptunium-237 (Np-237), and plutonium-239/240 (Pu-239/240).

5.2 SURFACE ACTIVITY GUIDELINES

For surface activity measurements, WEC is using the *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of License for Byproduct, Source, or Special Nuclear*

Material from the NRC Division of Fuel Cycle Safety and Safeguards, issued in April 1993 (NRC 1993).

Table 5.1. Acceptable Surface Activity Contamination Levels (dpm/100 cm^2)			
Nuclides	**Average**	**Maximum**	**Removable**
U-Nat, U-235, U-238, and associated decay products	5,000	15,000	1,000
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000	15,000	1,000

Table from NRC 1993 and WEC 2013b

5.3 SOIL CONCENTRATION GUIDELINES

Each radionuclide-specific derived concentration guideline level ($DCGL_W$) 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 2013a). Because each of the individual $DCGL_W$s represents 25 mrem/yr, the sum-of-fractions (SOF) approach is used to demonstrate compliance with the dose limit; therefore, a SOF greater than 1 would exceed the release criteria.. SOF calculations are performed as follows:

$$SOF_{TOTAL} = \sum_{j=0}^{n} SOF_j = \sum_{j=0}^{n} \frac{C_j}{DCGL_{W,j}}$$

Where C_j is the concentration of ROC "j," and $DCGL_{W,j}$ is the $DCGL_W$ for ROC "j." Note that gross concentrations are considered here for conservatism.

As depicted in Fig. 5.1 (Fig. 5.4 of the DP), $DCGL_W$s were calculated by WEC for four conceptual site models (CSMs), including Surface, Root, Deep, and Uniform contaminated soil strata (WEC 2009). Due to the fact that some areas of the site are known to have contaminated soil underneath clean material (e.g., burial pits), while other areas of the site are believed to be

contaminated only on the surface, WEC developed the following CSMs for three layers of contamination: Surface (0–0.15 meters [m]), Root (0.15–1.5 m), and Deep (1.5–6.7 m). The thickness of the cover and the contamination zone depth both depend on the CSM. The Uniform Stratum approach assumes uniform contamination is present from the surface to a depth of 6.7 m. Due to the fact that subsurface soils could, in the future, be excavated and brought to the surface, WEC also performed an excavation scenario evaluation to ensure that Deep Strata $DCGL_W$s would be acceptable if those soils were excavated and brought to the surface.

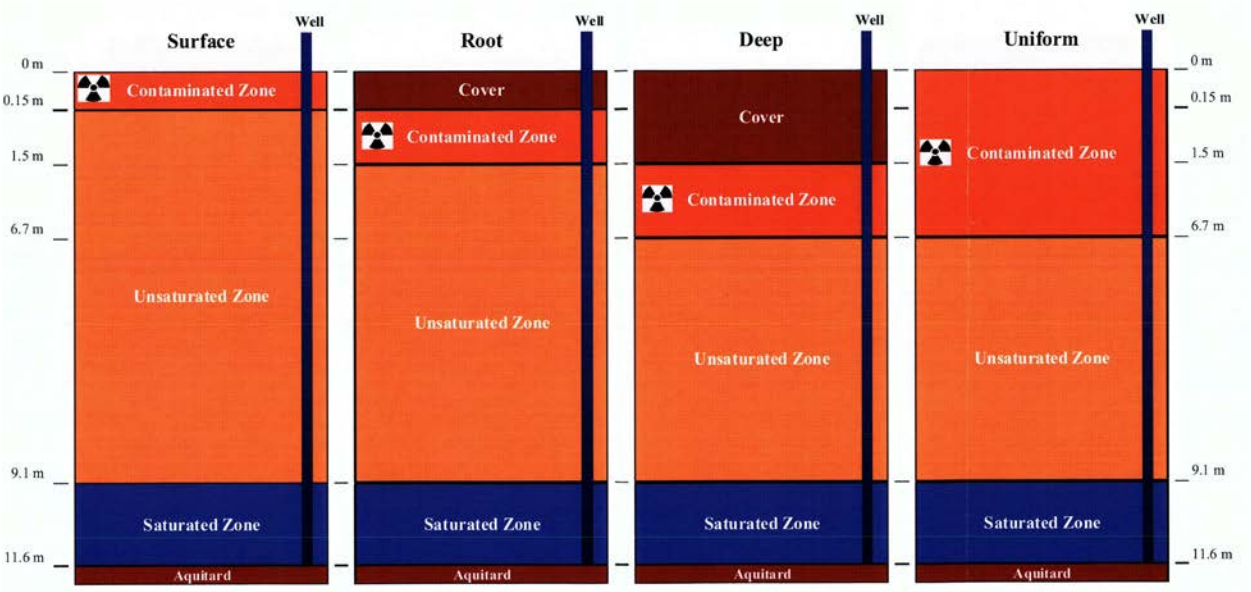

Fig. 5.1. CSMs for Site-Specific $DCGL_w$s

For this site, one of two approaches was to be used to determine compliance with applicable site guidelines: (1) the more conservative Uniform approach, or (2) the three-layered approach. In the case that Uniform criteria are not met, then the three-layered approach would be tested. For survey areas when the three-layered approach is applied, a SOF equation would also be used to combine the results of each layer in addition to the equation combining the concentrations of multiple radionuclides.

Np-237, Pu-239/240, and Am-241 are considered to be insignificant ROCs based on the aggregate dose of these radionuclides being less than 10% of the total effective dose equivalent (TEDE) for each CSM. Licensees are required to comply with the applicable dose criteria in 10 Code of Federal Regulations Part 20 (10 CFR 20), Subpart E; thus, the dose contribution from the insignificant radionuclides must be accounted for in demonstrating compliance with the dose criteria. WEC has

developed site-specific $DCGL_W$s to evaluate analytical results in residual soil and sediment; they have accounted for the dose contribution from the insignificant radionuclides; and, they have adjusted the $DCGL_w$ accordingly. The adjusted soil $DCGL_W$s are provided in Table 5.2. Deep Strata $DCGL_W$s have been replaced by alternate excavation scenario $DCGL_W$s to ensure that any Deep Strata anomalous contamination would be acceptable if brought to the surface by future excavation following license termination. For the LSA 05 (Barns and Cisterns) Areas, the conservative Uniform Stratum $DCGL_W$s from Table 5.2 were used.

Table 5.2. Adjusted Site-specific Soil $DCGL_W$ by CSM[a]

Radionuclide	Three Layer Approach $DCGL_W$s Values (pCi/g)[b]			Uniform Stratum (pCi/g)
	Surface Stratum	Root Stratum	Excavation Scenario	
Uranium-234	508.5	235.6	872.4	195.4
Uranium-235+D[c]	102.3	64.1	208.1	51.6
Uranium-238+D[c]	297.6	183.3	551.1	168.8
Technetium-99	151.0	30.1	74.0	25.1
Thorium-232+C[d]	4.7	2.0	5.2	2.0
Radium-226+C[d]	5.0	2.1	5.4	1.9

[a]Table adapted from WEC 2013a.
[b]The reported $DCGL_W$s are the activities for the parent radionuclide as specified (WEC 2013a) and were calculated to account for the dose contribution from insignificant radionuclides. Concentrations are reported in units of picocuries per gram (pCi/g).
[c]+D indicates the $DCGL_W$ includes short-lived (half-life ≤ 6 mo.) decay products.
[d]+C indicates the $DCGL_W$ includes all radionuclides in the associated decay chain.

6. PROCEDURES

At NRC's request, an ORAU survey team visited the Hematite Site on three occasions; June 3–6, 2013, August 26–29, 2013, and November 12–13, 2013 to perform in-process and confirmatory survey activities. These activities included visual inspections, surface scans, soil sample collection, and laboratory sample analyses. The confirmatory survey activities were conducted in accordance with the *Final–Project-Specific Plan for Independent Confirmatory Survey Activities for the Hematite Decommissioning Project* and the ORAU/ORISE Survey Procedures and ORAU Quality Program Manuals (ORAU/ORISE 2013a, 2013b, and ORAU 2013). In-process observations were brought to

the immediate attention of the NRC representative and are also noted in the Findings and Results section of this report. During the in-process surveys, the boundaries of the survey units (SUs) changed based on the radiological findings by WEC personnel and on-site logistics (staging of excavated and backfill soil) at the time of the surveys. ORAU performed confirmatory surveys on portions of the SUs that were available while on site.

6.1 CONFIRMATORY SURVEY FOCUS AREA

ORAU performed confirmatory survey activities on specific SUs (LSA 05-01, LSA 05-02, and LSA 05-03) where FSS activities were completed (Figs. 6.1 through 6.4). Due to the site working conditions during the in-process FSS surveys, portions of LSA 05-01 and LSA 05-03 were not accessible during the August 2013 confirmatory survey activities. The areas within those SUs that were accessible are indicated in Figs. A-5 and A-7. After these survey activities, it was determined that LSA 05-01 would be further subdivided into LSA 05-04 which is the portion within the original boundary of LSA 05-01 that was not surveyed during the August 2013 activities. During the November 2013 confirmatory activities, ORAU was able to complete the confirmatory surveys in the western portion of LSA 05-03. Survey activities consisted of gamma walkover survey scans, gamma radiation level measurements, and soil sampling. Table 6.1 provides a summary of the locations addressed during the confirmatory survey.

Table 6.1. Confirmatory Survey Unit Focus Areas

Survey Location	Description
LSA 05-01	Barns and Cistern open land survey area located south of State Road P. Contains the Cistern Burn Pit Area, the Red Room Roof Burial Pit, and the Limestone Fill Area that leads up to the slope to State Road P.
LSA 05-02	Barns and Cistern open land survey area located south of State Road P. Contains the Tile Barn Area which had been used to store both clean and contaminated equipment.
LSA 05-03	Barns and Cistern open land survey area located south of State Road P. Contains the Red Wood Barn which had been used to store both clean and contaminated equipment.

Fig. 6.1. LSA 05-01

Fig. 6.2. LSA 05-02

Fig. 6.3. LSA 05-03 East

Fig. 6.4. LSA 05-03 West

6.2 REFERENCE SYSTEM

Global positioning system (GPS) coordinates were used for referencing measurement and sampling locations. The specific reference system used was the North American Datum 1983 State Plane Missouri East FIPS 2401 Feet.

6.3 SURFACE SCANS

6.3.1 Concrete Surfaces

ORAU performed slow and thorough high-density alpha plus beta activity walkover scans of the accessible concrete surfaces within LSA 05-01 and LSA 05-02 focusing on locations where contamination may have concentrated during operations, as well as other judgmentally selected locations based on site observations (two separate scan surveys were performed on the LSA 05-02 concrete surfaces; one in June 2013 during which a fuel pellet was found, and the other during the final confirmatory survey of LSA 05-02 in August 2013). The surface scans were performed using a Ludlum Model 43-68 gas proportional detector coupled to a Ludlum Model 2221 ratemeter-scaler with an audible indicator. The detectors were also coupled to GPS systems that enabled real-time alpha plus beta count rate and spatial data capture (Figs. A-3 through A-4).

6.3.2 Soil Surfaces

ORAU performed slow and thorough high-density gamma walkover scans of the accessible surfaces of each of the SUs using a Ludlum Model 44-10 sodium iodide detector coupled to a Ludlum Model 2221 ratemeter-scaler with an audible indicator. The detectors were also coupled to GPS systems that enabled real-time gamma count rate and spatial data capture (Figs. A-5 through A-7). Due to findings during the June 2013 surveys of LSA 05-02, WEC personnel had to perform additional remedial actions within SU LSA 05-02 and ORAU resurveyed this area during the August 2013 surveys. During the August 2013 surveys, the western portion of LSA 05-03 was not ready for confirmatory surveys; therefore, ORAU performed surveys in the eastern portion of the LSA 05-03 during the August 2013 surveys and the western portion of the LSA 05-03 during the November 2013 surveys.

6.4 SURFACE ACTIVITY MEASUREMENTS

Construction material-specific background measurements were performed on concrete structures near Building 110. Surface activity measurements for alpha and beta activity were performed at 14 systematically selected locations on the LSA 05-02 concrete footer during the June 2013 survey activities (Fig. A-8) and at 20 locations during the August 2013 survey activities (Fig. A-9), at 2 judgmental locations on the miscellaneous concrete footer in the northwest corner of LSA 05-02 (Fig. A-9), and at 3 judgmental locations on the concrete pad in LSA 05-01 (Fig. A-3). Smears for gross alpha and gross beta removable activity were collected at 14 (June 2013) and 20 (August 2013) locations, respectively, on the LSA 05-02 concrete footer; smears were not collected at the other direct measurement locations.

