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March 22, 2013

Mr. Theodore Smith
U.S. Nuclear Regulatory Commission
Office of Federal and State Materials and Environmental Management Program
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SUBJECT: FINAL REPORT—GAMMA DETECTOR RESPONSE/SOIL CONCENTRATION CORRELATION STUDY AT THE AAR MANUFACTURING, INC. SITE, LIVONIA, MICHIGAN DCN 5204-SR-01-0 (RFTA NO. 12-015)

Dear Mr. Smith:

Enclosed is the final report for the gamma detector response/soil concentration correlation study at the AAR Manufacturing, Inc. site in Livonia, Michigan. The survey was designed to determine the relationship between sodium iodide detector response and the average thorium-232 concentration in soil. The report provides information and results of Oak Ridge Associated Universities' activities, performed under the Oak Ridge Institute for Science and Education contract, during the U.S. Nuclear Regulatory Commission's September 25–27, 2012 inspection. Comments on the draft report have been incorporated into this final report.

You may contact me via my information below, Erika Bailey at 865.576.6659, or Tim Vitkus at 865.576.5073 if you have any questions.

Sincerely,

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NAA:fr

Enclosure

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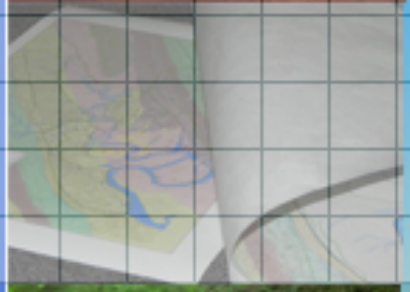

GAMMA DETECTOR RESPONSE/SOIL CONCENTRATION CORRELATION STUDY AT THE AAR MANUFACTURING, INC. SITE, LIVONIA, MICHIGAN

Nick A. Altic

Prepared for the
U.S. Nuclear Regulatory Commission

FINAL REPORT

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Oak Ridge Associated Universities manages the Oak Ridge Institute for Science and Education (ORISE) contract for the U.S. Department of Energy. ORISE focuses on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists.

GAMMA DETECTOR/SOIL CONCENTRATION CORRELATION STUDY AT THE AAR MANUFACTURING, INC. SITE, LIVONIA, MICHIGAN

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Prepared for the
U.S. Nuclear Regulatory Commission

FINAL REPORT

MARCH 2013

Prepared by Oak Ridge Associated Universities 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. F1008) between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy.

5204-SR-01-0

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GAMMA DETECTOR/SOIL CONCENTRATION CORRELATION STUDY AT THE AAR MANUFACTURING, INC. SITE, LIVONIA, MICHIGAN

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FINAL REPORT

MARCH 2013

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ACRONYMS

AA	alternate action
AAR	AAR Manufacturing, Inc.
AEC	U.S. Atomic Energy Commission
BKA	B. Koh and Associates, Inc.
cpm	counts per minute
CSXT	CSX Transportation, Inc.
$DCGL_W$	derived concentration guideline level
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FR	Finishing Room
GPS	global positioning system
MA/PR	Mill Area/Pickling Room
MRA	Melt Room Area
NRC	U.S. Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram
PSP	project-specific plan
PSQ	principal study question
R^2	coefficient of determination
RSS	ranked set sampling

GAMMA DETECTOR RESPONSE/SOIL CONCENTRATION CORRELATION STUDY AT THE AAR MANUFACTURING, INC. SITE, LIVONIA, MICHIGAN

1. INTRODUCTION

The site currently owned and occupied by AAR Manufacturing, Inc. (AAR) was once owned by the former Brooks and Perkins Company, which manufactured products containing thorium alloys from 1957 to 1981. In 1959, the Brooks and Perkins Company was issued a license from the U. S. Atomic Energy Commission (AEC), predecessor to the U.S. Nuclear Regulatory Commission (NRC), to possess and use 15,000 pounds of thorium. Process operations used a master magnesium-thorium alloy containing 40% thorium to produce alloy products such as HM21 (ingots), consisting of approximately 2% thorium, and HK31 (sheets) of approximately 3% thorium (BKA 1996). The master alloy was heated, melted, and then poured into molds. After the material had cooled, the castings were removed from the molds, cut, and trimmed. The scrap metal was recovered, heated and melted, rolled into sheets that were further heated and formed, and then pickled in an acid bath. The final product was sanded, ground, and brushed prior to shipping.

The manufacturing process of magnesium-thorium castings began in the Melt Room Area (MRA). The milling and pickling processes of the castings were performed in the Mill Area/Pickling Room (MA/PR), adjacent to the MRA. The final processing of the castings was performed in the Finishing Room (FR), located immediately west of the MA/PR (BKA 1996).

In 1970, Brooks and Perkins conducted a radiological survey to support termination of their license with the AEC. The radiological survey indicated that the residual radioactive material concentrations within the process areas and rooms were below the 1970 AEC guidelines for unrestricted release. The survey identified contamination outside of the MRA and the Melting and Scalping Rooms. Reportedly, contaminated material from the walkway outside of the MRA had been buried on-site, but this was not substantiated during the initial survey effort (BKA 1996). In 1971, Brooks and Perkins requested and received termination of its license.

AAR purchased the Brooks and Perkins property in 1981. AAR manufactures specialty items (aluminum cargo containers and related structural supports) for the aircraft industry. In 1994, the

NRC conducted an inspection of the site, including interior building surfaces and exterior land areas, and determined that there was thorium contamination in both interior and exterior locations. AAR contracted B. Koh and Associates, Inc. (BKA) to perform site characterization surveys in 1996 and 1999 and to perform limited remediation in January 2000. Final survey and sampling data for the remediated area were provided to the NRC in March 2000 (BKA 2000). In late 2006 into early 2007 AAR excavated 6,100 m^2 grids to a depth of 1 m. These grids were 118 and 210 in the eastern parcel and 73, 100, 219, and 249 in the western parcel (AAR 2007).

AAR is planning to perform additional remediation of the western portions of the site. For this remedial action, the NRC is considering a confirmatory survey where data could be acquired and used to estimate the mean soil thorium concentration in "real time" after remediation has been performed. Therefore, the NRC required a field study to determine the feasibility of the real time confirmatory survey and to determine if an acceptable correlation could be developed between a sodium iodide (NaI) detector's response and thorium concentration in soil. At the NRC's request, Oak Ridge Associated Universities (ORAU), under the Oak Ridge Institute for Science and Education (ORISE) contract, performed radiological surveys and soil sampling activities to determine if such a relationship could be established. The survey also included gamma radiation scans of the site boundary to investigate whether thorium contamination has migrated onto bordering properties. The CSX Transportation, Inc. (CSXT) railroad property was not included in the boundary scan as this property had already been surveyed and the results reported to the NRC (ORISE 2011a). Structural scans were originally planned to be performed on the concrete floor of the pickling area and the "New Addition" portions in the manufacturing facility.

2. SITE DESCRIPTION

The AAR site is located at 12633 Inkster Road in Livonia, Michigan, approximately 20 miles northwest of downtown Detroit (Fig. A-1). The site is bordered on the north and west by light industrial and commercial property, on the south by CSXT, and on the east by Inkster Road (Fig. A-2). The site includes a manufacturing facility and a small paint storage building that is centrally located.

The main facility consists of 172,000 ft^2 and houses areas formerly used for engineering and administrative offices, the primary manufacturing area, as well as pickling, materials storage, and milling areas. The adjacent paint storage building has approximately 1,500 ft^2 of area. Originally, two separate buildings (the old commercial building and the mill) occupied the site. During the 1970s, the buildings were connected. The New Addition to the mill was added over existing contaminated soil.

The correlation study area boundary was located along the western portion of the site, just north of CSXT railroad and east of the Ladbroke Race Track property. The study boundary consisted of a large woodland area which was overgrown with thick vegetation that limited the radiological survey activities. Accessibility was also impacted by large pieces of unconsolidated concrete dispersed within the study boundary.

3. RADIOLOGICAL SURVEY PLAN

The radiological surveys were performed during the period of September 25–27, 2012, in accordance with the project-specific plan (PSP) submitted to the NRC; the ORAU/ORISE Survey Procedures Manual; and the ORAU Quality Program Manual (ORAU/ORISE 2012a and b; ORAU 2012a). The correlation study activities included gamma radiation surface scan surveys; static gamma radiation measurements; and the collection of surface soil (0 to 15 cm) and subsurface soil (0.15 to 1 meter) samples. The PSP also included provisions to conduct limited radiological survey activities of the New Addition concrete slab and the pickling area floor. However, with approval from the NRC site representative these areas were eliminated from the project scope and a decision was made to redefine the correlation study boundary (due to the overgrowth). Also, NRC requested that investigative gamma scans be performed in the "front yard" between AAR and neighboring areas and transformer pads. These changes from the PSP were documented in the site logbook.

