ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

January 6, 2011

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**SUBJECT: RADIOLOGICAL SURVEY RESULTS FOR PORTIONS OF THE CSX TRANSPORTATION PROPERTY ADJACENT TO INKSTER ROAD, LIVONIA, MICHIGAN DCN: 2024-SR-01-0**

Dear Mr. Schmidt:

The Oak Ridge Institute for Science and Education (ORISE) performed radiological survey activities on portions of the CSX Transportation (CSXT) railroad property south of the AAR Manufacturing facility near Inkster Road in Livonia, Michigan on September 20 and 21, 2010. These survey activities were requested and approved by the U.S. Nuclear Regulatory Commission (NRC). Enclosed is the final report that summarizes ORISE's survey procedures and provides the results of the ORISE radiological survey activities. This final report incorporates the NRC comments on the draft report issued on November 1, 2010 and corrects the reported thorium concentrations for Sample S020. The survey included gamma surface scans, gamma direct measurements, and soil sampling.

If you have any questions, please direct them to me at my information listed below, Erika Bailey at 865.576.6659 or Tim Vitkus at 865.576.5073.

Sincerely,

Wade C. Adams

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# RADIOLOGICAL SURVEY RESULTS FOR PORTIONS OF THE CSX TRANSPORTATION PROPERTY ADJACENT TO INKSTER ROAD, LIVONIA, MICHIGAN

**W. C. Adams**

Prepared for the
U.S. Nuclear Regulatory Commission

ORISE
Oak Ridge Institute for Science and Education

Approved for public release; further dissemination unlimited.

The Oak Ridge Institute for Science and Education (ORISE) is a U.S. Department of Energy facility focusing 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. ORISE is managed by Oak Ridge Associated Universities. Established in 1946, ORAU is a consortium of 98 colleges and universities.

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# RADIOLOGICAL SURVEY RESULTS FOR PORTIONS OF THE CSX TRANSPORTATION PROPERTY ADJACENT TO INKSTER ROAD, LIVONIA, MICHIGAN

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**FINAL REPORT**

**JANUARY 2011**

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# RADIOLOGICAL SURVEY RESULTS FOR PORTIONS OF THE CSX TRANSPORTATION PROPERTY ADJACENT TO INKSTER ROAD, LIVONIA, MICHIGAN

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AAR | AAR Manufacturing, Inc. |
| AEC | Atomic Energy Commission |
| ARCADIS | ARCADIS Geraghty & Miller |
| BKG | background |
| CFR | Code of Federal Regulations |
| cm | centimeter |
| cpm | counts per minute |
| CSXT | CSX Transportation, Inc. |
| DCGL | derived concentration guideline level |
| EPA | U.S. Environmental Protection Agency |
| GPS | global positioning system |
| IEAV | Independent Environmental Assessment and Verification |
| ISM | Integrated Safety Management |
| ITP | Intercomparison Testing Program |
| JHA | Job Hazard Analyses |
| kg | kilogram |
| MAPEP | Mixed-Analyte Performance Evaluation Program |
| MDC | minimum detectable concentration |
| m | meters |
| mrem/yr | millirem per year |
| NaI(Tl) | sodium iodide (thallium-activated) |
| NIST | National Institute of Standards and Technology |
| NRC | U.S. Nuclear Regulatory Commission |
| NRIP | NIST Radiochemistry Intercomparison Testing Program |
| ORAU | Oak Ridge Associated Universities |
| ORISE | Oak Ridge Institute for Science and Education |
| pCi/g | picocuries per gram |
| ROC | radionuclides of concern |
| RSS | Ranked Set Sampling |
| SU | survey unit |
| TAP | total absorption peak |
| Th-228 | thorium-228 |
| Th-230 | thorium-230 |
| Th-232 | thorium-232 |
| UTM | Universal Transverse Mercator |
| VSP | Visual Sample Plan |