6.5 SOIL SAMPLING PROCEDURES

A ranked set sampling (RSS) process, following U.S. Environmental Protection Agency (EPA) guidance, was used to generate the random locations from which the soil samples were collected (EPA 2002). The process combines random sampling with the use of professional judgment to select the number of samples and the sampling locations. One-minute static gamma measurements collected from a population of random locations provided the measurable field screening method. The count data was then ranked (high, medium, or low) to determine which location would be sampled and submitted for laboratory analysis. FSS analytical soil results were not available prior to the confirmatory surveys; therefore, previous characterization results and data from the initial LSA 05-02 FSS activities were used as inputs to determine the number of sample locations for each SU. The number of confirmatory samples collected for each survey unit was such that the mean concentration estimated would fall within 0.25 of the predicted mean SOF at the one-sided, 95% confidence level. RSS direct measurement locations were determined to be 18, leading to a total of six randomly selected soil samples to be collected from each SU, based on the characterization statistical inputs. Visual Sample Plan (VSP) software was used to generate the random coordinates comprising the soil investigations and sample selection population (Figs. A-10 through A-13). A detailed description of this process is provided in Appendix E.

Soil samples were collected at six random locations from the surface (0 to 15 cm) within LSA 05-01 and LSA 05-03 (Figs. A-14 and A-17). Six random soil samples were collected during each survey of

LSA 05-02 during the June 2013 (Fig. A-15) and August 2013 (Fig. A-16) survey trips. Judgmental soil samples were collected from three locations in LSA 05-02 during the June 2013 survey activities and from three locations near the concrete pad in LSA 05-01 during the August 2013 survey activities and two locations in LSA 05-03—one during the August 2013 survey and one during the November 2013 survey (Figs. A-14 and A-17).

7. SAMPLE ANALYSIS AND DATA INTERPRETATION

Scan data, direct measurement data, smears, and soil samples were returned to the ORAU facility in Oak Ridge, Tennessee for laboratory analysis and data interpretation. Sample analyses were performed in accordance with the ORAU/ORISE Laboratory Procedures Manual (ORAU/ORISE 2013c). Smears were analyzed for gross alpha and gross beta activity using a low-background proportional counter. Smear and direct measurement data were converted to units of disintegrations per minute per one hundred square centimeters (dpm/100 cm^2). Soil samples were analyzed by solid-state gamma spectroscopy and liquid scintillation counting. Analytical results were reported in units of picocuries per gram (pCi/g). Alpha spectroscopy was not performed; therefore, U-234 concentrations were determined using ORAU analytical laboratory results for U-238 and U-235 to calculate U-238/U-235 ratios and then by interpolation with Table 14-5 of the DP to determine the U-234/U-235 ratio. By multiplying the U-234/U-235 ratio by the U-235 result, the U-234 concentration was inferred (refer to Table B-3). The analytical results were evaluated and compared to applicable Uniform Stratum $DCGL_W$ guidelines presented in Table 5.2.

8. FINDINGS AND RESULTS

This section discusses results for each confirmatory activity.

8.1 DOCUMENT REVIEW

The ORAU review of WEC's data summary reports for the three LSA 05 FSS SUs indicated that there were several calculation errors and inconsistencies within the reports (WEC 2013c, 2013d, and 2013e). These deficiencies were discussed with the NRC site representative and those results were presented to and corrected by the licensee.

8.2 SURFACE SCANS

Surface scan results for LSA 05-01, LSA 05-02, and LSA 05-03 are discussed below. The reported surface activities represent gross counts that have not been subjected to background correction.

8.2.1 LSA 05-01

8.2.1.1 Concrete Pad Surfaces

Alpha-plus plus-beta activity surface scans detected three locations of elevated alpha-plus-beta activity on the concrete surface. These locations were not detected with the audible indicators during the scan surveys as the heavy equipment in the area prevented the surveyor from hearing the audible increase in activity. A post-survey review of the electronically captured scan data indicated approximately three areas of elevated residual alpha-plus-beta radiation on the concrete pad surfaces within LSA 05-01. Overall alpha-plus-beta instrument response ranged from less than 125 to 1,061 counts per minute (cpm) with a background of 291 cpm (Fig. A-3).

8.2.1.2 Soil Surfaces

Gamma surface scans did not detect any areas of elevated residual gamma radiation within the accessible soil surfaces of LSA 05-01. Overall gamma instrument response ranged from less than 4,000 to 13,900 cpm with a background of 7,100 cpm (Fig. A-5).

8.2.2 LSA 05-02

8.2.2.1 Concrete Pad Surfaces

Alpha-plus-beta surface scans did not detect any areas of elevated alpha-plus-beta radiation on the concrete surfaces within LSA 05-02. Overall alpha-plus-beta instrument response ranged from less than 125 to 741 cpm with a background of 291 cpm (Fig. A-4).

8.2.2.2 Soil Surfaces

Gamma surface scan did not detect any areas elevated residual gamma radiation within the accessible soil surfaces of LSA 05-02. Overall gamma instrument response ranged from less than 8,300 cpm to 14,267 cpm with a background of 7,100 cpm (Fig. A-6).

8.2.3 LSA 05-03

Gamma surface scans did not detect any areas with elevated residual gamma radiation within the accessible soil surfaces of LSA 05-03; there were no concrete surface surveys. Overall instrument response ranged from less than 6,700 to 16,800 cpm with a background of 7,100 cpm (Fig. A-7). Because the trench exhibited elevated gamma radiation levels, based on experience due to geometry factors and at the request of the NRC site representative, the RSS location within the trench at RSS-1-1-1 was also sampled as a judgmental sample (Sample 5184S0050; Figs. A-7, A-13, and A-17).

8.3 SURFACE ACTIVITY MEASUREMENTS ON CONCRETE SURFACES

8.3.1 LSA 05-01

The beta surface activities ranged from 250 to 1,100 dpm/100 cm^2 (Table B-2); alpha measurements not performed.

8.3.2 LSA 05-02

The surface activities ranged from -23 to 130 dpm/100 cm^2 for alpha and -280 to 740 dpm/100 cm^2 for beta activity on the concrete footer; removable activity on the concrete footer ranged from -1 to 4 dpm/100 cm^2 for alpha and -2 to 5 dpm/100 cm^2 for beta activity. Although surface activities on the concrete footer were slightly elevated for alpha, the results are below the maximum value of 300 dpm/100 cm^2 in Table 5.1. For the miscellaneous pad in the northwest corner, the alpha surface activity ranged from 0 to 71 dpm/100 cm^2 and the beta surface activity ranged from 330 to 940 dpm/100 cm^2; there were no removable activity measurements performed (Tables B-1 and B-2).

8.4 RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES

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 Tables B-3 (U-234 inferred calculations) and B-4 (ROC concentrations for soil samples).

8.4.1 Confirmatory Soil Results

Samples collected from LSA 05-01, -02, and -03 resulted in low-level detections of Ra-226, Th-232, U-234 (inferred), U-235/236 (as reported but interpreted here as U-235), and U-238 in the systematic soil samples. However, several of the biased (judgmental samples) exceeded the DCGLs

(and/or SOF). Two Tc-99 concentrations exceeded the Tc-99 DCGL limit of 25.1 pCi/g. A summary of the radionuclide ranges is provided in Table 8.1. Table 8.2 provides the statistical comparison of the confirmatory LSA 05 FSS SU data results with the FSS statistical data results. The complete sample results for the LSA 05 FSS SUs are provided in Table B-4.

Table 8.1. ORAU ROC Activity Range Summary in pCi/g

ROC	Soil Activity Concentration Range		
U-234	0.6	to	853.6
U-235	0.02	to	47.1
U-238	0.46	to	192
Tc-99	-0.22	to	50.9
Th-232	0.18	to	1.41
Ra-226	0.48	to	1.43

Table 8.2. LSA 05 Statistical Comparison of Survey Unit Sum of Fractions for Systematic Samples

	LSA 05-01		LSA 05-02		LSA 05-03	
	ORAU	WEC[a]	ORAU	WEC[a]	ORAU	WEC[a]
Survey Unit Average	0.07	0.12	0.33	0.25	0.12	0.15
Standard Deviation[b]	0.10	0.21	0.22	0.30	0.22	0.14
Minimum	0.01	0.01	0.20	0.02	0.04	0.08
Maximum	0.14	0.39	0.50	0.67	0.29	0.29

[a]WEC values calculated with WEC LSA 05 data summary data
[b]95% standard deviation

A graphical comparison of the data is provided in Fig. 8.1 and indicates that the mean concentrations of the confirmatory LSA 05 SU sample populations overlap within the 95% confidence interval, based on the planning inputs for each LSA 05 SU.

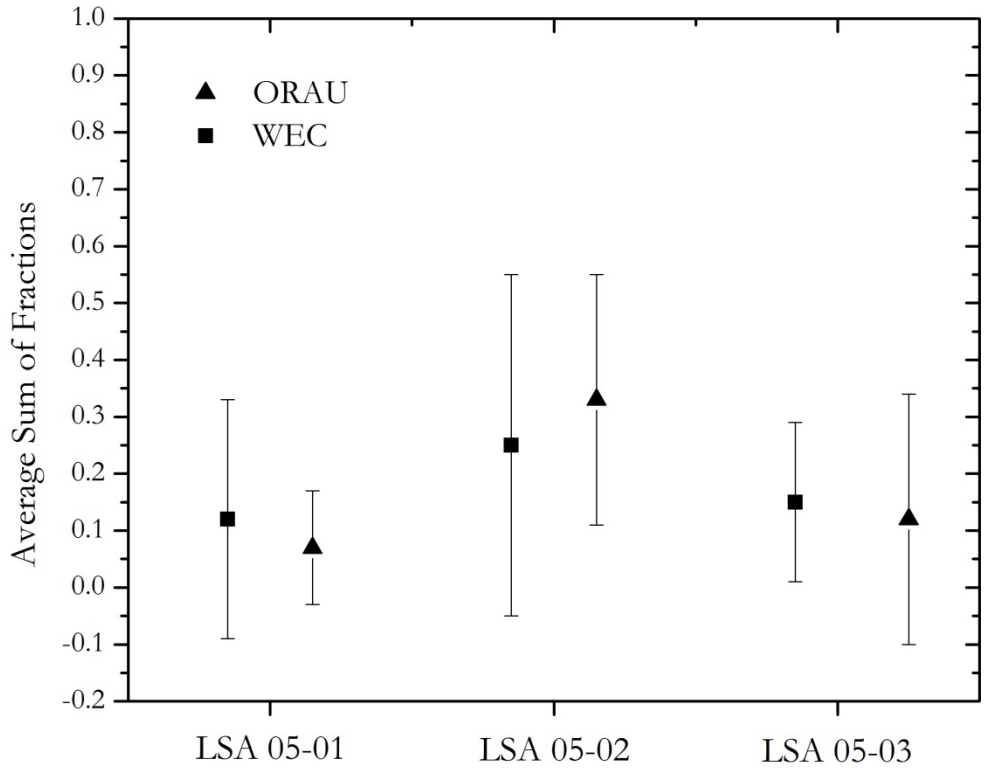

Fig. 8.1. Error Bar Chart for Comparison of LSA 05 Survey Units Sum of Fractions Data

8.4.2 Split Soil Sample Comparison Results

Two locations (three samples) of elevated gamma radiation were identified within LSA 05-02 during the June 2013 survey. ORAU and WEC personnel collected split samples from these locations which resulted in the removal of soil from an approximately one square meter area down to a depth of six inches at soil sample locations 5184S0024 and 5184S0026. ORAU detected a partial fuel pellet from sample location 5184S0025. These soil samples were split with WEC personnel with the fuel pellet being in the WEC portion of the split sample. Since these are split samples and not the exact same samples, the comparison data between the ORAU and WEC sample analyses results will not be evaluated by statistical means (e.g., duplicate error ratio). The split sample comparison results for LSA 05-02 are provided in Table B-5. The two samples from the same area in the northwest portion of the SU had SOFs that exceeded 1 (due to elevated uranium concentrations in those samples).

9. COMPARISON OF RESULTS WITH GUIDELINES

Analytical laboratory results for soil LSA 05 SUs were compared to radionuclide-specific Uniform $DCGL_W$s, both by considering individual ROCs and by using a SOF calculation (Table B-4). Note, these comparisons to the Uniform Stratum $DCGL_W$s are made using gross concentrations (i.e., the concentrations are not adjusted for soil background). As per WEC analyses, the average SOF values were calculated by subtracting Ra-226 and Th-232 background values of 0.9 and 1.0 pCi/g, respectively. All of the final confirmatory LSA 05 systematic soil samples met the individual ROC $DCGL_W$s and SOF criteria. The three biased (judgmental) soil samples collected within LSA 05-01 were above the SOF DCGL of 1 and two of the samples had Tc-99 concentrations that exceeded the Tc-99 individual sample DCGL of 25.1 pCi/g. The licensee will be performing an elevated measurement comparison (EMC) assessment evaluation and will provide that data for review at a later date (NRC 2013).

10. SUMMARY

At NRC's request, ORAU conducted confirmatory surveys of the Hematite Decommissioning Project during the periods of June 3–June 6, 2013, August 26–29, 2013, and November 12–13, 2013. The survey activities included in-process inspections, document review, gamma walkover surveys, soil sampling activities, laboratory analysis of confirmatory soil samples, and comparison analysis of split samples.

Results for the split samples indicated a high level of comparability between the WEC and ORAU/ORISE radiological laboratories. Analytical practices and procedures appear to be sufficient in providing quality radiochemical data.