3.1 DATA QUALITY OBJECTIVES

The data quality objectives (DQO) process provides a formalized method for planning radiation surveys, improving survey efficiency and effectiveness, and ensuring that the type, quality, and quantity of data collected are adequate for the intended decision applications (EPA 2006). The

radiological correlation study was designed using a graded approach. The level of effort was affected by the site conditions, time constraints, and site personnel decisions. Furthermore, DQO definition, implementation, and assessment are iterative processes because newly collected data may form the basis for redefining the evaluation.

The seven steps of the DQO process are as follows:

1. State the problem.
2. Identify the decision/objective.
3. Identify inputs to the decision/objective.
4. Define the study boundaries.
5. Develop a decision rule.
6. Specify limits on decision errors.
7. Optimize the design for obtaining data.

Historical site information and limited survey results provided to ORAU were reviewed and DQOs for this survey effort were developed. Due to decisions made by the NRC and ORAU site personnel while onsite, portions of the original PSP DQOs were not implemented during this site visit. These decisions were documented in the site logbook.

3.1.1 State the Problem

The relationship between NaI instrument response and Th-232 concentration in soil is unknown. Th-232 concentration is expected to exhibit variability with respect to soil depth, further confounding the relationship. Additionally, it is unknown whether contamination has migrated offsite. Therefore, the problem statement was as follows:

> *Determine if there is a correlation between NaI detector response and Th-232 concentration and if contamination has spread offsite.*

3.1.2 Identify the Decision/Objective

The second step in the DQO process identifies the principal study question (PSQ) and alternate actions (AAs), develops a decision statement, and organizes multiple decisions, as appropriate. This is done by specifying AAs that could result from a "yes" response to the PSQ and combining the

PSQ and AAs into a decision statement. Table 3.1 presents the PSQ and AAs combined into the decision statement as defined in the original PSP.

Table 3.1. Survey Decision Process

Principal Study Questions	Actions
Can NaI response be used as a predictor of average Th-232 concentration in soil?	**Yes:** Surface scans are acceptable for estimating Th-232 concentration in soil during confirmatory survey activities. **No:** Surface scans are not acceptable for estimating Th-232 concentration in soil; other sampling options must be explored.
Is there contamination at the site area boundary?	**Yes:** The NRC may alter remedial action planning to address this contamination. **No:** The NRC may not be required to alter remedial action planning to address contamination.
Decision Statements	
Determine the correlation between NaI detector response and Th-232 concentration; determine if there is contamination at the site boundary.	

3.1.3 Identify Inputs to the Decision/Objective

Laboratory analysis of soil samples collected during this survey trip was compared with NaI instrument response at the sample locations. Static NaI detector measurements were also collected at soil sample locations to support correlation calculations. Additionally, data from the 1999 characterization report and the 2004 ORISE confirmatory report were used to supplement the relationship established during the current survey activities (BKA 1999; ORISE 2004). Gamma walkover scans were used to identify potential contamination at the site boundary.

3.1.4 Define the Study Boundaries

Boundaries for the correlation study were originally limited to the grids tentatively identified for remediation (Solutient 2011). However, once the survey team was onsite, the study boundary was redefined to include the grids listed in Table 3.2; the study boundary is depicted graphically in Appendix A, Fig. A-2

Table 3.2. Grids Included in Correlation Study Boundary[a]									
Grid Numbers									
74	98	122W	126	158	218	265	216W	281W	283S
75	99	123	155W	187	219	266	246W	282S	155W
76	100	124	156	188	247	284E	263W	217	122W
97W	101	125	157	189	249	186W	264	248	

[a]Grid numbers were taken from BKA 1999.

3.1.5 Develop a Decision Rule

Calculate the coefficient of determination (R^2) between NaI detector response and Th-232 concentration. If R^2 is above the threshold as defined in Section 3.1.6, then conclude that NaI detector response can be used as a predictor of Th-232 concentration in soil.

There was no specific decision rule for the site boundary. The objective was to collect as much data as possible in the allotted time for turnover to the NRC.

3.1.6 Specify Limits on Decision Errors

The BKA 1999 characterization data were used as inputs for determining that 33 samples were required to estimate the Th-232 mean concentration at the 90% confidence level with an acceptable confidence interval of ± 25% of the mean.

An R^2 value of 0.75 for the regression correlation between the gamma count rates and soil concentrations was selected such that 75% of the variation in Th-232 concentration is explained by variation in NaI instrument response and uncertainty in the surficial depth of contamination.

There were no specified limits on decision errors for the site boundary.

3.1.7 Optimize the Design

A ranked set sampling (RSS) approach was used, following U.S. Environmental Protection Agency (EPA) guidance, to select the soil sample locations. RSS provides a methodology to estimate the mean concentration of a population, but does not require the assumption of a normal distribution. A set size of 3, corresponding to high, medium, and low NaI response, was used. Specifics as to the

number of cycles and required samples were determined using Visual Sample Plan software. Based on specified limits in the original PSP DQO decision errors, the RSS approach resulted in 109 ranking locations from which the 33 sample locations were to be selected. However, once onsite, the study boundary was revised and the mean and standard deviation for the new study boundary had to be recalculated using the BKA characterization data. Those new values were used in a Visual Sample Plan run to determine the number of ranking locations and soil samples required. Based on those results, 21 soil samples were required from 63 RSS locations. Figure A-3 shows the RSS locations. Additional details of the survey design are provided in Sections 3.3 and 3.4.

Because this study was to establish, if possible, a correlation between detector response and Th-232 concentration, judgmental sampling was also performed. Gamma walkover data were reviewed and large gaps in the range of detector responses that were not intrusively sampled using the RSS approach were selected as judgmental sample locations. For example, if no RSS location represented the 30,000 to 50,000 counts per minute (cpm) range, the Field Lead directed the collection of a judgmental sample from such an area.

Also, to support the correlation, soil cores were to be collected at each RSS sample location and divided into 0 to 0.15-m and 0.15 to 1.0-m intervals. The 0 to 0.15-m interval was analyzed separately as this interval would have the most influence on NaI responses. Judgmental locations also included 0 to 0.15-m and 0.15 to 1.0-m intervals.

3.2 REFERENCE SYSTEM

ORAU referenced survey results using global positioning system (GPS) coordinates or other prominent site features. The coordinate reference system that was used was the North American Datum 1983 Michigan State Plane with units represented in meters. Measurement and sampling locations were documented on detailed survey maps. Specific areas were also digitally photographed.

3.3 LAND AREA SURFACE SCANS

3.3.1 Study Area

Medium-density walkover surface scans for gamma radiation were conducted within the limits of the study boundary. Scans were performed using a Ludlum model 44-10 2 × 2 NaI detector coupled to

a Ludlum model 2221 ratemeter-scaler with an audible indicator. Electronic data collection was facilitated using detectors that were coupled to GPS data loggers, enabling real-time gamma count rate and position data capture. This enabled the collection of scanning count rate data at one-second intervals, thus allowing for evaluations of the electronically captured data distributions, possible outliers, and/or comparisons with soil sample results.

3.3.2 Additional Survey Areas

At the request of the NRC site representative, medium-density gamma scans were performed on the soil surface of the "front yard" in between AAR and the neighboring areas and transformers. Scans were performed using NaI detectors coupled to ratemeter-scalers with audible indicators. The gamma scan data and coordinates from these surveys were also captured electronically with the GPS data loggers.

3.4 SOIL SAMPLING

One-minute static gamma counts were collected using the NaI detector at each sample location prior to sample collection. Static measurements were collected on contact with the soil and at an offset of 10 inches away from the soil surface. Soil samples were collected at sample locations generated by the RSS approach, as described in Section 3.1.7 using hand and/or power augers (depending on the availability of a generator) and other standard sampling equipment (e.g., stainless steel bowls, trowels). Table B-1 provides the RSS ranking data. Equipment was decontaminated prior to reuse. For the core sampling, soil was augered to a depth of 1 m or until refusal. The soil contained a large amount of rocks, which made sampling difficult (see Fig. 3.1). Soil from the 0.15–1.0 m interval was homogenized and a representative aliquot of the homogenized mixture was collected for analysis. The number of samples collected was adequate to estimate the mean activity concentration level across the study boundary, taking into account the decision errors discussed in Section 3.1.6.