# RADIOLOGICAL SURVEY RESULTS FOR PORTIONS OF THE CSX TRANSPORTATION PROPERTY ADJACENT TO INKSTER ROAD, LIVONIA, MICHIGAN

## 1.0 INTRODUCTION AND SITE HISTORY

The CSX Transportation, Inc. (CSXT) property, that is the subject of this radiological survey report, is located along Inkster Road in Livonia, Michigan. The CSXT site is adjacent to the southern boundary of the AAR Manufacturing, Inc. (AAR) property and is north of a Wayne County Public Services Department facility. AAR purchased their property from the Brooks and Perkins Corporation, which had been licensed by the Atomic Energy Commission (AEC) to use radioactive thorium in on-site manufacturing processes. In March 1994, the U.S. Nuclear Regulatory Commission (NRC) had informed AAR that radioactive contamination had been detected at the site and requested that AAR perform radiological surveys and remediation activities. A June 12, 1997 letter from the NRC also informed CSXT that radioactive materials, from the AAR site, were believed to be present on the adjacent CSXT property (NRC 1997).

In 1998, CSXT contracted with ARCADIS Geraghty & Miller (ARCADIS) to evaluate the potential radioactive contamination on the CSXT property. ARCADIS performed radiological survey activities consisting of total alpha, beta and gamma count field-screening measurements within the thorium investigation area. A report, documenting the radiological findings and assumptions, was submitted to the CSXT on June 5, 1998 (ARCADIS 1998). The results of the ARCADIS radiological surveys indicated that the average CSXT site thorium "…concentrations do not exceed any guideline concentrations under site use scenario." ARCADIS also performed a dose assessment using RESRAD dose modeling software to simulate dose exposure rates based on the average thorium concentrations determined during the November 1999 radiological investigations and submitted the report to NRC on September 13, 2000 (ARCADIS 2000). The ARCADIS conclusion was that the "modeling results demonstrate that neither remedial measures nor restrictions in site usage are required at this site. The total site dose exposure does not exceed the NRC acceptable exposure criteria of 25 mrem/yr."

At the request of the NRC's Division of Waste Management and Environmental Protection, the Independent Environmental Assessment and Verification (IEAV) program of the Oak Ridge

Institute for Science and Education (ORISE) performed radiological survey activities at the CSXT railroad area south of the AAR facility adjacent to Inkster Road in Livonia, Michigan.

## 2.0 SITE DESCRIPTION

The CSXT property investigated during this radiological survey is adjacent to the southern fence line border of the AAR Manufacturing facility in Livonia, Michigan (Figure A-1). Three railroad tracks run east to west and the northern most railroad track is approximately 12 meters from the AAR fence line boundary (Figure A-2). The site was overgrown with brush and littered with old railroad ties and various other wastes (bottles, cans, plastics, papers, car battery, etc.). In an effort to provide access to the fence line soils for scanning and soil sampling, CSXT personnel performed land clearing activities to cut down the brush, small trees and tall grasses.

## 3.0 RADIONUCLIDES OF CONCERN

The radionuclides of concern (ROC) for the CSXT property were natural thorium (Th-232 and Th-228) and Th-230.

## 4.0 OBJECTIVES

The objectives of the radiological survey were to provide independent radiological survey and sampling data to support future NRC decisions regarding the current radiological status of the CSXT property.

## 5.0 DOCUMENT REVIEW

ORISE personnel reviewed the CSXT dose assessment report (ARCADIS 2000) and comments addressing the technical issues within the report were submitted via electronic mail to the NRC on May 4, 2010 (ORISE 2010a). Information was evaluated to address NRC concerns on the validity of the CSXT radiological survey procedures and dose modeling assumptions.