All final confirmatory survey ROC concentrations from the LSA 05-02 and LSA 05-03 soil samples were below the individual Uniform $DCGL_W$ limits and also satisfied the SOF $DCGL_W$ criteria. Three judgmental soil samples collected from the LSA 05-01 exceeded the unity rule SOF and two exceeded the Tc-99 individual DCGLw. EMC calculations for this area will be provided for NRC review at a later date.

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APPENDIX A
FIGURES

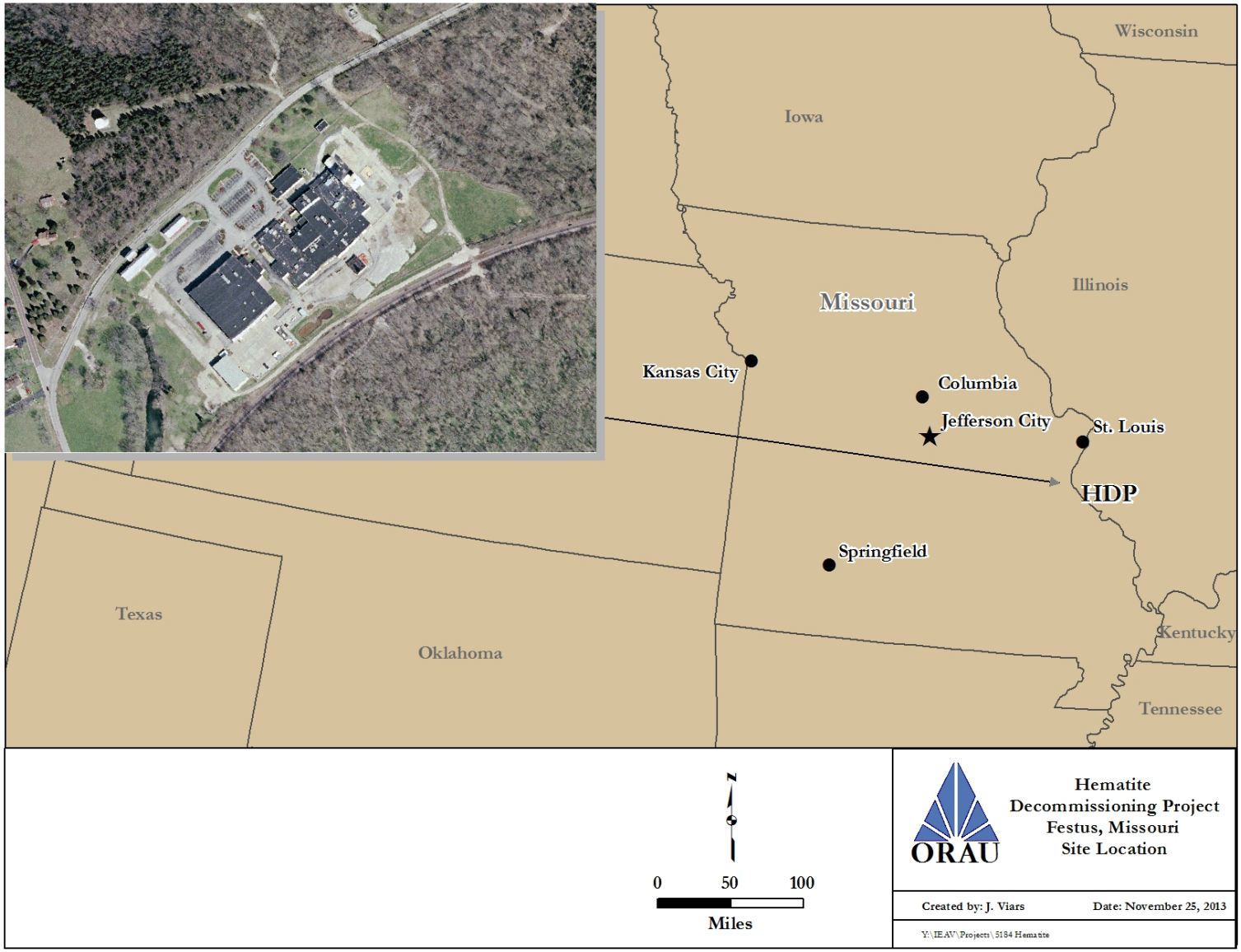


Fig. A-1. Location of Hematite Decommissioning Project, Festus, Missouri

Fig. A-2. Plot Plan of Hematite Decommissioning Project Indicating LSA 05 Survey Units

Fig. A-3. LSA 05-01 Concrete Pad—Alpha Plus Beta Scans and Direct Measurement Locations