Fig. 3.1. Rocks in Soil

4. SAMPLE ANALYSIS AND DATA INTERPRETATION

Scan data and volumetric samples were returned to the ORAU/ORISE 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 2012c). Samples were analyzed by solid-state gamma spectroscopy for Th-232 via associated decay products. The spectra were also reviewed for other identifiable photopeaks. Soil sample results are reported in units of picocuries per gram (pCi/g). Analytical laboratory results were evaluated and compared to the gamma scan count rate values per the DQOs.

5. FINDINGS AND RESULTS

This section discusses results for each confirmatory survey activity.

5.1 SURFACE SCANS

Surface scan results for the study boundary and the "front yard" are discussed below. Gamma radiation levels represent gross counts that have not been subjected to background correction.

5.1.1 Study Area

The gamma scans of the study area determined that gamma radiation levels ranged from background to 81,000 cpm. Flags were placed at locations exhibiting elevated gamma radiation, in order to mark possible judgmental sample locations. The discrete location associated with a detector response of 81,000 cpm was one of five areas identified as exhibiting elevated activity. Figure A-4 shows ORAU gamma scan coverage and detector response in cpm for the entire study area.

5.1.2 Site Boundary/Front Yard

ORAU personnel performed a 0.25–0.5 meters per second medium-density walkover gamma scan of soil areas within the "front yard" on the east side of the AAR site. ORAU personnel also performed gamma walkover scans around the AAR site boundary, focusing on the southern boundary. Access to the site boundary on the north side of the building was blocked; therefore this area was not investigated. However, the southern boundary was identified as being the most important for assessing whether contamination has spread offsite. The gamma radiation scans ranged from background to 81,000 cpm. Gamma scan results for the "front yard" and site boundary are illustrated in Fig. A-5. Five locations of elevated direct gamma radiation were marked for further investigation. Locations in the "front yard" had static gamma measurements of 25,000 cpm in the northeast corner, 50,000 cpm in the southeast yard outside the transformer pad, and 80,000 cpm outside the transformer pad. Two locations along the site boundary in the north-west corner had static gamma measurements of 24,000 and 38,000 cpm.

5.2 THORIUM CONCENTRATIONS IN SOILS

This section discusses the ORAU/ORISE laboratory sample results for the thorium concentration in soil.

5.2.1 Study Area Soils

A summary of the laboratory sample results for thorium concentration in soil samples collected from the study area is presented in Table B-2. As indicated in the data table B-2, not all core samples could be collected as planned within the time constraints of the on-site activities. Due to a significant amount of rocks present in the soil, as shown in Fig. 3.1, a much greater amount of time was required to sample each location than planned.

Th-228 and Th-232 concentrations ranged from 0.33 to 123 pCi/g. Sample 5204S0026 contained the highest thorium concentration — a core sample (0.15 to 1 m) from judgmental location S0022. Several judgmental locations were subject to a high-response-low-activity scenario, due to the majority of the contamination being below 15 cm but close enough to the surface to contribute significant detector response.

5.2.2 Site Boundary Soils

A judgmental surface soil sample (0 to 15 cm) was collected from each of the two locations marked for further investigation in the northwest corner of the site. The laboratory sample results for these two judgmental samples are presented in Table 5.1.

Table 5.1. Radionuclide Concentration for Judgmental Samples Collected Along the Site Boundary

Sample ID	NaI Response (cpm)		Radionuclide Concentration and Uncertainty (pCi/g)[a]	
	Pre[b]	Post[c]	Th-228	Th-232
5204S0038	23,987	21,524	10.63 ± 0.76	10.2 ± 1.1
5204S0039	31,365	38,048	19.4 ± 1.4	18.3 ± 1.9

[a]Uncertanties represent the total propagated uncertainties at the 95% confidence level.
[b]Static measurement was taken before sample collection.
[c]Static measurement was taken after sample collection.

5.3 CORRELATION STUDY

Analytical soil sample results and static NaI instrument responses were analyzed using Origin Pro (OriginLab v8.6) software. Instrument response was plotted along the abscissa and the average 0–1 m Th-232 concentration along the ordinate. In order to determine the average Th-232 concentration in the 0 to 1 m layer of soil each portion of the core (surface sample and core sample) was weighted by its respective sample depth to the total sample depth. A regression line (form of $y = m*x + b$) was added using the linear fit function.

5.3.1 Evaluation of Laboratory Results versus Field Measurements

Random and judgmental Th-232 surface concentrations were plotted against the corresponding static NaI detector measurements that were made on contact with the soil. The 10-inch offset static NaI measurements were not used in the correlation study because at some locations the offset instrument response was higher than the contact response, likely due to gamma "shine" contributions from neighboring thorium deposits. Figure 5.1 presents all Th-232 concentrations in surface soil plotted against their respective contact NaI detector response.

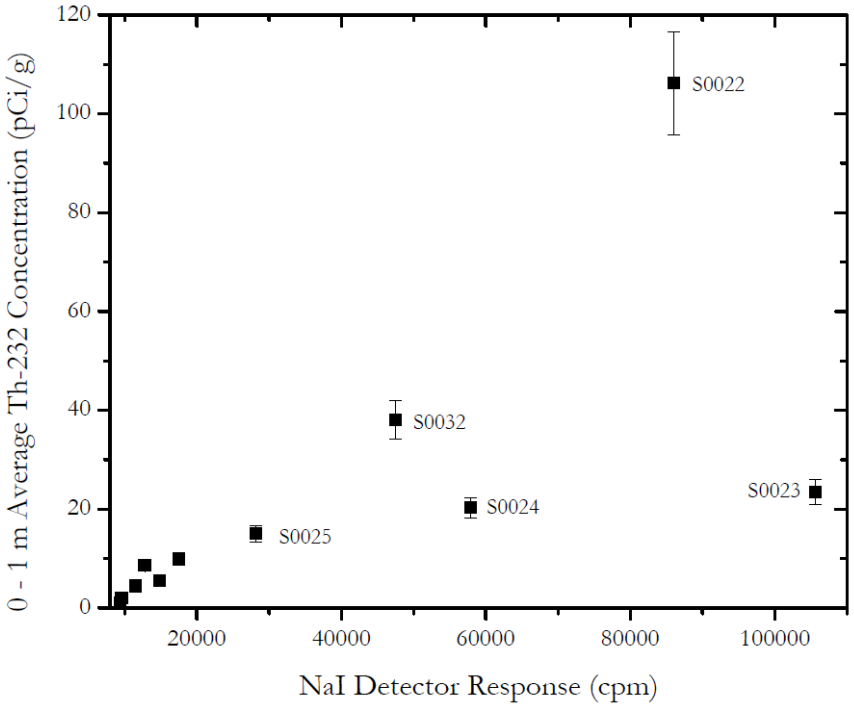

Fig. 5.1. Th-232 Concentration in all Surface Soil Samples Plotted against Respective Contact NaI Response*

*Error bars represent the total propagated uncertainty at the 95% confidence level.

Figure 5.1 shows a positive correlation between NaI detector response and the average Th-232 concentration in surface soil, but there are several anomalous data points also present. All of the anomalous data points are from judgmental sample locations.

The cause of the anomalous data points seen in Fig. 5.1 is not overly apparent by simply examining the graph. There are a couple of possible scenarios that caused these anomalies. The first is that the

contamination resided deep in the soil, and the second is that the NaI detector was responding to gamma "shine" originating from somewhere near to the sample point. The first scenario is not very likely as the NaI detector was used to qualitatively scan each sample borehole. For every borehole, the detector response was observed to peak somewhere between 12 and 18 inches below the surface, meaning that large amounts of contamination below the sampled depth are not likely. The second scenario is the more likely cause of the anomalies. For a given sample location, if the majority of the contamination was in a discrete area that was close to the sample collected, the resulting detector response would be high and the Th-232 concentration in that soil sample would be low. Some sample locations had to be moved slightly (less than 30 cm in any direction) to avoid large rocks in the soil (see Fig. 3.1).