## 6.0 RADIOLOGICAL SURVEY PROCEDURES

ORISE personnel visited the CSXT property from September 20 through 21, 2010 to perform visual inspections and independent measurements and sampling. The radiological survey activities were conducted in accordance with a project-specific plan, the ORISE Survey Procedures Manual and the Oak Ridge Associated Universities (ORAU) Quality Program Manual (ORISE 2010b and 2008 and ORAU 2009).

For the radiological surveys, ORISE divided the CSXT property into two survey unit (SU) areas. ORISE performed gamma surface scans and soil sampling in each SU. In the survey plan, ORISE had initially divided the area to be surveyed into three SUs; however, due to several of the original randomly selected soil locations being located within the railroad tracks, the logistics for surveying the uneven terrain, and the time constraints for the radiological survey activities, with concurrence from the NRC technical reviewer/acting project manager, ORISE reduced the originally planned radiological survey activities by 33% (to two SUs instead of three and 24 random soil samples instead of 36). This deviation was documented in the site logbook.

### 6.1 REFERENCE SYSTEM

Global positioning system (GPS) coordinates were used for referencing measurement and sampling locations. The specific reference system used was the Universal Transverse Mercator (UTM) Coordinate System (Zone 17 North; North American Datum 83).

### 6.2 SURFACE SCANS

High density (approximately 90% scan coverage due to overgrowth and terrain) gamma radiation surface scans were conducted over the soil surface within each of the SUs. Surface scans were performed using sodium iodide (thallium-activated) [NaI(Tl)] scintillation detectors coupled to ratemeters or ratemeter-scalers with audible indicators. Detectors were also coupled to GPS systems that enabled real-time gamma count rate and position data capture. Field personnel relied on the audio output to identify and mark for further investigations any locations of elevated direct gamma radiation that might suggest the presence of residual contamination (Figures A-3 and A-4).

At the request of the NRC, ORISE also performed gamma scans north of the northeast portion of SU1. Neither ORISE nor NRC personnel could ascertain the exact extent of the CSXT property boundary and whether or not this small parcel was within the site boundary (Figure A-3).

### 6.3 RANKED SET SAMPLING

In each of the SUs, ORISE performed a Ranked Set Sampling (RSS) approach, following U.S. Environmental Protection Agency (EPA) guidance, for randomly selecting locations for gamma measurements and soil sampling (EPA 2002). Visual Sample Plan (VSP) software was used to generate the random coordinates comprising the soil investigation and sample selection population.

These measurement/sample points were down-loaded to the GPS and were based upon the ORISE-generated reference survey units established on the site.

RSS provides a methodology to determine the necessary number of soil samples to estimate the mean concentration of a population; however, it does not require the assumption of a normal distribution. The process combines random sampling with the use of professional judgment to select sampling locations. Professional judgment relies upon the ability to assess the magnitude of gamma radiation levels between randomly selected locations. In this case, the gamma count rate data collected at randomly selected locations provided the measurable field screening method that correlates with the relative concentrations of the gamma-emitting ROCs—the Th-232 progeny. The count rate data obtained were then used to select a specific sampling location.

The RSS process uses a ranking method of the field screening measurement population to create the ranked sets; the first phase of the soil sample location selection process is to randomly partition the gamma measurement locations into sets of equal size. The set size is maintained at three locations to minimize ranking errors. With a set size of three locations, three sets, requiring nine measurement locations, are randomly combined into one cycle. Three soil sample locations are then selected for each cycle based on the following ranking criteria:

Set 1: the lowest of three gamma measurement locations within Set 1 is sampled.

Set 2: the medium of three gamma measurement locations with Set 2 is sampled.

Set 3: the highest of three gamma measurement locations within Set 3 is sampled.

Twelve soil samples from each SU were determined to be adequate to estimate the mean concentrations at the 95% confidence level. The estimated Th-232 mean concentration and variability used to calculate the required number of samples was obtained from the ARCADIS sample results (ARCADIS 2000). Therefore, the CSXT soil sampling plan required four RSS cycles within each SU from which the 12 soil samples were collected.