Fig. A-4. LSA 05-02 Concrete Pads—Alpha Plus Beta Scans

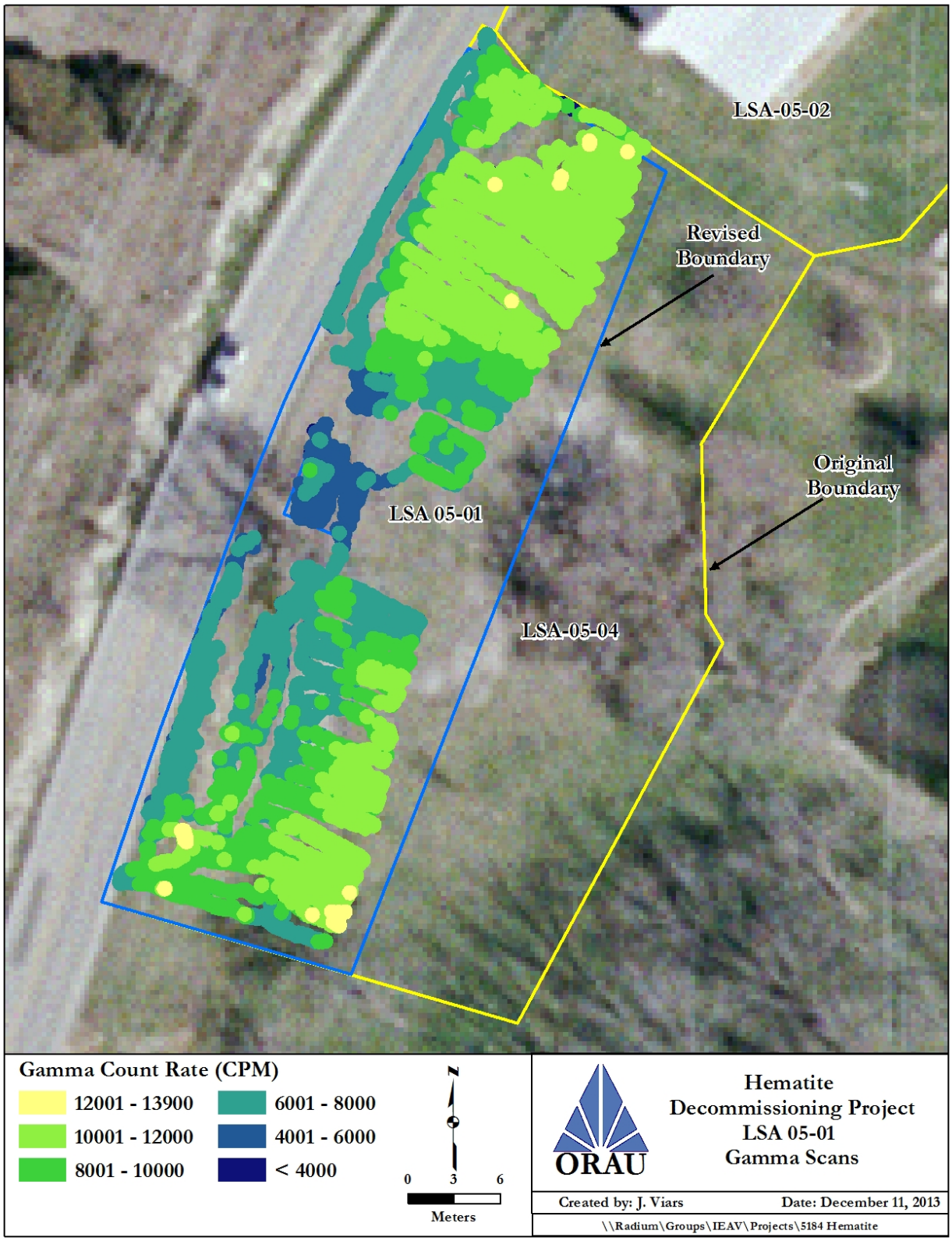


Fig. A-5. LSA 05-01—Gamma Walkover Scans

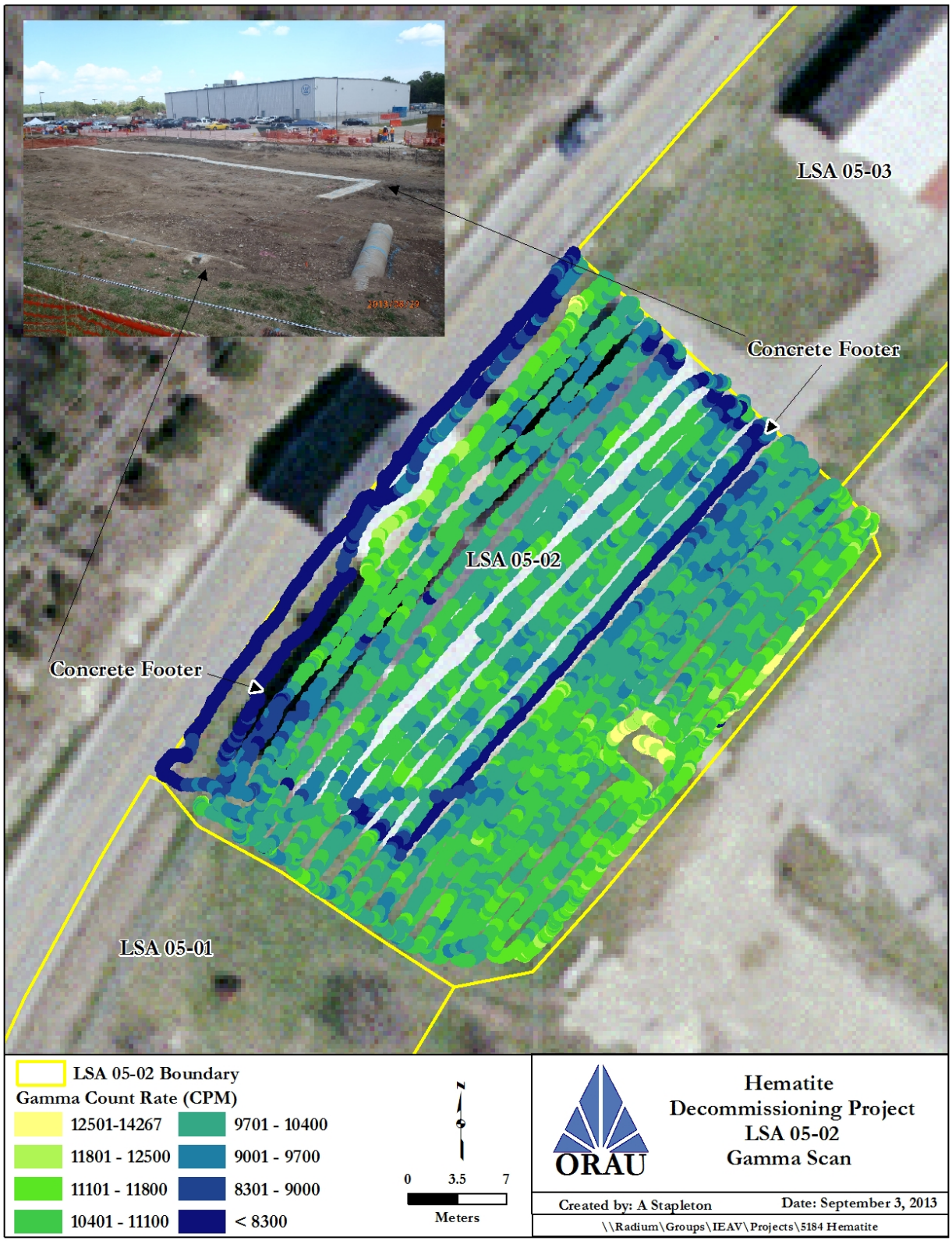


Fig. A-6. LSA 05-02—Gamma Walkover Scans

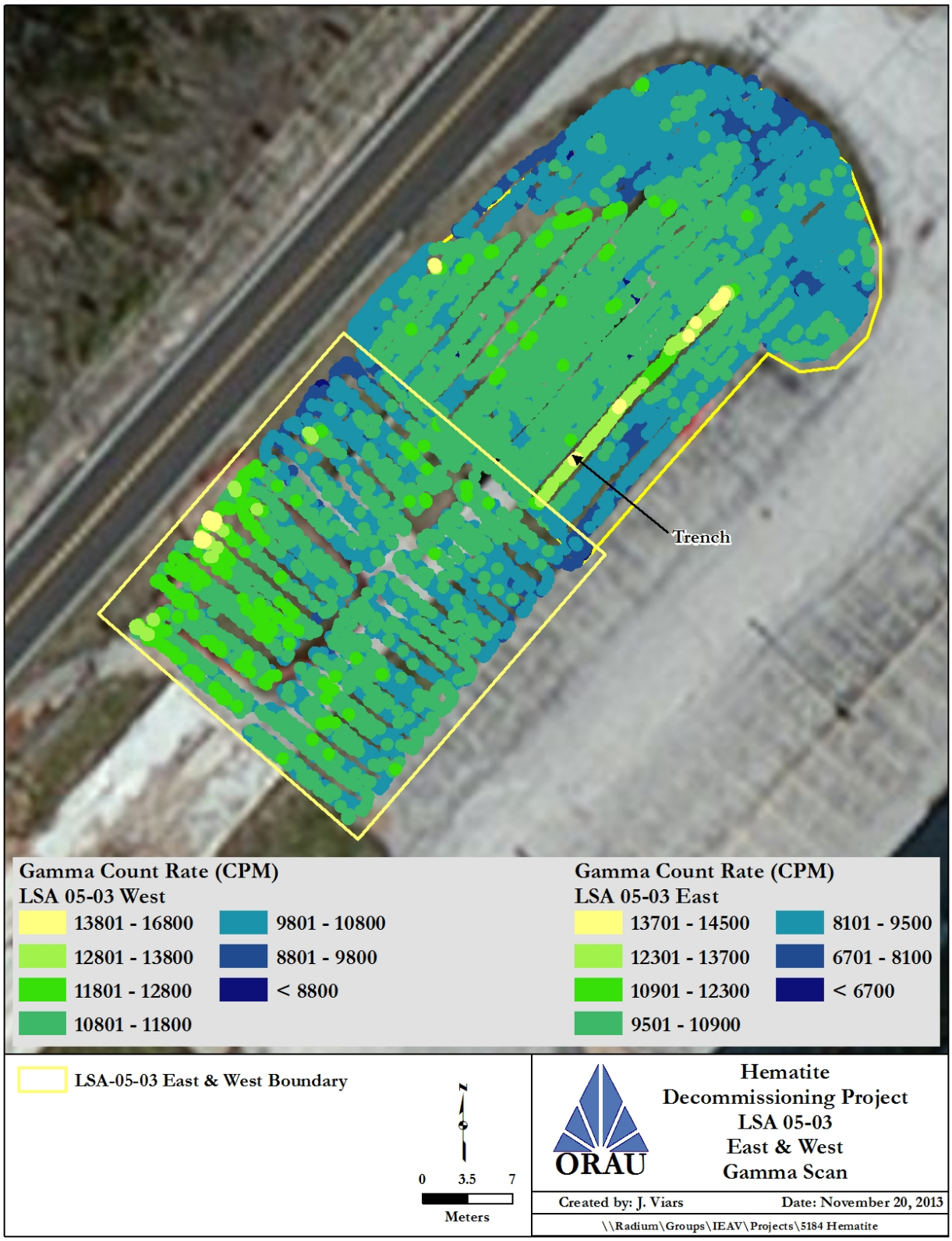


Fig. A-7. LSA 05-03—Gamma Walkover Scans

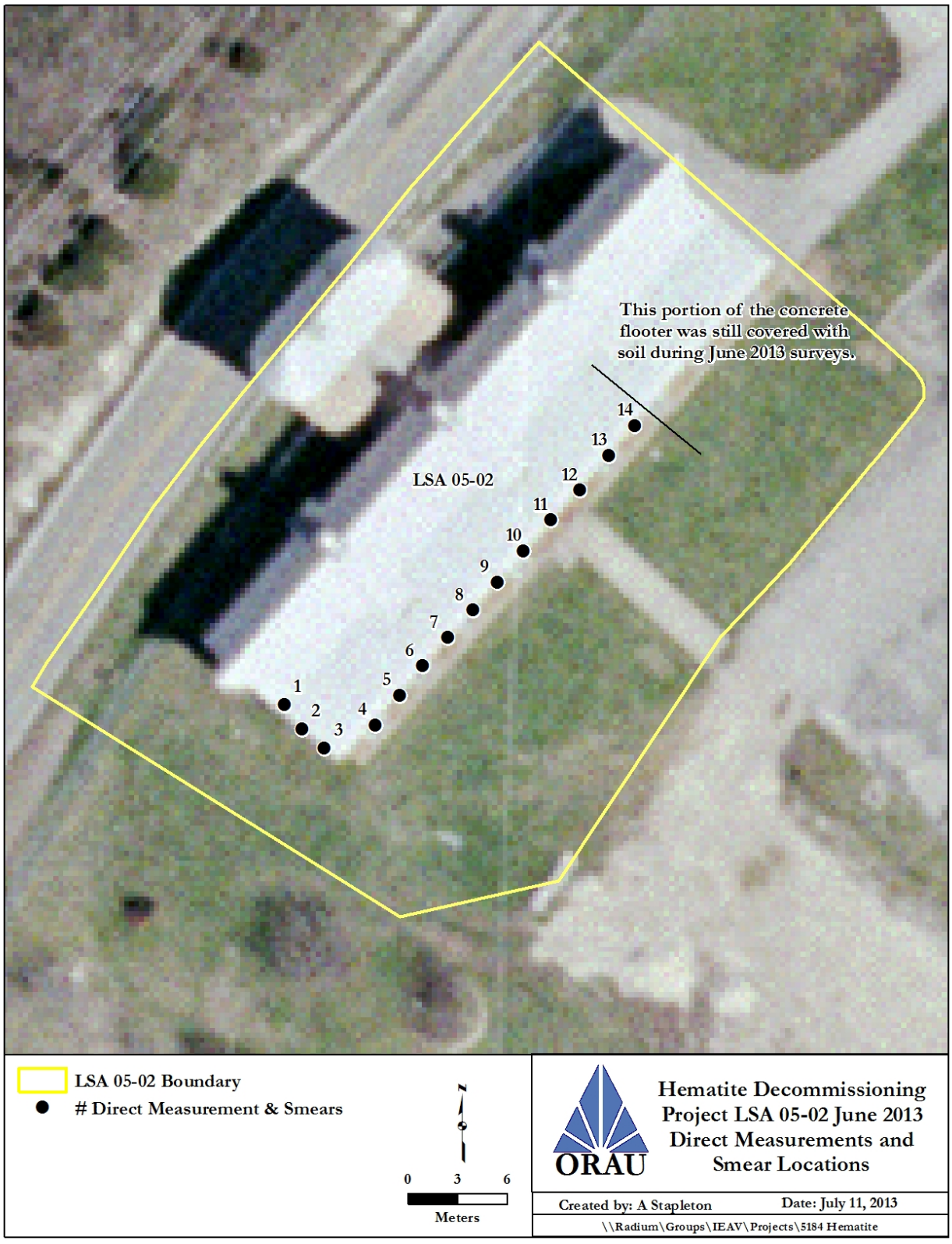


Fig. A-8. LSA 05-02—June 2013, Concrete Footer, Direct Measurement Locations

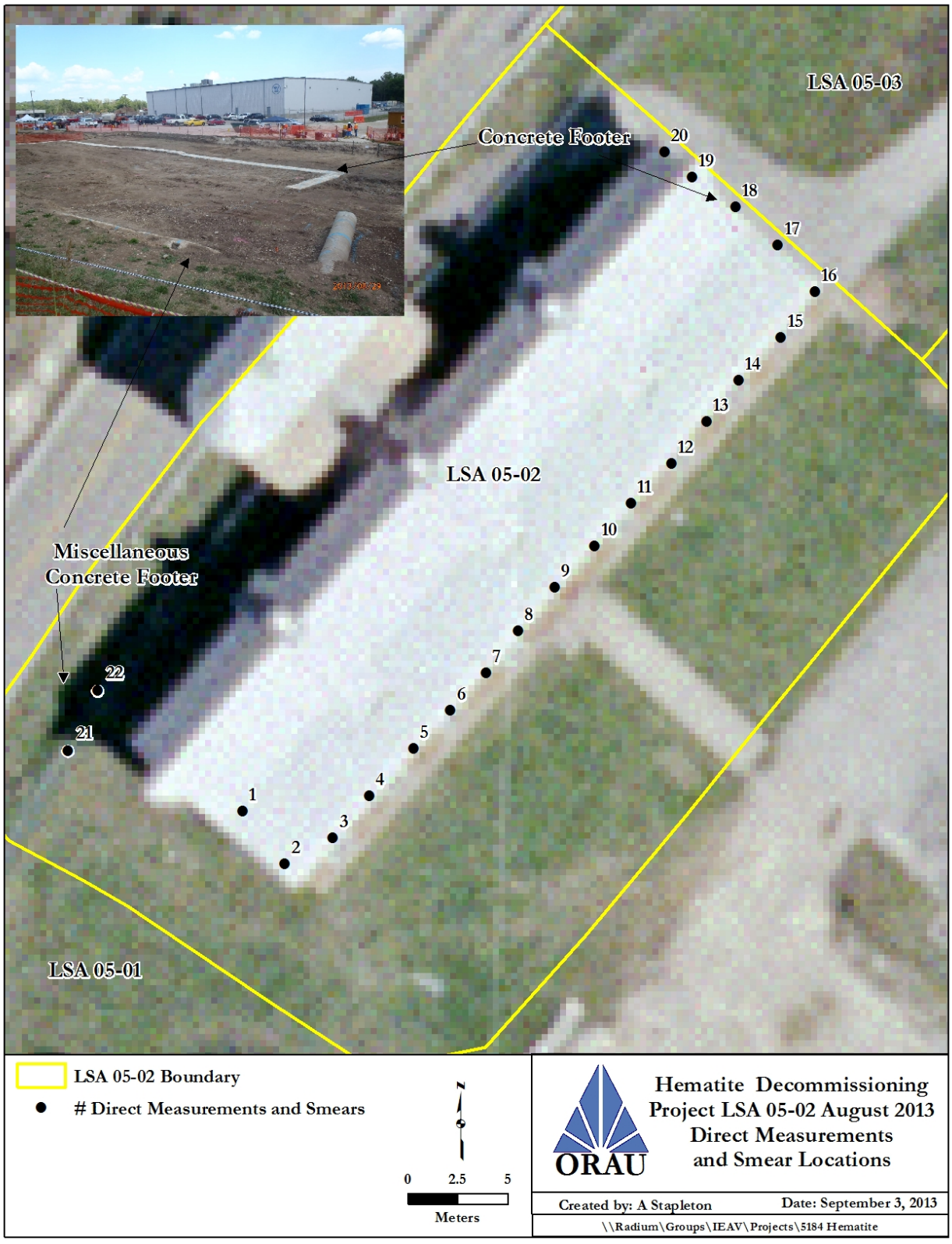


Fig. A-9. LSA 05-02—August 2013, Concrete Footer, Direct Measurement Locations

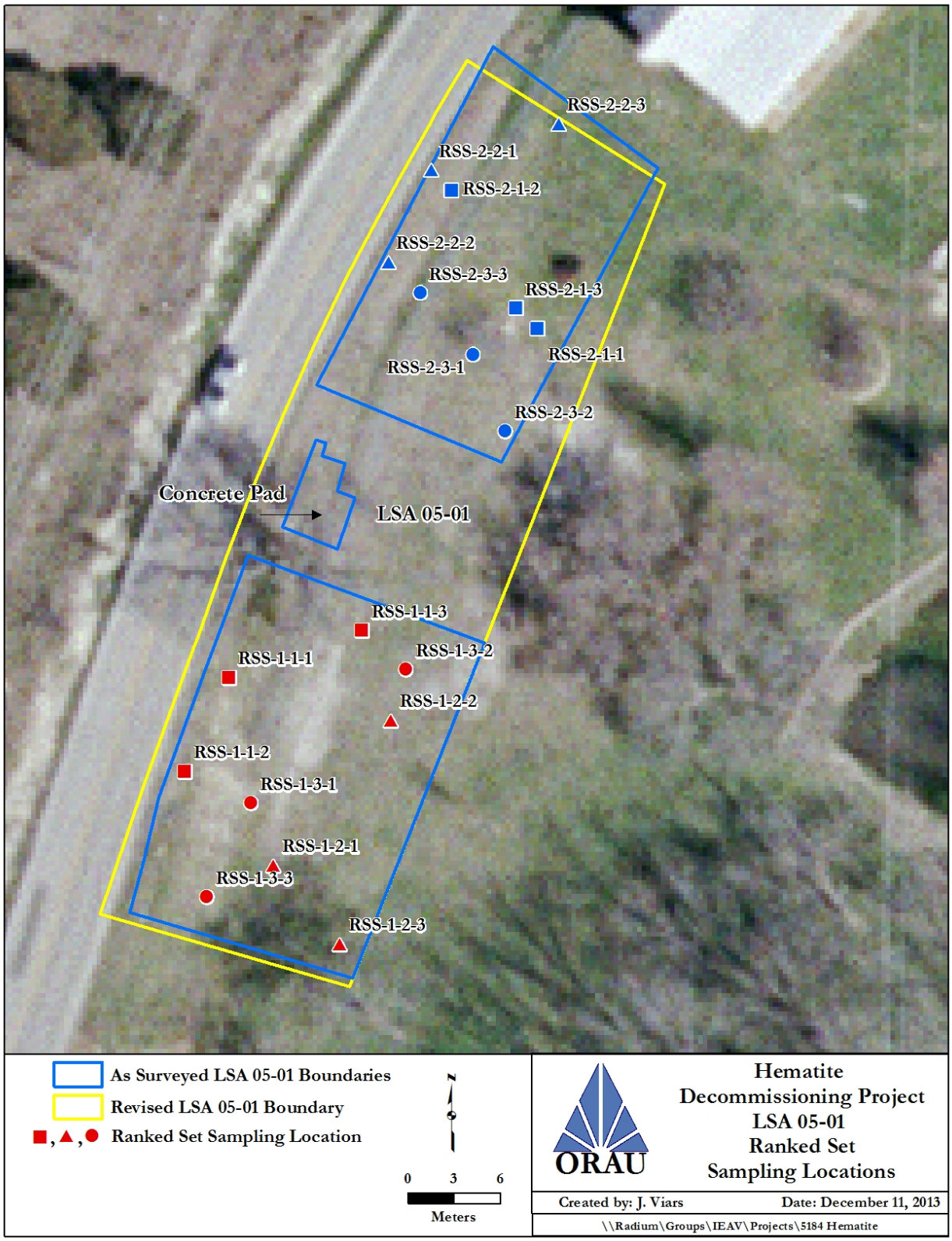


Fig. A-10. LSA 05-01—Ranked Set Sampling Locations

Fig. A-11. LSA 05-02—June 2013, Ranked Set Sampling Locations

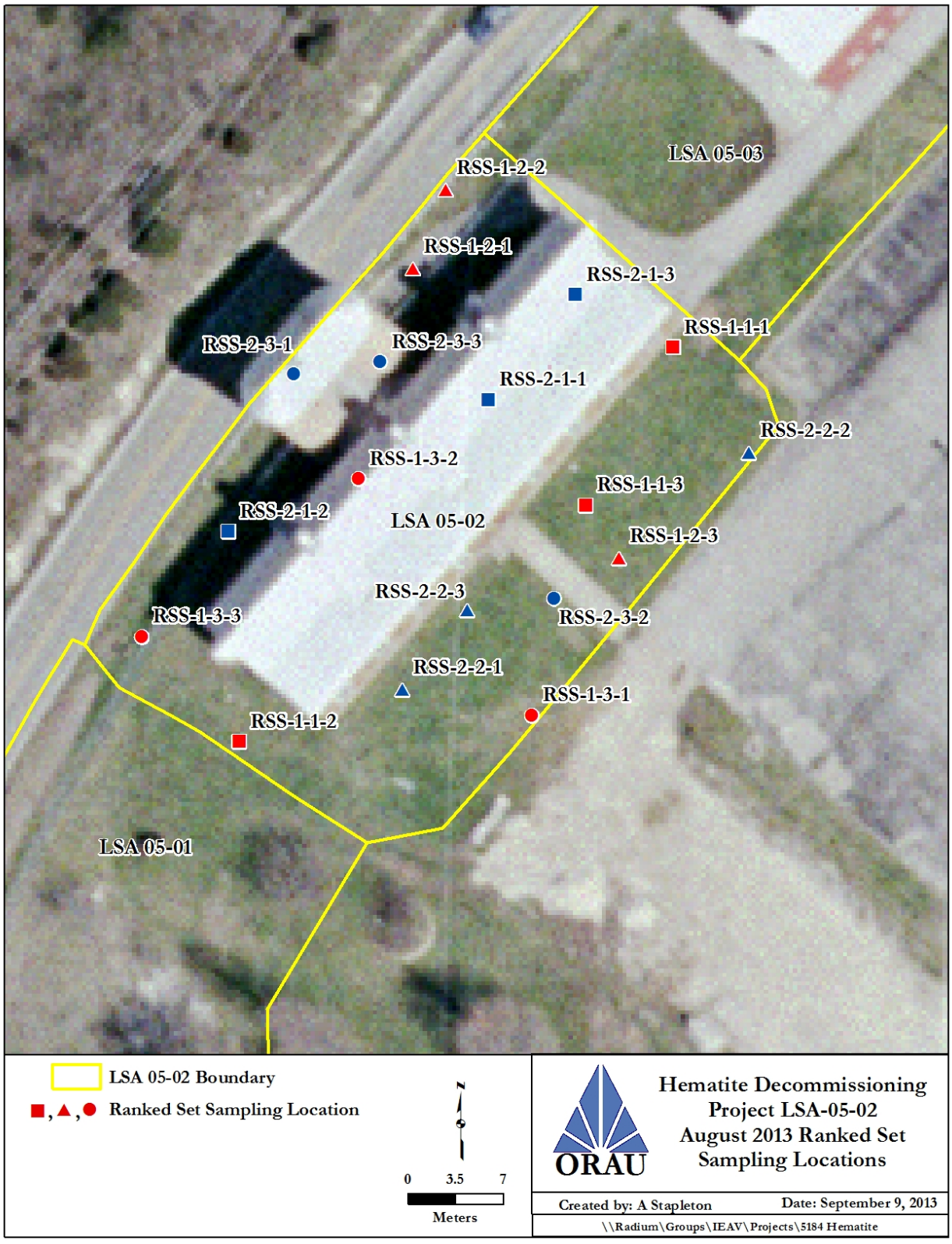


Fig. A-12. LSA 05-02—August 2013, Ranked Set Sampling Locations

Fig. A-13. LSA 05-03—Ranked Set Sampling Locations

Fig. A-14. LSA 05-01—Soil Sampling Locations

Fig. A-15. LSA 05-02—June 2013, Soil Sampling Locations

Fig. A-16. LSA 05-02—August 2013, Soil Sampling Locations

Fig. A-17. LSA 05-03—Soil Sampling Locations

APPENDIX B
DATA TABLES

Table B-1. LSA-05-02 Surface Activity Measurements During June 2013 Surveys Hematite Decommissioning Project Festus, Missouri								
Location[a]	Coordinates (ft)		Surface Material	Surface Activity		Removable Activity		Meets Guideline
				Total Alpha	Total Beta	Alpha	Beta	
	East	North		(dpm/100 cm^2)	(dpm/100 cm^2)	(dpm/100 cm^2)		
1	826614.76	864662.87	Concrete	-23	-14	-1	2	Yes
2	826618.27	864657.99	Concrete	-8	200	-1	-2	Yes
3	826622.7	864654.24	Concrete	-8	130	-1	1	Yes
4	826629.93	864659.55	Concrete	30	71	-1	0	Yes
5	826638.98	864670.56	Concrete	0	-92	4	0	Yes
6	826646.26	864670.12	Concrete	-15	28	4	-1	Yes
7	826647.1	864676.11	Concrete	-15	-280	-1	1	Yes
8	826652.08	864681.6	Concrete	38	56	-1	2	Yes
9	826657.03	864687.08	Concrete	-15	7	-1	-1	Yes
10	826662.18	864693.3	Concrete	-8	-220	-1	1	Yes
11	826667.65	864699.44	Concrete	8	110	1	0	Yes
12	826673.26	864705.29	Concrete	-15	35	-1	-2	Yes
13	826679.11	864712.2	Concrete	-23	-49	-1	0	Yes
14	826684.23	864718.07	Concrete	8	-110	-1	2	Yes

[a]Refer to Fig. A-8.

Table B-2. LSA-05-02 and LSA-05-01 Surface Activity Measurements in August 2013 Hematite Decommissioning Project Festus, Missouri								
Location[a]	Coordinates[a] (ft)		Surface Material	Surface Activity		Removable Activity		Meets Guideline
				Total Alpha	Total Beta	Alpha	Beta	
	East	North		(dpm/100 cm^2)	(dpm/100 cm^2)	(dpm/100 cm^2)		
LSA-05-02 Concrete Footer								
1	826617.0	864664.4	Concrete	62	740	-1	-2	Yes
2	826624.0	864655.8	Concrete	79	200	-1	-2	Yes
3	826631.9	864660.1	Concrete	110[b]	480	-1	0	Yes
4	826637.8	864666.9	Concrete	97	540	-1	3	Yes
5	826643.2	864675.9	Concrete	53	380	-1	0	Yes
6	826651.1	864680.9	Concrete	71	450	-1	4	Yes
7	826656.8	864687.0	Concrete	71	500	-1	-2	Yes
8	826662.0	864693.9	Concrete	71	500	-1	-1	Yes
9	826668.1	864700.9	Concrete	97	380	-1	0	Yes
10	826674.6	864707.7	Concrete	88	590	1	-1	Yes
11	826680.5	864714.7	Concrete	44	200	1	1	Yes
12	826687.1	864721.2	Concrete	71	360	1	3	Yes