Removing the judgmental samples from the plot provides a better correlation of instrument response to soil concentration. Figure 5.2 shows only the weighted average Th-232 concentration at random sampling locations vs. detector response. A positive correlation between NaI detector response and average Th-232 concentration in soil is apparent. Linear regression performed on the data provided an R^2 value of 0.79, meaning that 79% of the variation in Th-232 concentration can be explained by variation in NaI detector response. The best fit line of the data set in Fig. 5.2 has a slope of 1.1×10^{-3} pCi g^{-1} cpm^{-1} and a y-intercept of -9.13 pCi/g. The 95% confidence bands for the trendline are also plotted in Fig. 5.2.

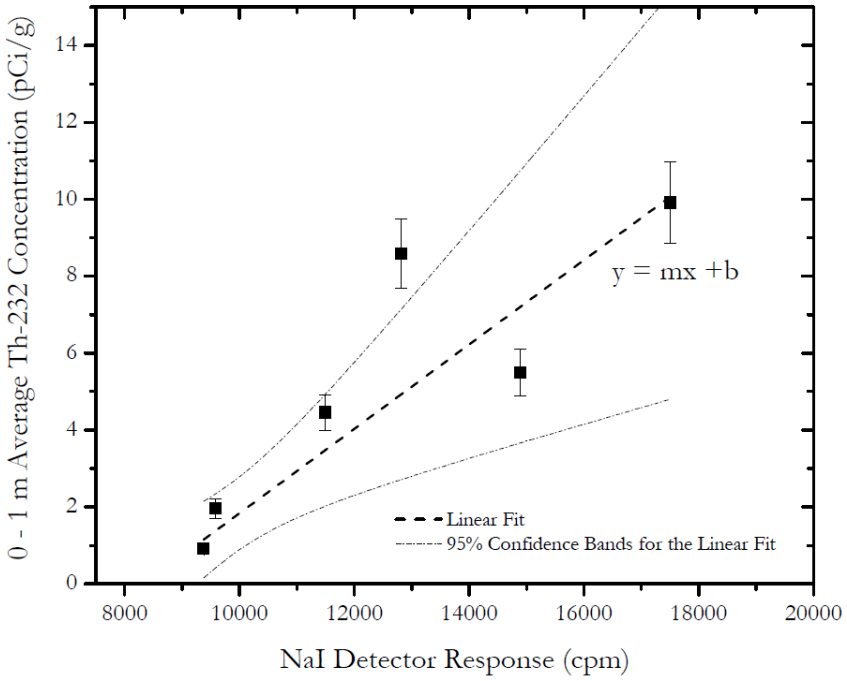

Fig. 5.2. Th-232 Concentration in Random Surface Soil Samples Plotted against Respective Contact NaI Response*

*Error bars represent the total propagated uncertainty at the 95% confidence level. Confidence bands are the 95% confidence level.

The standard error of the estimate was used to evaluate the variability in the predicted Th-232 concentration. The standard error of the estimate is analogous to the standard deviation of a distribution and is calculated using Equation 5.1.

Equation 5.1

$$\sigma_{est} = \sqrt{\frac{\Sigma(Y - Y_{est})^2}{n-2}}$$

Where:

σ_{est} = standard error of the estimate
Y_{est} = estimated concentration based on the regression equation
Y = actual concentration
n = number of scores

In Equation 5.1, n-2 degrees of freedom are used because two parameters (the slope and intercept) were estimated in order to calculate the sum of the squares. Using the data presented in Fig. 5.1,

σ_{est} is calculated as 2.09. A σ_{est} of 2.09 means that 68.2% of the actual analytical data points should fall within ± 2.09 pCi/g of the trend line in Fig. 5.2. The equation for estimating the Th-232 concentration is presented as:

$$C_{Th\text{-}232}\,[pCi/g] = (1.11 \times 10^{-3} \cdot X\,[cpm] - 9.13) \pm 4.10$$

The error in the equation above is at the 95% confidence level (i.e. 1.96 · 2.09). The regression equation is valid for detector responses up to 17,500 cpm. Extrapolating the trendline to detector responses above 17,500 cpm should be cautioned. One would expect the trend to continue as linear, but looking at Fig. 5.1, this may not be apparent.

5.3.2 Th-232 Concentration Cross-check

An average 0 to 1 m Th-232 concentration was calculated using the regression equation in Section 5.3.1. The scan average NaI detector response was used as the X input into the regression equation. Table 5.2 presents the surface average Th-232 concentration calculated by the regression equation and as determined from analysis of the RSS samples. The regression equation was able to predict the average Th-232 concentration in the 0 to 1 m soil layer for the study area at the 95% confidence level.

Table 5.2. Average 0–1 m Th-232 Concentration in the Study Area

Scenario	Instrument Response (cpm)	Th-232 Concentration (pCi/g)	
		Sample Analytical Average[a]	By Regression[b]
Scan Average	15,000	5.22 ± 6.97	7.37 ± 4.10
Judgmental Surface Static Average	65,000	40.58 ± 73.79	62.40 ± 4.10

[a]Error represents the population standard deviation (95% confidence level)
[b]Error represents the standard error of the estimate (95% confidence level)

The large error in Table 5.2 for the sample analytical average is due to the small number of judgmental samples with a high variability in Th-232 concentration. The error in the predicted average judgmental concentration does not provide much meaning as the input (NaI detector response) is outside the limits of the regression. The regression equation overestimated the Th-232 concentration in judgmental samples mostly because S0023 and S0024 are lowering the average

analytical concentration. Looking at Fig. 5.3 the extrapolated trendline provides a reasonable prediction for the average Th-232 concentration in the soil cores.

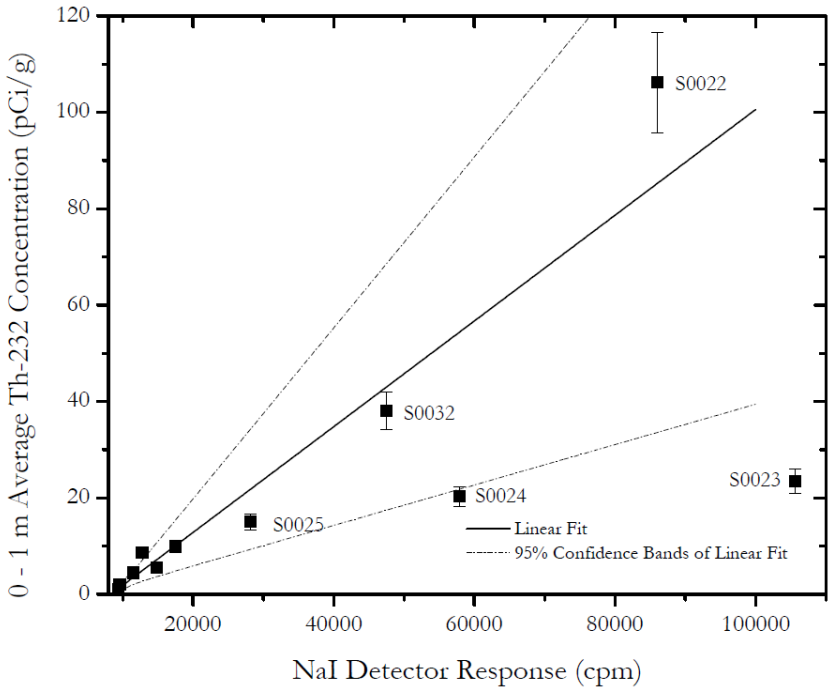

Fig. 5.3. Average Th-232 Soil Concentration with Trendline and Confidence Bands Forecasted to 100,000 cpm*

*Error bars represent the total propagated uncertainty at the 95% confidence level. Confidence bands are the 95% confidence level.

6. SUMMARY

At the NRC's request, ORAU conducted surveys of the AAR Manufacturing site during the period of September 25 through September 27, 2012. The survey activities included walkover surveys and sampling activities. Once the survey team was onsite, the NRC personnel decided to forgo survey activities in the "New Addition" and the pickling area. Areas of the planned study boundary were inaccessible due to overgrowth/large pieces of concrete covering the soil surface; therefore, the study boundary was redefined.

Gamma walkover scans of the site boundary and "front yard" identified multiple areas of elevated gamma radiation. As a result, two judgmental samples were collected. Sample results were above thorium background levels

The answer to the PSQ relating to the relationship between thorium concentration in soil and NaI instrument response is "Yes." NaI instrument response can be used as a predictor of Th-232 concentration in the 0 to 1 m layer. An R^2 value of 0.79 was determined for the surface soil relationship, thus satisfying the DQOs. Moreover, the regression was cross-checked by comparing the predicted Th-232 soil core concentration to the average Th-232 concentration (Section 5.3.2). Based on the cross-check, the regression equation provides a reasonable estimate for the Th-232 concentration at the judgmental locations. Consideration must be given when applying this equation to other soil areas of the site. If the contamination was heterogeneously distributed, and not distributed in a discrete layer as it was in the study area, then using the regression equation to predict Th-232 concentration would not be applicable.