13	826692.8	864728.1	Concrete	18	200	-1	0	Yes
14	826698.1	864734.8	Concrete	44	620	-1	2	Yes
15	826705.0	864741.8	Concrete	18	380	-1	1	Yes
16	826710.6	864749.3	Concrete	26	350	-1	3	Yes
17	826704.5	864756.9	Concrete	18	540	-1	5	Yes
18	826697.6	864763.1	Concrete	130[b]	200	-1	5	Yes
19	826690.5	864768.0	Concrete	88	740	1	-1	Yes
20	826686.1	864772.1	Concrete	44	280	-1	-1	Yes

Table B-2. LSA-05-02 and LSA-05-01 Surface Activity Measurements in August 2013 Hematite Decommissioning Project Festus, Missouri								
Location[a]	Coordinates[a] (ft)		Surface Material	Surface Activity		Removable Activity		Meets Guideline
				Total Alpha	Total Beta	Alpha	Beta	
	East	North		(dpm/100 cm^2)	(dpm/100 cm^2)	(dpm/100 cm^2)		
Miscellaneous Pad LSA-05-02								
1	826588.6	864674.4	Concrete	71	940	—[c]	—	Yes
2	826593.4	864684.2	Concrete	0	330	—	—	Yes
LSA-05-01 Concrete Pad								
1	826532.5	864570.6	Concrete	—	1100	—	—	Yes
2	826534.7	864579.0	Concrete	—	970	—	—	Yes
3	826531.5	864579.2	Concrete	—	250	—	—	Yes

[a]Refer to Figs. A-3 and A-9.
[b]These were discrete areas and did not exceed the maximum values; the immediately adjacent 1 m^2 area did not exceed the average value.
[c]Measurement not performed.

Table B-3. U-234 Calculations for LSA-05-01, -02 and -03 Soil Samples Hematite Decommissioning Project Festus, Missouri											
Sample	U-238 (pCi/g)			U-235 (pCi/g)			U-238/ U-235	U-234/ U-235[b]	Enrichment (% U-235)[c]	U-234 (pCi/g)	
	Result	95% Error	MDC[a]	Result	95% Error	MDC				Result	95% Error
5184S0018	11.05	0.85	0.90	2.41	0.22	0.32	4.59	18.15	3.3	43.8	4.0
5184S0019	1.58	0.50	1.10	0.05	0.11	0.25	31.60	22.85	0.5	1.1	2.5
5184S0020	6.46	0.72	1.20	1.57	0.18	0.31	4.11	18.13	3.6	28.5	3.3
5184S0021	1.75	0.40	0.83	0.33	0.10	0.21	5.30	18.23	2.8	6.0	1.8
5184S0022	2.07	0.61	1.40	0.41	0.14	0.31	5.05	18.20	3	7.5	2.5
5184S0023	4.95	0.67	1.30	0.84	0.16	0.32	5.89	18.30	2.6	15.4	2.9
5184S0024	44.8	3.1	2.10	10.21	0.64	0.32	4.39	18.14	3.5	185.2	11.6
5184S0025	16.2	1.2	1.00	3.66	0.26	0.27	4.43	18.14	3.4	66.4	4.7
5184S0026	192	12	5.20	47.1	2.9	0.68	4.08	18.12	3.7	853.6	52.6
5184S0041	1.45	0.58	1.30	0.21	0.14	0.31	6.90	18.43	2.2	3.9	2.6
5184S0042	1.63	0.50	1.10	0.02	0.17	0.33	81.50	32.29	0.2	0.6	5.5
5184S0043	1.21	0.52	1.20	0.05	0.14	0.29	24.20	21.47	0.7	1.1	3.0
5184S0044	1.80	0.41	1.20	0.21	0.20	0.38	8.57	18.68	1.8	3.9	3.7
5184S0045	1.48	0.52	1.20	0.07	0.10	0.24	21.14	20.90	0.7	1.5	2.1
5184S0046	1.63	0.55	1.20	0.09	0.13	0.30	18.11	20.35	0.9	1.8	2.6
5184S0047	1.71	0.59	1.30	0.33	0.22	0.41	5.18	18.22	2.9	6.0	4.0
5184S0048	1.64	0.49	1.10	0.18	0.10	0.24	9.11	18.77	1.7	3.4	1.9
5184S0049	1.10	0.40	0.91	0.05	0.10	0.23	22.00	21.06	0.7	1.1	2.1
5184S0050	1.13	0.55	1.30	0.11	0.10	0.23	10.27	18.96	1.5	2.1	1.9
5184S0051	1.88	0.29	0.53	0.53	0.08	0.13	3.55	18.10	4.2	9.6	1.4
5184S0052	2.68	0.48	0.91	0.64	0.12	0.21	4.19	18.13	3.6	11.6	2.2
5184S0053	0.81	0.30	0.64	0.09	0.06	0.14	9.00	18.75	1.7	1.7	1.1
5184S0054	1.42	0.30	0.90	0.08	0.10	0.23	17.75	20.28	0.9	1.6	2.0
5184S0055	0.46	0.30	0.69	0.03	0.10	0.20	15.33	19.84	1.0	0.6	2.0

Table B-3. U-234 Calculations for LSA-05-01, -02 and -03 Soil Samples Hematite Decommissioning Project Festus, Missouri											
Sample	U-238 (pCi/g)			U-235 (pCi/g)			U-238/ U-235	U-234/ U-235[b]	Enrichment (% U-235)[c]	U-234 (pCi/g)	
	Result	95% Error	MDC[a]	Result	95% Error	MDC				Result	95% Error
5184S0056	1.08	0.39	0.88	0.09	0.09	0.22	12.00	19.25	1.3	1.7	1.7
5184S0057	2.04	0.38	0.71	0.32	0.09	0.18	6.38	18.36	2.4	5.9	1.7
5184S0058	1.61	0.41	0.87	0.17	0.08	0.17	9.47	18.83	1.6	3.2	1.5
5184S0059	1.82	0.42	0.86	0.30	0.10	0.20	6.07	18.32	2.5	5.5	1.8
5184S0060	1.67	0.32	0.66	0.20	0.08	0.17	8.35	18.65	1.8	3.7	1.5
5184S0061	2.04	0.36	0.71	0.08	0.08	0.18	25.50	21.71	0.1	1.7	1.7
5184S0062	1.62	0.39	0.81	0.15	0.08	0.19	10.80	19.05	1.4	2.9	1.5
5184S0063	6.35	0.52	0.83	0.90	0.11	0.19	7.06	18.45	2.0	16.6	2.0

[a]MDC = minimum detectable concentration

[b]From Table 14-5 "Radioactivity and Isotopic Ratios Relative to Enrichment" in the Hematite DP Rev 1.2.

[c]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.

.

Table B-4. Radionuclide Concentration in LSA 05-01, -02, and -03 Soil Samples
Hematite Decommissioning Project
Festus, Missouri

Sample ID	Sample Coordinates (ft)		Radionuclide Concentration (pCi/g)[a]						SOF[c]
	East	North	Tc-99	Ra-226	Th-232	U-234[b]	U-235	U-238	
Uniform $DCGL_w$[d]			25.1	1.9	2	195.4	51.6	168.8	< 1
LSA 05-01[e]									
5184S0053	826542	864545	1.75 ± 0.33[f]	0.59 ± 0.06	0.46 ± 0.10	1.7 ± 1.1	0.09 ± 0.06	0.81 ± 0.30	0.08
5184S0054	826561	864525	0.98 ± 0.29	0.98 ± 0.07	0.92 ± 0.13	1.6 ± 2.0	0.08 ± 0.10	1.42 ± 0.30	0.10
5184S0055	826557	864538	0.07 ± 0.22	0.80 ± 0.07	0.71 ± 0.11	0.6 ± 2.0	0.03 ± 0.10	0.46 ± 0.30	0.01
5184S0056	826580	864609	0.12 ± 0.25	0.90 ± 0.06	1.00 ± 0.14	1.7 ± 1.7	0.09 ± 0.09	1.08 ± 0.39	0.02
5184S0057	826548	864623	0.15 ± 0.26	0.71 ± 0.07	0.35 ± 0.09	5.9 ± 1.7	0.32 ± 0.09	2.04 ± 0.38	0.05
5184S0058	826555	864617	1.06 ± 0.29	0.95 ± 0.08	1.09 ± 0.16	3.2 ± 1.5	0.17 ± 0.08	1.61 ± 0.41	0.14
Average			0.69	0.82	0.76	2.5	0.13	1.24	0.07
Standard Dev.[g]			1.34	0.30	0.59	3.7	0.20	1.12	0.10
Minimum			0.07	0.59	0.35	0.6	0.03	0.46	0.01
Maximum			1.75	0.98	1.09	5.9	0.32	2.04	0.14
LSA 05-01 Judgmental Soil Samples[e]									
5184S0051	826540	864568	46.2 ± 1.1	0.73 ± 0.06	0.18 ± 0.05	9.6 ± 1.4	0.53 ± 0.08	1.88 ± 0.29	1.91
5184S0052	826540	864576	50.9 ± 1.2	1.03 ± 0.09	0.29 ± 0.09	11.6 ± 2.2	0.64 ± 0.12	2.68 ± 0.48	2.18
5184S0059	826525	864574	23.27 ± 0.89	0.95 ± 0.08	0.70 ± 0.12	5.5 ± 1.8	0.30 ± 0.10	1.82 ± 0.42	1.00
LSA 05-02 June 2013[h]									
5184S0018	826606	864717	-0.16 ± 0.23	0.53 ± 0.05	0.52 ± 0.09	43.8 ± 4.0	2.41 ± 0.22	11.05 ± 0.85	0.33
5184S0019	826680	864698	0.30 ± 0.27	0.95 ± 0.09	0.99 ± 0.16	1.1 ± 2.5	0.05 ± 0.11	1.58 ± 0.50	0.05
5184S0020	826647	864705	3.65 ± 0.46	0.80 ± 0.07	0.87 ± 0.13	28.5 ± 3.3	1.57 ± 0.18	6.46 ± 0.72	0.36
5184S0021	826597	864692	0.11 ± 0.26	0.48 ± 0.06	0.31 ± 0.07	6.0 ± 1.8	0.33 ± 0.10	1.75 ± 0.40	0.05
5184S0022	826730	864711	0.70 ± 0.29	0.91 ± 0.09	1.04 ± 0.16	7.5 ± 2.5	0.41 ± 0.14	2.07 ± 0.61	0.11
5184S0023	826697	864681	1.78 ± 0.35	0.91 ± 0.08	1.04 ± 0.16	15.4 ± 2.9	0.84 ± 0.16	4.95 ± 0.67	0.22
LSA 05-02 Judgmental Soil Samples[h]									
5184S0024	826618	864712	0.20 ± 0.26	0.58 ± 0.06	0.65 ± 0.11	185 ± 12	10.21 ± 0.64	44.8 ± 3.1	1.42
5184S0025	826622	864683	2.89 ± 0.42	0.87 ± 0.08	0.86 ± 0.14	66.4 ± 4.7	3.66 ± 0.26	16.2 ± 1.2	0.62

Table B-4. Radionuclide Concentration in LSA 05-01, -02, and -03 Soil Samples Hematite Decommissioning Project Festus, Missouri									
Sample ID	**Sample Coordinates (ft)**		**Radionuclide Concentration (pCi/g)[a]**						**SOF[c]**
	East	**North**	**Tc-99**	**Ra-226**	**Th-232**	**U-234[b]**	**U-235**	**U-238**	
5184S0026[i]	826618	864712	0.17 ± 0.26	0.55 ± 0.09	0.43 ± 0.15	854 ± 53	47.1 ± 2.9	192 ± 12	6.43
LSA 05-02 August 2013[j]									
5184S0041	826712	864741	-0.05 ± 0.27	1.29 ± 0.12	1.30 ± 0.21	3.9 ± 2.6	0.21 ± 0.14	1.45 ± 0.58	0.39
5184S0042	826699	864691	-0.04 ± 0.26	1.43 ± 0.11	1.41 ± 0.21	0.6 ± 5.5	0.02 ± 0.17	1.63 ± 0.50	0.50
5184S0043	826678	864653	-0.21 ± 0.28	1.23 ± 0.10	1.33 ± 0.20	1.1 ± 3.0	0.05 ± 0.14	1.21 ± 0.52	0.34
5184S0044	826689	864754	-0.03 ± 0.27	1.14 ± 0.10	1.08 ± 0.18	3.9 ± 3.7	0.21 ± 0.20	1.80 ± 0.41	0.20
5184S0045	826663	864678	-0.03 ± 0.25	1.24 ± 0.10	1.31 ± 0.20	1.5 ± 2.1	0.07 ± 0.10	1.48 ± 0.52	0.35
5184S0046	826683	864681	-0.03 ± 0.22	1.10 ± 0.10	1.16 ± 0.19	1.8 ± 2.6	0.09 ± 0.13	1.63 ± 0.55	0.20
Average			-0.06	1.24	1.27	2.13	0.11	1.53	0.33
Standard Dev.g			0.14	0.23	0.24	2.79	0.16	0.40	0.22
Minimum			-0.21	1.10	1.08	0.65	0.02	1.21	0.20
Maximum			-0.03	1.43	1.41	3.92	0.21	1.80	0.50
LSA-05-03[k]									
5184S0047	826794	864914	0.01 ± 0.26	1.19 ± 0.11	1.10 ± 0.20	6.0 ± 4.0	0.33 ± 0.22	1.71 ± 0.59	0.25
5184S0048	826809	864879	-0.14 ± 0.22	1.20 ± 0.10	1.21 ± 0.18	3.4 ± 1.9	0.18 ± 0.10	1.64 ± 0.49	0.29
5184S0049	826826	864897	0.83 ± 0.29	0.87 ± 0.06	0.86 ± 0.14	1.1 ± 2.1	0.05 ± 0.10	1.10 ± 0.40	0.05
5184S0060	826734	864786	0.13 ± 0.17	0.67 ± 0.06	0.82 ± 0.13	3.7 ± 1.5	0.20 ± 0.08	1.67 ± 0.32	0.04
5184S0061	826718	864772	0.09 ± 0.17	0.88 ± 0.06	1.09 ± 0.14	1.7 ± 1.7	0.08 ± 0.08	2.04 ± 0.36	0.07
5184S0062	826710	864791	0.17 ± 0.17	0.78 ± 0.06	1.03 ± 0.15	2.9 ± 1.5	0.15 ± 0.08	1.62 ± 0.39	0.05
Average			0.18	0.93	1.02	3.5	0.17	1.63	0.12
Standard Dev.g			0.66	0.43	0.29	4.9	0.19	0.59	0.22
Minimum			-0.14	0.67	0.82	1.1	0.05	1.10	0.04
Maximum			0.67	1.10	1.13	8.9	0.49	2.34	0.29
LSA-05-03 Judgmental Soil Sample[i]									
5184S0050	826828	864873	-0.22 ± 0.23	0.98 ± 0.10	1.18 ± 0.20	2.1 ± 1.9	0.11 ± 0.10	1.13 ± 0.55	0.14
5184S0063	826691	864819	0.01 ± 0.17	0.82 ± 0.07	1.08 ± 0.16	16.6 ± 2.0	0.90 ± 0.11	6.35 ± 0.52	0.18

[a]These values are gross concentrations; background concentrations have not been subtracted. Background values are from HDP FSS Data Summary Report for Stockpile 2, Table 5-1: those values are 0.9 pCi/g for Ra-226 and 1 pCi/g for Th-232 (WEC 2012).
[b]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-3.
[c]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 follow: Th-232 is 1.0 pCi/g and Ra-226 is 0.9 pCi/g (WEC 2012).
[d]$DCGL_W$ values are from the Uniform Stratum column in Table 5.2.
[e]Refer to Fig. A-14.
[f]Uncertainties represent the 95% upper confidence level interval, based on total propagate uncertainties.
[g]Two sigma standard deviation (1.96*standard deviation).
[h]Fig. A-15.
[i]Samples in red text are subsurface soil samples collected at the 30 to 45 cm depth.
[j]Fig. A-16.
[k]Fig. A-17.

Table B-5. Comparison of Split Soil Samples From LSA 05-02 in June 2013												
Sample ID		Tc-99						Ra-226				
ORAU	WEC[a]	ORAU			WEC[a]			ORAU			WEC[a]	
5184S0025	L050236PUB00	2.89	±	0.42[b]	7.81	±	0.87	0.87	±	0.08	0.82	± 0.13
5184S0024	L050237PUB00	0.20	±	0.26	0.29	±	0.20	0.58	±	0.06	0.58	± 0.18
5184S0026	L050238PUB00	0.17	±	0.26	0.62	±	0.09	0.55	±	0.09	0.37	± 0.16
Sample ID		Th-232						U-234 (inferred)				
ORAU	WEC[a]	ORAU			WEC[a]			ORAU			WEC[a]	
5184S0025	L050236PUB00	0.86	±	0.14	0.92	±	0.16	66.4	±	4.7	72	± ---[c]
5184S0024	L050237PUB00	0.65	±	0.11	0.84	±	0.23	185	±	12	144	± ---
5184S0026	L050238PUB00	0.43	±	0.15	0.29	±	0.17	854	±	53	509	± ---
Sample ID		U-235						U-238				
ORAU	WEC[a]	ORAU			WEC[a]			ORAU			WEC[a]	
5184S0025	L050236PUB00	3.66	±	0.26	3.97	±	0.50	16.2	±	1.2	18.2	± 2.5
5184S0024	L050237PUB00	10.21	±	0.64	7.9	±	1.1	44.8	±	3.1	33.4	± 4.2
5184S0026	L050238PUB00	47.1	±	2.9	28.1	±	3.1	192	±	12	114.0	± 12.6
Sample ID		Sum of Fractions										
ORAU	WEC[a]	ORAU			WEC[a]							
5184S0025	L050236PUB00	0.62			0.86							
5184S0024	L050237PUB00	1.42			1.10							
5184S0026	L050238PUB00	6.43			3.85							

[a]WEC results provided in email from NRC (NRC 2013).
[b]Uncertainties represent the 95% upper confidence level interval, based on total propagated uncertainties.
[c]Results not calculated by WEC.