7. REFERENCES

AAR 2007. *Final Remediation Report for the Former Brooks and Perkins site (AAR Manufacturing).* Partners Environmental Consulting, Inc. Solon, Ohio. April. 11.

BKA 1996. *Site Characterization Report Former Brooks and Perkins, Inc. Site AAR Manufacturing Group, Inc. Livonia, MI.* B. Koh and Associates, Inc. Owings Mills, Maryland. April.

BKA 1999. *Site Characterization Report – Phase II Former Brooks and Perkins, Inc. Site AAR Manufacturing Group, Inc. Livonia, MI.* B. Koh and Associates, Inc. Owings Mills, Maryland. August.

BKA 2000. *Site Summary of Final Survey and Sampling Data for the Former Brooks and Perkins, Inc. Site AAR Manufacturing Group, Inc. Livonia, MI.* B. Koh and Associates, Inc. Owings Mills, Maryland. April.

EPA 2006. *Data Quality Assessment: Statistical Methods for Practitioners.* EPA QA/G-9S. U.S. Environmental Protection Agency. Washington, DC. February.

ORAU 2012a. *Quality Program Manual for the Independent Environmental Assessment and Verification Program.* Oak Ridge Associated Universities. Oak Ridge, Tennessee. June 28.

ORAU 2012b. *Health and Safety Manual.* Oak Ridge Associated Universities. Oak Ridge, Tennessee. May 18.

ORAU/ORISE 2012a. *Project-Specific Survey Plan for AAR Manufacturing, Inc., Livonia, Michigan.* DCN: 5204-PL-01-0 (RFTA: 12-015). Oak Ridge Institute for Science and Education, managed and operated by Oak Ridge Associated Universities. Oak Ridge, Tennessee. September 24.

ORAU/ORISE 2012b. *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. May 11.

ORAU/ORISE 2012c. *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.

ORISE 2004. *Revision I – Confirmatory Survey of Portions of the AAR Manufacturing, Inc. Site, Livonia, Michigan.* Oak Ridge Institute for Science and Education, managed and operated by Oak Ridge Associated Universities. Oak Ridge, Tennessee. October.

ORISE 2011a. *Radiological Survey Results for Portions of the CSX Transportation Property Adjacent to Inkster Road, Livonia, Michigan.* DCN: 2024-SR-01-0. Oak Ridge Institute for Science and Education, managed and operated by Oak Ridge Associated Universities. Oak Ridge, Tennessee. January 6.

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

Solutient 2011. *AAR Western Parcel Strategic Waste Excavation and Site Restoration for 12633 Inkster Road, Livonia, MI Site.* Draft Remedial Work Plan for Regulatory Review, No. 2011817, Revision 0. Solutient Technologies, LLC. North Canton, Ohio. August 17.

APPENDIX A
FIGURES

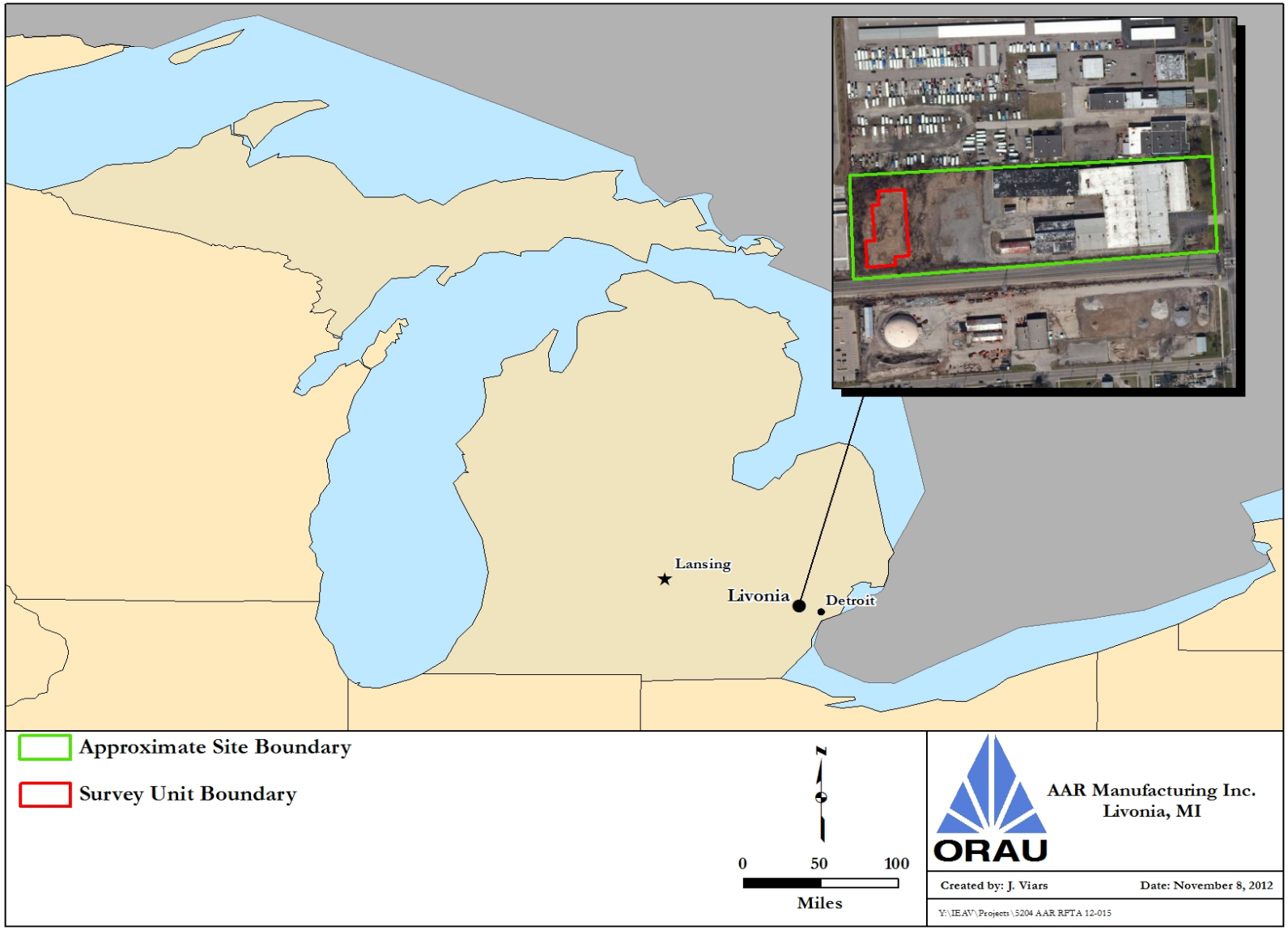

Fig. A-1. Location of the AAR Manufacturing, Inc., Site in Livonia, Michigan

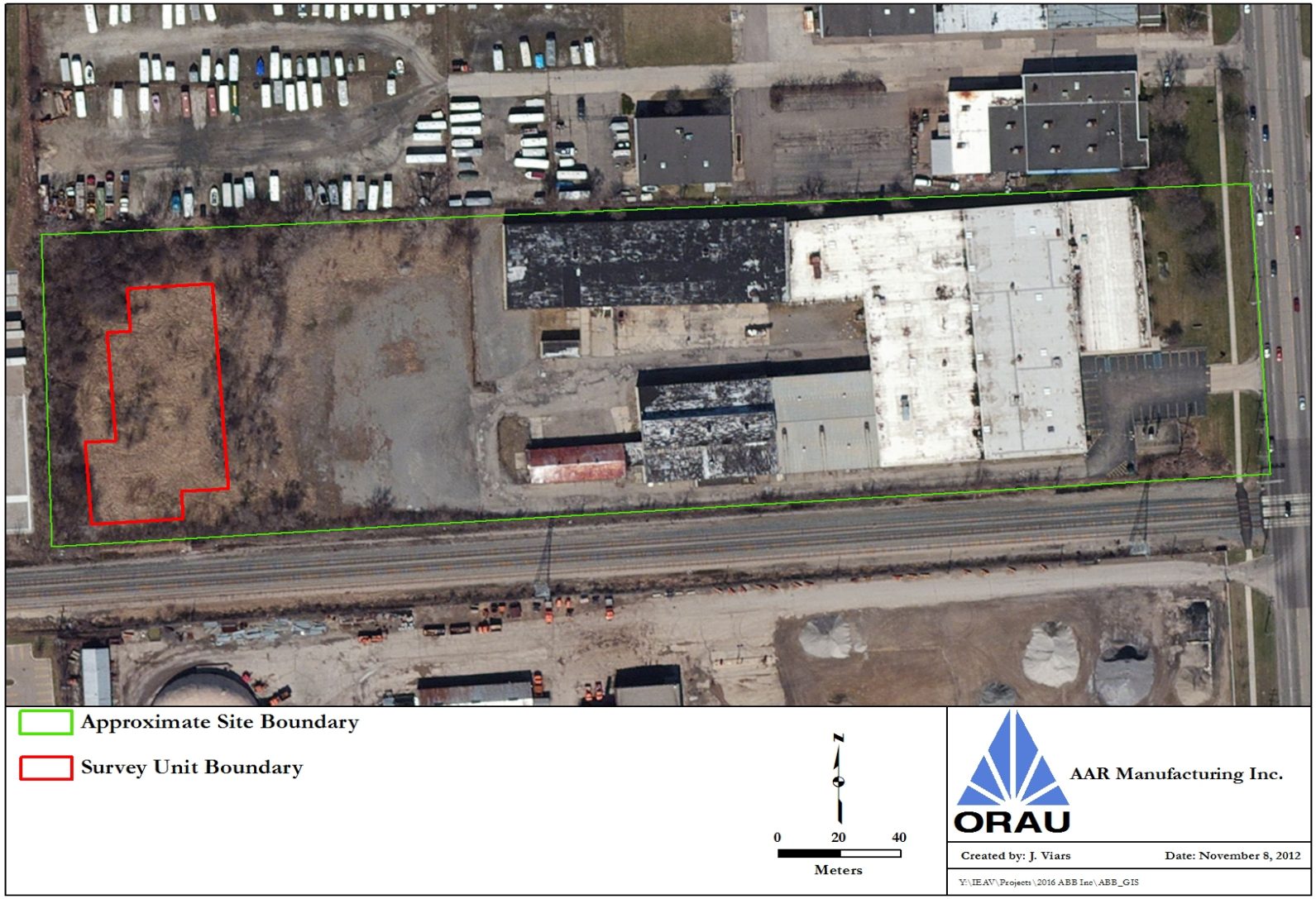

Fig. A-2. AAR Site Indicating the Study Area and Site Boundary

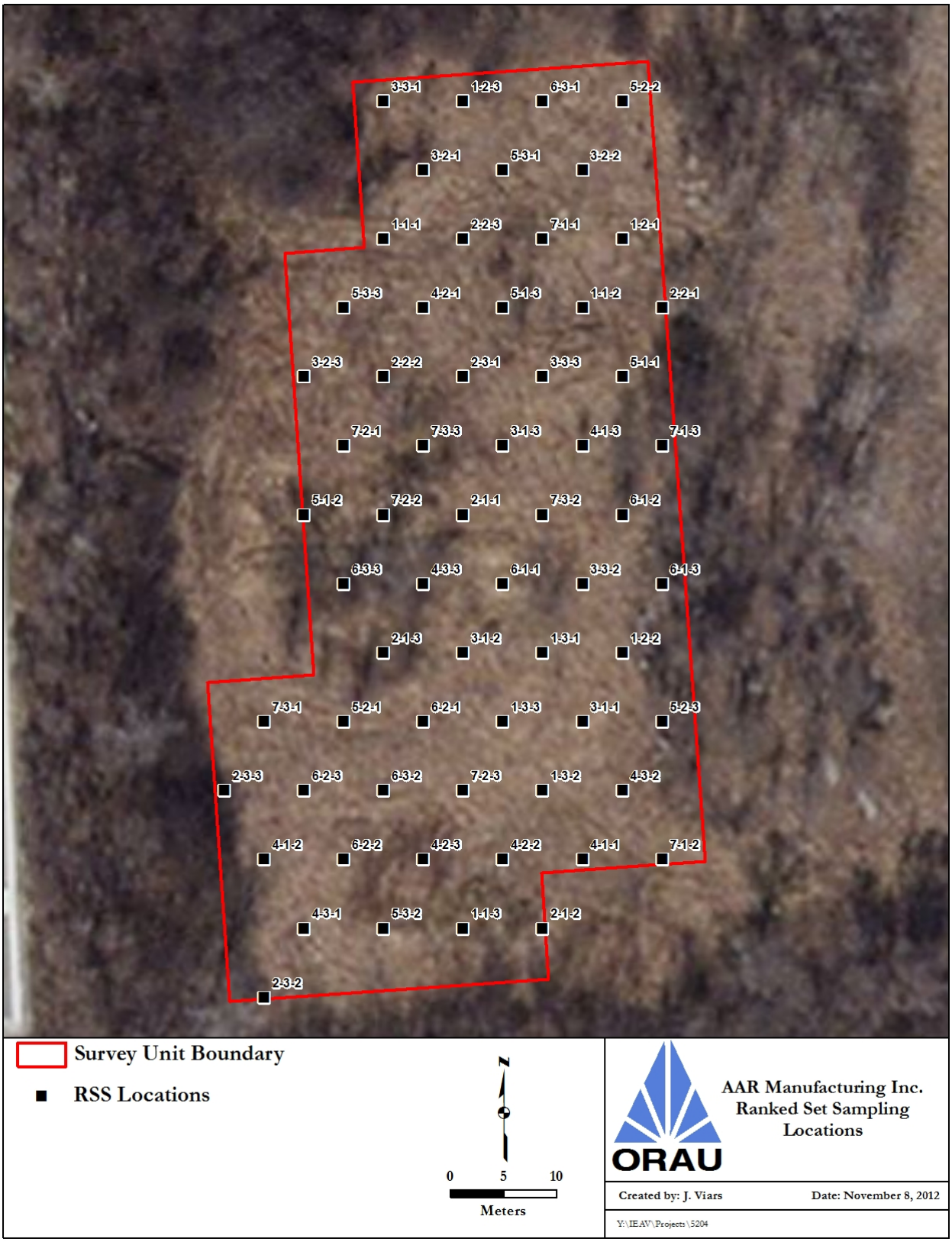

Fig. A-3. RSS Ranking Locations for the Study Area

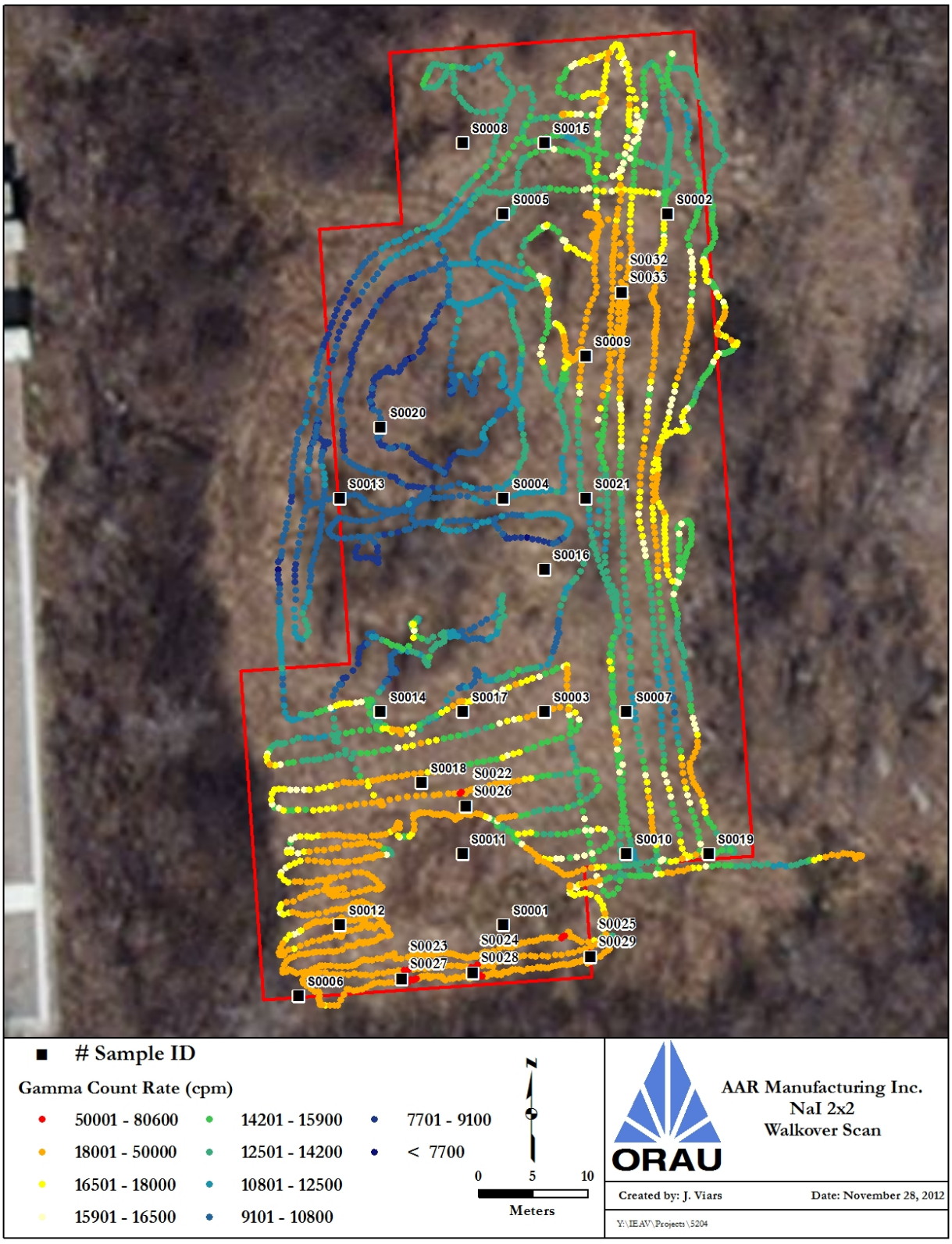

Fig. A-4. Gamma Scan Results and Soil Sample Locations for the Study Area

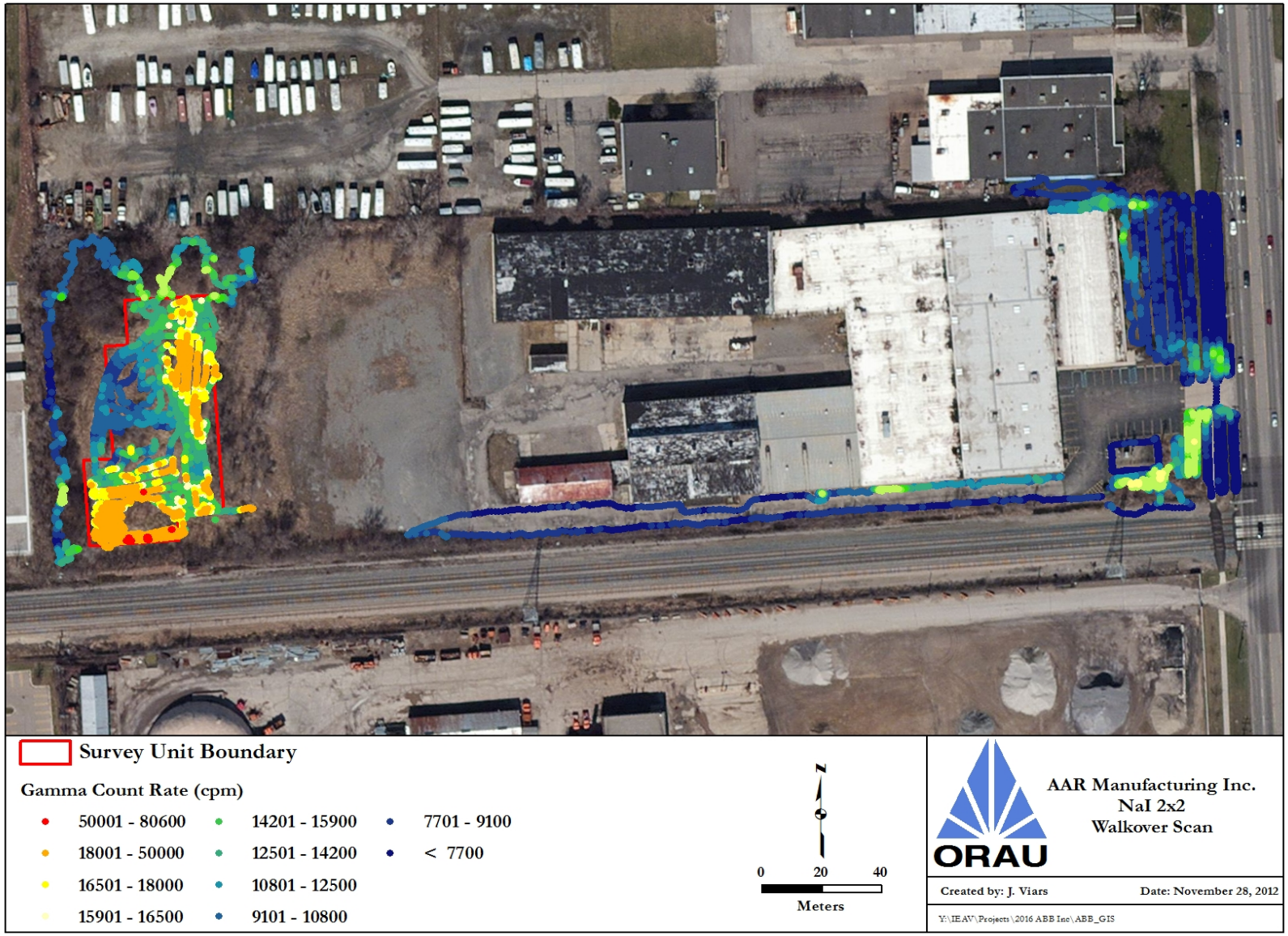

Fig. A-5. Gamma Scan Results for the Site Boundary and Front Yard

APPENDIX B
DATA TABLES

Table B-1. RSS Data Sheet							
Location	**RSS Ranking Value**	**Gamma Count Rate (cpm)**	**Soil Sample**	**Location**	**Value**	**Gamma Count Rate (cpm)**	**Soil Sample**
RSS 1-1-1	L	8,971	—	RSS 4-2-3	M	7,836	5204S0011
RSS 1-1-2	L	18,237	—	RSS 4-3-1	H	15,104	5204S0012
RSS 1-1-3	L	6,990	5204S0001	RSS 4-3-2	H	10,152	—
RSS 1-2-1	M	11,503	5204S0002	RSS 4-3-3	H	7,454	—
RSS 1-2-2	M	11,612	—	RSS 5-1-1	L	17,498	—
RSS 1-2-3	M	8,559	—	RSS 5-1-2	L	6,465	5204S0013
RSS 1-3-1	H	6,060	—	RSS 5-1-3	L	9,724	—
RSS 1-3-2	H	9,700	—	RSS 5-2-1	M	8,912	5204S0014