APPENDIX C
MAJOR INSTRUMENTATION

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the author or his employer.

C.1 SCANNING AND MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

C.1.1 Gamma

Ludlum NaI Scintillation Detector Model 44-10, Crystal:2 in × 2 in
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)

C.1.2 Beta

Ludlum Gas Proportional Detector Model 43-68, 126 cm^2 physical area
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to:
Trimble Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

C.1.2 Laboratory Analytical Instrumentation

High Purity Extended Range Intrinsic Detector
CANBERRA/Tennelec Model No: ERVDS30-25195
(Canberra, Meriden, CT)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, TN) and
Multichannel Analyzer
Canberra's Apex Gamma Software
Dell Workstation
(Canberra, Meriden, CT)

High Purity Extended Range Intrinsic Detector
Model No. GMX-45200-5
(AMETEK/ORTEC, Oak Ridge, TN)
used in conjunction with:
Lead Shield Model SPG-16-K8
(Nuclear Data)
Multichannel Analyzer
Canberra's Apex Gamma Software
Dell Workstation
(Canberra, Meriden, CT)

High-Purity Germanium Detector
Model GMX-30-P4, 30% Eff.
(AMETEK/ORTEC, Oak Ridge, TN)
Used in conjunction with:
Lead Shield Model G-16

(Gamma Products, Palos Hills, IL) and
Multichannel Analyzer
Canberra's Apex Gamma Software
Dell Workstation
(Canberra, Meriden, CT)

Low Background Gas Proportional Counter
Model LB-5100-W
(Tennelec/Canberra, Meriden, CT)

APPENDIX D
SURVEY AND ANALYTICAL PROCEDURES

D.1 PROJECT HEALTH AND SAFETY

The proposed survey and sampling procedures were evaluated to ensure that any hazards inherent to the procedures themselves were addressed in current job hazard analyses. All survey and laboratory activities were conducted in accordance with Oak Ridge Associated Universities (ORAU) health and safety and radiation protection procedures (ORAU 2012 and ORAU/ORISE 2011).

Pre-survey activities included the evaluation and identification of potential health and safety issues. Survey work was performed per the ORAU generic health and safety plans and a site-specific Integrated Safety Management pre-job hazard checklist. Hematite Decommissioning Project (HDP) personnel also provided site-specific safety awareness training. An ORAU safety walkdown of the site indicated that the reuse stockpiles had uneven terrain that could cause slip and trip hazards and steep slopes on portions of the pile that would be inaccessible due to safety issues.

D.2 CALIBRATION AND QUALITY ASSURANCE

Calibration of all field and laboratory instrumentation was based on sources/standards traceable to the National Institute of Standards and Technology (NIST).

Analytical and field survey activities were conducted in accordance with procedures from the following ORAU and ORAU/ORISE documents:

- *Survey Procedures Manual* (ORAU/ORISE 2013b)
- *Laboratory Procedures Manual* (ORAU/ORISE 2013c)
- *Quality Program Manual* (ORAU 2013)

The procedures contained in these manuals were developed to meet the requirements of 10 CFR 830 Subpart A, *Quality Assurance Requirements* and Department of Energy Order 414.1D *Quality Assurance* (CFR 2012 and DOE 2011).

Quality control procedures included:

- Daily instrument background and check-source measurements to confirm that equipment operation was within acceptable statistical fluctuations

- Participation in Mixed-Analyte Performance Evaluation Program, NIST Radiochemistry Intercomparison Testing Program, and Intercomparison Testing Program Laboratory Quality Assurance Programs
- Training and certification of all individuals performing procedures
- Periodic internal and external audits

D.3 SURVEY PROCEDURES

D.3.1 SURFACE SCANS

D.3.1.1 Concrete

Structural surface scans were performed by passing the detectors slowly over the surface; the distance between the detector and the surface was maintained at a minimum—nominally about 1 cm. Building structural surfaces were scanned using a floor monitor gas proportional detector (550 cm^2) and/or a small area (126 cm^2) hand-held gas proportional detector. Identification of elevated radiation levels was based on increases in the audible signal from the recording and/or indicating instrument.

The identification of elevated radiation levels that could exceed the site criteria was determined based on an increase in the audible signal from the indicating instrument, surveyor diligence, and judgmental observations.

The beta scan minimum detectable concentrations (MDCs) were estimated using the calculational approach described in NUREG-1507[1]. The scan MDC is a function of many variables, including the background level. Site surface activity background levels were within the typical range of 200 to 270 cpm for the hand-held gas proportional detectors. The hand-held gas proportional background for surface activity was re-determined on site and was 231 cpm. Additional parameters selected for the calculation of beta scan MDC included a one-second observation interval, a specified level of performance at the first scanning stage of 95% true positive rate and 25% false positive rate, which yields a d′ value of 2.32 (NUREG-1507, Table 6.1), and a surveyor efficiency of 0.5. To illustrate an

[1]NUREG-1507. Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. US Nuclear Regulatory Commission. Washington, DC; June 1998.

example for the hand-held gas proportional detectors with 0.8 mg/cm^2 windows, the minimum detectable count rate (MDCR) and scan MDC can be calculated as follows:

b_i = (231 cpm) (1 s) (1 min/60 s) = 3.85 counts

MDCR = (2.32) (3.85 counts)^{½} [(60 s/min) / (1 s)] = 273 cpm

$MDCR_{surveyor}$ = 273 / (0.5)^{½} = 386 cpm

The scan MDC is calculated using the total scanning efficiency (ε_{total}) of 0.11:

$$\text{Scan MDC} = \frac{MDCR_{surveyor}}{\varepsilon_{total}} \text{ dpm/100 cm}^2$$

The scan MDC for the hand-held gas proportional detector was calculated to be 3,500 dpm/100 cm^2.

D.3.1.2 Soil

A NaI(Tl) scintillation detector was used to scan for elevated gamma radiation. Identification of elevated radiation levels was based on increases in the audible signal from the recording and/or indicating instrument. ORAU Survey Procedures (ORAU/ORISE 2013a) require a minimum scan speed of 0.5 to 1 meter per second (m/s) based on the site contaminant and the $DCGL_W$ for the primary contaminant of concern. The scan minimum detectable concentrations for the NaI scintillation detectors were 2.8 pCi/g for Ra-226 and 1.8 pCi/g for Th-232, and ranged from 80.0 pCi/g for natural uranium to 132 pCi/g for highly enriched uranium as provided in NUREG-1507 (Table 6.4 [NRC 1998]). Any audible increase in radiation levels were investigated by ORAU. It is standard procedure for the ORAU staff to pause and investigate any locations where gamma radiation is distinguishable from background levels.

D.3.2 SURFACE ACTIVITY MEASUREMENTS

Measurements of total alpha and total beta surface activity levels were performed using hand-held gas proportional detectors coupled to portable ratemeter-scalers. Count rates which were integrated over one minute with the detector held in a static position, were converted to activity levels (dpm/100 cm^2) by dividing the count rate by the total static efficiency ($\varepsilon_i \times \varepsilon_s$) and correcting for the

physical area of the detector. ORISE determined construction material-specific backgrounds for each surface type encountered for determining net count rates.

The MDC for surface activity measurements was calculated using the following equation:

$$MDC = \frac{3 + (4.65\sqrt{BKG})}{T * \varepsilon_{Total} * G}$$

Where:

BKG	=	background (total counts) in time interval, T
T	=	count time (min) used for field instruments
ε_{Total}	=	total efficiency = ε_i x ε_s
ε_i	=	instrument efficiency
ε_s	=	source efficiency
G	=	geometry (physical detector area $cm^2/100$)

The alpha static MDC for the gas proportional detector was 69 dpm/100 cm^2 using the total efficiency of 0.11 and an instrument background of 2 cpm. The beta static MDC for the gas proportional detector was 520 dpm/100 cm^2 using the total efficiency of 0.11 and an instrument background of 221 cpm. The physical surface area assessed by the gas proportional detectors used was 126 cm^2.

D.3.3 REMOVABLE ACTIVITY MEASUREMENT

Removable gross alpha and gross beta activity levels were determined using numbered filter paper disks, 47 mm in diameter. Moderate pressure was applied to the smear and approximately 100 cm^2 of the surface was wiped. Smears were placed in labeled envelops with the location and other pertinent information recorded.

D.3.4 SOIL SAMPLING

Approximately 0.5 to 1.0 kg of soil was collected at each sample location. Collected samples were placed in a plastic bag, sealed, and labeled in accordance with ORAU survey procedures.

D.4 RADIOLOGICAL ANALYSIS

D.4.1 GAMMA SPECTROSCOPY

Samples of soil were dried, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker or other appropriate container. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights and volumes were determined and the samples counted using intrinsic germanium detectors coupled to a pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. All total absorption peaks (TAPs) associated with the radionuclides of concern were reviewed for consistency of activity. TAPs used for determining the activities of radionuclides of concern and the typical associated minimum detectable concentration for a one-hour count time were:

Radionuclide	TAP[a] (MeV)	MDC[b] (pCi/g)
Ra-226 by Pb-214	0.352	0.08
Th-232 by Ac-228	0.911	0.17
U-235	0.143	0.30
U-238 by Th-234	0.063	0.96

[a]Spectra were also reviewed for other identifiable total absorption peaks (TAPs) that would not be expected at this site.
[b]MDC = minimum detectable concentration.

D.4.2 TC-99 ANALYSES

Tc-99 was quantified by radiochemical separation using extraction chromatography and counted by liquid scintillation. Samples were homogenized and leached with dilute nitric acid. The leachates were passed through an extraction chromatographic column containing a resin (TEVA resin) which is highly specific for technetium in the pertechnatate form. The technetium is absorbed onto the extraction resin. The resin is added to a scintillation vial containing an appropriate cocktail and counted using a liquid scintillation analyzer. All interfering beta emitting radionuclides are effectively removed (including C-14, P-32, S-35, Sr-90, Y-90, and Th-234) using TEVA resin under the conditions in this procedure. The typical minimum detectable concentration (MDC) for a five gram sample and a 60-minute count time was 0.25 pCi/g.

D.4.3 GROSS ALPHA/GROSS BETA ANALYSES

Smears were counted on a low-background gas proportional system for gross alpha and beta activity. The minimum detectable activities of the procedure were 11 dpm and 14 dpm for alpha and beta, respectively.

D.4.4 UNCERTAINTIES

The uncertainties associated with the analytical data presented in the tables of this report represent the total propagated uncertainties for that data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels.

D.5 DETECTION LIMITS

Detection limits, referred to as minimum detectable concentrations, were based on 3 plus 4.65 times the standard deviation of the background count [$3 + (4.65\ (BKG)^{1/2})$]. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.

APPENDIX D REFERENCES

10 CFR 830 Subpart A. *Quality Assurance Requirements.* U.S. Department of Energy Code of Federal Regulations. Accessible at http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr;sid=ed5895d29b2e304754f1b99ba774261b;rgn=div5;view=text;node=10%3A4.0.2.5.26;idno=10;cc=ecfr#10:4.0.2.5.26.1

DOE 2011. *Quality Assurance.* U.S. Department of Energy Order 414.1D. Washington, DC. April 25.

NRC 1998. *Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions.* NUREG-1507. U.S. Nuclear Regulatory Commission. Washington, DC. June.

ORAU 2012. *Health and Safety Manual.* Revision 16. Oak Ridge Associated Universities. Oak Ridge, Tennessee; May 12.

ORAU 2013. *Quality Program Manual for the Independent Environmental Assessment and Verification Program.* Oak Ridge Associated Universities. Oak Ridge, Tennessee; August 15.

ORAU/ORISE 2011. *Radiation Protection Manual.* Oak Ridge Institute for Science and Education, managed and operated by Oak Ridge Associated Universities. Oak Ridge, Tennessee. December 3.

ORAU/ORISE 2013b. *Survey Procedures Manual for the Independent Environmental Assessment and Verification Program.* Oak Ridge Institute for Science and Education, managed and operated by Oak Ridge Associated Universities. Oak Ridge, Tennessee. January 18.

ORAU/ORISE 2013c. *Laboratory Procedures Manual for the Independent Environmental Assessment and Verification Program.* Oak Ridge Institute for Science and Education, managed and operated by Oak Ridge Associated Universities. Oak Ridge, Tennessee. August 15.