RSS 1-3-3	H	12,081	5204S0003	RSS 5-2-2	M	11,375	—
RSS 2-1-1	L	7,625	5204S0004	RSS 5-2-3	M	8,639	—
RSS 2-1-2	L	16,490	—	RSS 5-3-1	H	10,621	5204S0015
RSS 2-1-3	L	13,445	—	RSS 5-3-2	H	6,868	—
RSS 2-2-1	M	14,957	—	RSS 5-3-3	H	5,519	—
RSS 2-2-2	M	5,494	—	RSS 6-1-1	L	5,218	5204S0016
RSS 2-2-3	M	8,668	5204S0005	RSS 6-1-2	L	13,319	—
RSS 2-3-1	H	8,774	—	RSS 6-1-3	L	10,915	—
RSS 2-3-2	H	11,793	5204S0006	RSS 6-2-1	M	15,684	5204S0017
RSS 2-3-3	H	10,455	—	RSS 6-2-2	M	18,383	—
RSS 3-1-1	L	7,535	5204S0007	RSS 6-2-3	M	10,578	—
RSS 3-1-2	L	7,996	—	RSS 6-3-1	H	11,045	—
RSS 3-1-3	L	8,254	—	RSS 6-3-2	H	12,896	5204S0018
RSS 3-2-1	M	9,739	5204S0008	RSS 6-3-3	H	5,267	—
RSS 3-2-2	M	10,699	—	RSS 7-1-1	L	11,752	—
RSS 3-2-3	M	5,789	—	RSS 7-1-2	L	10,329	5204S0019
RSS 3-3-1	H	10,825	—	RSS 7-1-3	L	11,842	—
RSS 3-3-2	H	8,994	—	RSS 7-2-1	M	6,592	5204S0020
RSS 3-3-3	H	12,333	5204S0009	RSS 7-2-2	M	5,763	—
RSS 4-1-1	L	8,965	5204S0010	RSS 7-2-3	M	11,120	—
RSS 4-1-2	L	11,873	—	RSS 7-3-1	H	7,504	—
RSS 4-1-3	L	12,609	—	RSS 7-3-2	H	8,644	5204S0021
RSS 4-2-1	M	6,765	—	RSS 7-3-3	H	8,069	—
RSS 4-2-2	M	10,465	—				

Table B-2. Radionuclide Concentration in Soils for the Study Area

Sample ID		Judgmental or Random (J/R)	NaI Response (cpm)		Radionuclide Concentration (pCi/g)[a]			
					Surface (0 - 0.15 m)		Core (0.15 - 1 m)	
0–0.15 m	0.15–1 m		Contact	10" Offset	Th-228	Th-232	Th-228	Th-232
5204S0001	—[b]	R	10,610	10,862	0.64 ± 0.06	0.76 ± 0.12	—	—
5204S0002	—	R	16,320	15,436	3.07 ± 0.23	3.21 ± 0.38	—	—
5204S0003	—	R	17,363	17,986	3.35 ± 0.25	3.44 ± 0.41	—	—
5204S0004	5204S0030	R	11,498	11,098	1.51 ± 0.12	1.70 ± 0.22	4.94 ± 0.36	4.57 ± 0.51
5204S0005	5204S0037	R	12,820	12,590	2.06 ± 0.16	2.22 ± 0.27	9.71 ± 0.68	9.7 ± 1.0
5204S0006	—	R	16,982	17,389	4.80 ± 0.35	5.24 ± 0.59	—	—
5204S0007	—	R	11,605	11,900	2.88 ± 0.22	2.97 ± 0.36	—	—
5204S0008	—	R	13,881	13,600	2.31 ± 0.18	2.39 ± 0.30	—	—
5204S0009	5204S0031	R	17,508	18,348	2.39 ± 0.18	2.56 ± 0.31	11.21 ± 0.78	11.5 ± 1.2
5204S0010	—	R	13,295	13,743	3.10 ± 0.23	2.98 ± 0.33	—	—
5204S0011	—	R	10,951	13,984	0.72 ± 0.07	0.80 ± 0.15	—	—
5204S0012	—	R	22,698	21,897	6.18 ± 0.44	6.34 ± 0.71	—	—
5204S0013	5204S0034	R	9,580	9,781	1.06 ± 0.10	1.18 ± 0.18	2.09 ± 0.16	1.98 ± 0.26
5204S0015	5204S0036	R	14,894	14,720	3.83 ± 0.28	3.86 ± 0.44	5.78 ± 0.42	5.68 ± 0.63
5204S0016	—	R	7,895	8,595	0.33 ± 0.04	0.36 ± 0.09	—	—
5204S0017	—	R	21,003	20,780	3.36 ± 0.25	3.49 ± 0.40	—	—
5204S0018	—	R	19,678	19,088	5.08 ± 0.37	5.38 ± 0.60	—	—

Table B-2. Radionuclide Concentration in Soils for the Study Area

Sample ID		Judgmental or Random (J/R)	NaI Response (cpm)		Radionuclide Concentration (pCi/g)[a]			
					Surface (0 - 0.15 m)		Core (0.15 - 1 m)	
0–0.15 m	0.15–1 m		Contact	10" Offset	Th-228	Th-232	Th-228	Th-232
5204S0019	—	R	16,143	15,498	2.80 ± 0.22	2.88 ± 0.33	—	—
5204S0020	5204S0035	R	9,376	9,623	1.01 ± 0.08	1.04 ± 0.15	0.89 ± 0.08	0.90 ± 0.13
5204S0021	—	R	13,037	12,666	2.81 ± 0.21	2.78 ± 0.34	—	—
5204S0022	5204S0026	J	86,055	65,266	6.41 ± 0.46	6.33 ± 0.70	120.5 ± 8.4	123 ± 12
5204S0023	5204S0027	J	105,612	74,390	11.01 ± 0.78	10.7 ± 1.2	26.6 ± 1.8	26.5 ± 2.8
5204S0024	5204S0028[c]	J	57,890	52,924	22.1 ± 1.5	22.7 ± 2.3	21.6 ± 1.5	19.8 ± 2.0
5204S0025	5204S0029[c]	J	28,182	25,733	58.5 ± 4.0	59.5 ± 6.2	6.97 ± 0.49	7.11 ± 0.78
5204S0032	5204S0033[c]	J	47,490	32,766	4.54 ± 0.33	4.29 ± 0.50	43.5 ± 3.0	44.0 ± 4.6

[a]Uncertainties are total propagated uncertainties, based on the 95% confidence interval.
[b] = not collected
[c]sample refusal

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: 5.1 cm × 5.1 cm
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to:
Trimble Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

C.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, Tennessee) and
Multichannel Analyzer
Canberra's Gamma Software
Dell Workstation
(Canberra, Meriden, CT)

High-Purity, Intrinsic Detector
Model No. GMX-45200-5
CANBERRA Model No: GC4020
(Canberra, Meriden, CT)
Used in conjunction with:
Lead Shield Model G-11
Lead Shield Model SPG-16-K8
(Nuclear Data)
Multichannel Analyzer
Canberra's Gamma Software
Dell Workstation
(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 activities performed by ORAU were conducted in accordance with ORAU health and safety and radiation protection procedures (ORAU 2012b; ORISE 2011b).

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 (ISM) pre-job hazard checklist.

D.2 CALIBRATION AND QUALITY ASSURANCE

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

Field survey activities were conducted in accordance with procedures from the following Independent Environmental Assessment and Verification Program documents:

- Survey Procedures Manual (ORAU/ORISE 2012b)
- Laboratory Procedures Manual (ORAU/ORISE 2012c)
- Quality Program Manual (ORAU 2012a)

The procedures contained in these manuals were developed to meet the requirements of U.S. Department of Energy Order 414.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations
- Training and certification of all individuals performing procedures
- Periodic internal audits

D.3 SURVEY PROCEDURES

D.3.1 SURFACE SCANS

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. Additionally, the detectors were coupled to GPS units with data loggers, enabling real-time recording in one-second intervals of both geographic position and the gamma count rate. Positioning data files were downloaded from field data loggers for plotting using commercially available software (accessible at http://trl.trimble.com/docushare/dsweb/Get/Document-261826/GeoExpl2005_100A_GSG_ENG.pdf). Position and gamma count rate data files were transferred to a computer system, positions differentially corrected, and the results plotted on geo-referenced aerial photographs. Positional accuracy was within 0.5 meters at the 95th percentile.

ORAU Survey Procedures (ORAU/ORISE 2012b) require a minimum scan speed of 0.5 to 1 meter per second (m/s) based on the site contaminant and the DCGL for the primary contaminant of concern. The scan minimum detectable concnetrations (MDCs) for the NaI scintillation detectors were 2,100 pCi/g for Th-230 and 1.8 pCi/g for Th-232, as provided in NUREG-1507 (for surface soils). 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 SOIL SAMPLING

Approximately 0.5 to 1 kg of soil was collected at each sample location. Collected samples were placed in a plastic bag, sealed, and labeled in accordance with ORAU/ORISE survey procedures. The ranked set sampling (RSS) samples were collected as individual samples from the randomly selected soil sample locations as determined by Visual Sampling Plan software. The judgmental soil samples were collected as individual samples from an area of elevated gamma radiation based on gamma scans.

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) that wereassociated with the radionuclides of concern were reviewed for consistency of activity. TAPs used for determining the activities of the radionuclides of concern and the typical associated MDCs for a four-hour count time were:

Radionuclide	TAP[a] (MeV)	MDC (pCi/g)
Th-228 by Pb-212	0.238	0.04
Th-232 by Ac-228	0.911	0.07

[a]Spectra were also reviewed for other identifiable TAPs that would not be expected at this site.

D.5 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.6 DETECTION LIMITS

Detection limits, referred to as MDCs, were based on 95% confidence level via NUREG 1507 method. 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.