APPENDIX E

ORAU STATISTICAL SURVEY DESIGN FOR THE LSA 05 SURVEY UNITS AT THE HEMATITE DECOMMISSIONING PROJECT IN FESTUS, MISSOURI

E.1 SURVEY DESIGN SUMMARY

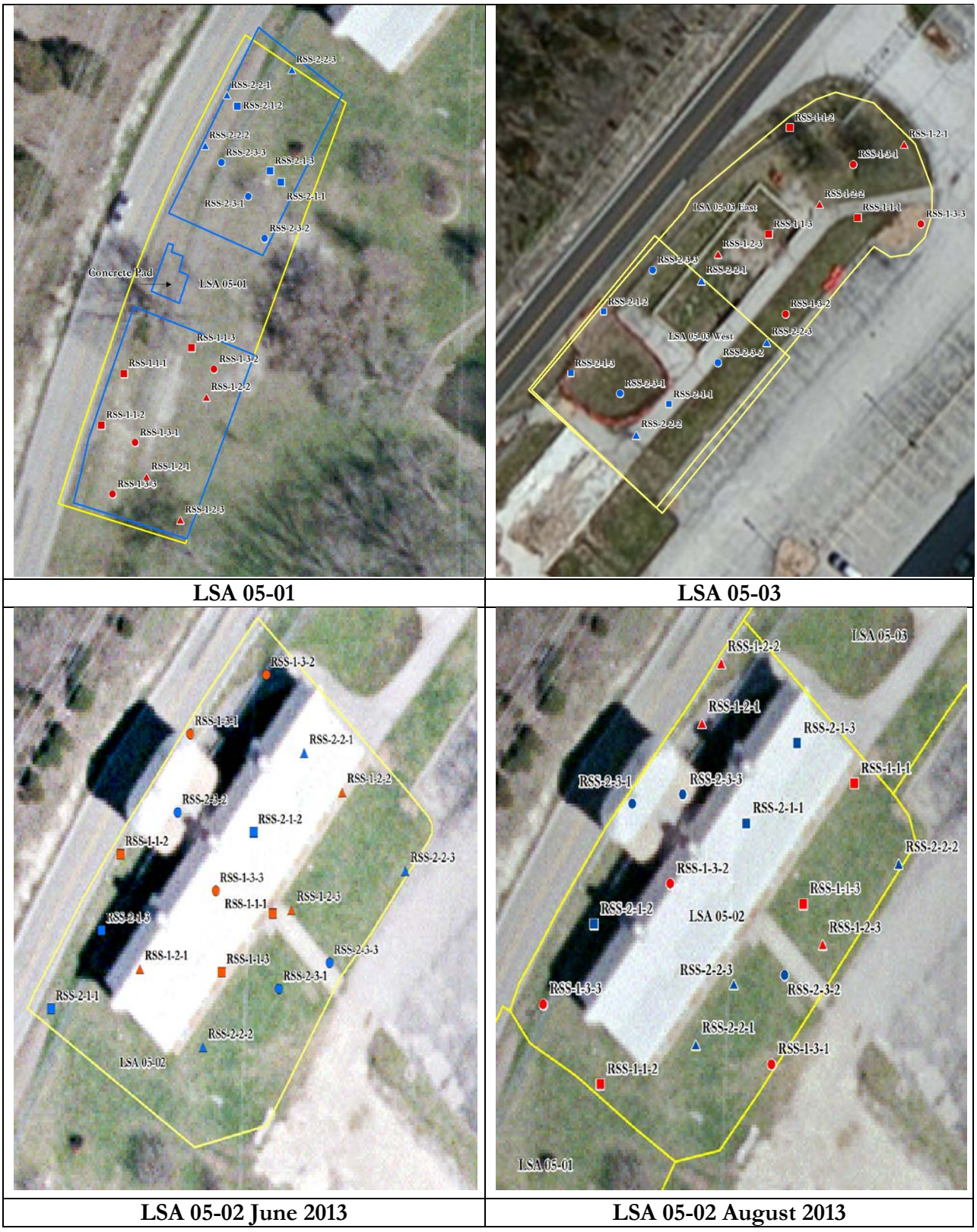
ORAU used available preliminary final status survey data to develop a defensible statistical sampling and survey design for the LSA 05 survey units at the Hematite Decommissioning Project Site property in Festus, Missouri. A ranked set sampling (RSS) design was selected using associated statistical assumptions as well as general guidelines for conducting post-sampling data analysis. The selected RSS statistical approach, as set forth in U.S. Environmental Protection Agency (EPA) QA/G-5S, calculates the number of samples required to determine a confidence interval for the mean that meets the boundaries provided by the user (EPA 2002). ORAU used the RSS data inputs, in conjunction with Visual Sample Plan (VSP), to determine how many sampling locations to choose and where within the sampling area to collect RSS gamma measurements and soil samples.

The following table summarizes the balanced RSS design developed for LSA 05.

Summary of Sampling Design for LSA 05 Survey Units	
Primary Objective of Design	Estimate the Population Mean
Sample placement (location) in the field	Simple random sampling
Formula for calculating number of sampling locations	Balanced ranked set sampling equations in EPA QA/G-5S (EPA 2002)
Number of ranks (m)(chosen set size)	3
Calculated number of cycles (r)	2
Number of samples to analyze (m x r)	6
Number of field locations to rank(m^2 x r)	18
Number of selected sample areas[a]	3

[a]The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.

Fig. E-1 demonstrates the detailed VSP measurement locations in the field for the three survey units (SUs) from the confirmatory survey activities. There were 18 RSS measurement locations within SUs LSA 5-01, LSA 05-02, and LSA 05-03 from which six soil samples were collected. Table E-1 lists the sampling coordinates generated by VSP that were identified in the field for these LSA 05 SUs and the direct gamma measurement results that were used to determine the sampling locations.



LSA 05-01	LSA 05-03
LSA 05-02 June 2013	LSA 05-02 August 2013

Fig. E-1. Example of the RSS Measurement/Sampling Plan for the ORAU Confirmatory Survey Units for LSA 05-01, LSA 05-02, and LSA 05-03

Table E-1. Ranked Set Sampling Gamma Measurements LSA 05 Barns and Cistern Open Land Area Confirmatory Survey Activities Hematite Decommissioning Project Festus, Missouri									
East (ft)	North (ft)	RSS Measurement Location				Gamma Count Rate (cpm)[a]	Code[b]	Surface Soil Sample ID[c]	Subsurface Gamma Counts (cpm)[a]
		Cycle	Set	#	Symbol				
LSA 05-01: Cistern Burn Pit, Red Room Roof Burial Pit and Limestone Fill Areas[d]									
826514.0	864535.0	1	1	1	■	6,986	L	—[e]	—
826504.6	864515.0	1	1	2	■	6,636	L	—	—
826542.4	864545.1	1	1	3	■	5,898	L	5184S0053	6,855
823523.5	864495.0	1	2	1	▲	10,422	M	—	—
826561.3	864525.0	1	2	2	▲	10,441	M	5184S0054	11,230
826537.7	864478.4	1	2	3	▲	11,776	M	—	—
826518.8	864508.4	1	3	1	●	8,752	H	—	—
826556.6	864538.4	1	3	2	●	9,210	H	5184S0055	9,403
826509.3	864488.4	1	3	3	●	8,765	H	—	—
826579.8	864609.3	2	1	1	■	11,360	L	5184S0056	11,914
826561.6	864638.7	2	1	2	■	11,643	L	—	—
826575.2	864613.6	2	1	3	■	11,443	L	—	—
826557.1	864643.1	2	2	1	▲	6,820	M	—	—
8265478.0	864623.5	2	2	2	▲	7,070	M	5184S0057	7,009
826584.3	864652.9	2	2	3	▲	11,080	M	—	—
826566.1	864603.8	2	3	1	●	10,033	H	—	—
826573.0	864587.5	2	3	2	●	6,369	H	—	—
826554.8	864616.9	2	3	3	●	10,644	H	5184S0058	11,196
LSA 05-02: Tile Barn Area – June 2013[f]									
826671.8	864697.3	1	1	1	■	9,187	L	—	—
826605.5	864716.5	1	1	2	■	8,486	L	5184S0018	8,800
826649.7	864678.1	1	1	3	■	10,000	L	—	—
826613.8	864679.0	1	2	1	▲	10,028	M	—	—
826702.1	864736.7	1	2	2	▲	8,745	M	—	—
826680.0	864698.2	1	2	3	▲	9,282	M	5184S0019	10,219
826636.9	864755.9	1	3	1	●	6,820	H	—	—
826669.0	864775.1	1	3	2	●	7,156	H	—	—
826646.9	864704.6	1	3	3	●	10,687	H	5184S0020	11,413
826575.1	864666.2	2	1	1	■	11,042	L	—	—

Table E-1. Ranked Set Sampling Gamma Measurements LSA 05 Barns and Cistern Open Land Area Confirmatory Survey Activities Hematite Decommissioning Project Festus, Missouri									
East (ft)	**North (ft)**	**RSS Measurement Location**				**Gamma Count Rate (cpm)[a]**	**Code[b]**	**Surface Soil Sample ID[c]**	**Subsurface Gamma Counts (cpm)[a]**
		Cycle	**Set**	**#**	**Symbol**				
826663.5	864723.9	2	1	2	■	10,237	L	—	—
826597.2	864691.8	2	1	3	■	4,936	L	5184S0021	4,849
826685.6	864749.5	2	2	1	▲	7,889	M	—	—
826641.4	864653.4	2	2	2	▲	10,141	M	—	—
826729.7	864711.1	2	2	3	▲	8,101	M	5184S0022	8,553
826674.5	864672.6	2	3	1	●	9,377	H	—	—
826630.3	864730.3	2	3	2	●	8,082	H	—	—
826696.6	864681.1	2	3	3	●	10,228	H	5184S0023	11,095
LSA 05-02: Tile Barn Area – August 2013[g]									
826712.1	864741.3	1	1	1	■	10,651	L	5184S0041	10,948
826607.8	864646.5	1	1	2	■	10,974	L	—	—
826691.3	864703.4	1	1	3	■	11,145	L	—	—
826649.5	864760.2	1	2	1	▲	12,379	M	—	—
826657.4	864779.2	1	2	2	▲	7,952	M	—	—
826699.1	864690.7	1	2	3	▲	11,618	M	5184S0042	11,919
826678.2	864652.8	1	3	1	●	12,111	H	5184S0043	12,980
826636.5	864709.7	1	3	2	●	11,009	H	—	—
826584.3	864671.8	1	3	3	●	9,629	H	—	—
826667.8	864728.6	2	1	1	■	10,654	L	—	—
826605.2	864697.0	2	1	2	■	10,831	L	—	—
826688.6	864753.9	2	1	3	■	10,587	L	5184S0044	11,272
826646.9	864659.1	2	2	1	▲	10,994	M	—	—
826730.4	864716.0	2	2	2	▲	12,355	M	—	—
826662.6	864678.1	2	2	3	▲	11,077	M	5184S0045	12,011
826620.8	864735.0	2	3	1	●	8,906	H	—	—
826683.4	864680.9	2	3	2	●	13,850	H	5184S0046	14,189
826641.7	864737.8	2	3	3	●	10,915	H	—	—
LSA 05-03: Red Wood Barn Area[h]									
826827.8	864872.7	1	1	1	■	13,629	L	—	—
826794.3	864914.4	1	1	2	■	9,860	L	5184S0047	10,159

Table E-1. Ranked Set Sampling Gamma Measurements
LSA 05 Barns and Cistern Open Land Area Confirmatory Survey Activities
Hematite Decommissioning Project
Festus, Missouri

East (ft)	North (ft)	RSS Measurement Location				Gamma Count Rate (cpm)[a]	Code[b]	Surface Soil Sample ID[c]	Subsurface Gamma Counts (cpm)[a]
		Cycle	Set	#	Symbol				
826783.8	864865.0	1	1	3	■	10,803	L	—	—
826850.8	864906.7	1	2	1	▲	9,840	M	—	—
826808.9	864878.9	1	2	2	▲	10,091	M	5184S0048	10,595
826758.7	864855.7	1	2	3	▲	10,448	M	—	—
826825.7	864897.4	1	3	1	●	9,876	H	5184S0049	10,199
826792.2	864827.9	1	3	2	●	9,061	H	—	—
826859.1	864869.6	1	3	3	●	9,504	H	—	—
826734.4	864786.3	2	1	1	■	11,250	L	5184S0060	11,704
826702.1	864829.2	2	1	2	■	12,462	L	—	—
826686.0	864800.6	2	1	3	■	11,926	L	—	—
826750.6	864843.5	2	2	1	▲	11,391	M	—	—
826718.3	864772.0	2	2	2	▲	11,068	M	5184S0061	12,608
826782.9	864814.9	2	2	3	▲	8,719	M	—	—
826710.2	864791.1	2	3	1	●	11,244	H	5184S0062	12,738
826758.6	864805.4	2	3	2	●	10,346	H	—	—
826726.4	864848.3	2	3	3	●	10,371	H	—	—

[a]cpm = counts per minute
[b]L = low, M = medium, H = high: RSS decisions determined by which of the set of three gamma readings in the set meet the High, Medium, or Low value as designated.
[c]Refer to Figs. A-14 through A-17
[d]Refer to Figs. A-10 and A-14
[e]Sample not collected
[f]Refer to Figs. A-11 and A-15
[g]Refer to Figs. A-12 and A-16
[h]Refer to Figs. A-13 and A-17