### 6.4 GAMMA DIRECT MEASUREMENTS

A one-minute static gamma count rate measurement was performed at each of the 36 RSS locations determined per SU (Figures A-5 and A-6). The data within a given cycle-set were then ranked as exhibiting either the lowest, medium, or highest gamma count; these data are provided in Table B-1.

Gamma direct measurements were also performed at judgmentally-selected elevated gamma radiation level locations determined by surface scans.

## 6.5 SOIL SAMPLING

### 6.5.1 RSS Sample Locations

Soil samples were then collected in accordance with the RSS process as described in Section 6.3 within the four RSS cycles within each SU: Set 1, lowest gamma radiation location; Set 2, medium location; Set 3, highest location (Figures A-7 and A-8). A total of twelve random surface (0 to 15 cm) samples were collected from each survey unit. Table B-1 provides the RSS method showing field assessment data and the location selected for soil sampling.

### 6.5.2 Judgmentally-Selected Locations

Judgmental surface soil samples were collected from eight locations based on ORISE gamma scan results; and, three subsurface soil samples were collected based on an increase in gamma radiation levels at the bottom of the sampled location (Figures A-7 and A-8).

### 6.5.3 Background Soil Samples

ORISE collected background soil samples during a previous site visit to the adjacent AAR facility in August 2003 (ORISE 2004).

# 7.0 SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to the ORISE laboratory in Oak Ridge, Tennessee for analysis and interpretation. Sample analyses were performed in accordance with the ORISE Laboratory Procedures Manual (ORISE 2010c). Gamma measurement results were reported in units of counts per minute (cpm). Soil samples were analyzed by gamma spectroscopy for Th-230, Th-228 and Th-232. The spectra were also reviewed for any other identifiable photopeaks to ensure there were no indications of other potential ROCs. Soil sample results were reported in units of picocuries per gram (pCi/g). The data generated were provided to the NRC for evaluation. Additional information regarding instrumentation and procedures may be found in Appendices C and D.

# 8.0 FINDINGS AND RESULTS

The results for each radiological survey procedure component are discussed below.

## 8.1 DOCUMENT REVIEW

ARCADIS radiological survey data were used to determine the number of random soil samples necessary to estimate the mean Th-232 concentrations. Specifically, the inputs used were the ARCADIS-reported average Th-232 concentrations and the observed variability (ARCADIS 2000).

## 8.2 SURFACE SCANS

Gamma radiation surface scans identified several areas of elevated gamma radiation, primarily along the northern fence line. The gamma scan ranges within each SU are provided in Figures A-3 and A-4 and ranged from less than 4,000 to approximately 88,000 cpm for SU1 and less than 4,200 to 36,000 cpm for SU2. Figures A-9 and A-10 provide frequency histograms of the walkover gamma count rate data population for each of the SUs. The elevated gamma radiation areas are also identified in Figures A-3 and A-4.

## 8.3 GAMMA DIRECT MEASUREMENTS

### 8.3.1 RSS Gamma Measurements

The summary data for the two SUs are presented in Table 1; the average background gamma count rate was 5,600 cpm for SU1 and 6,200 cpm for SU2. The data for the individual direct gamma measurements are provided in Table B-1.

**TABLE 1:
RANKED SET SAMPLING GAMMA DIRECT MEASUREMENTS
SUMMARY RESULTS**

| Survey Areas | Gamma Direct Measurement (cpm) | | |
|---|---|---|---|
| | Minimum | Maximum | Background |
| **Survey Unit 1** | 5,100 | 68,000 | 5,600 |
| **Survey Unit 2** | 5,900 | 18,000 | 6,200 |

### 8.3.2 Judgmental Gamma Measurements

Judgmental gamma direct measurements, collected at eight locations of elevated gamma radiation (sample locations S014, S021, and S025 through S035; sample locations S033 through S035 are subsurface soil sample locations for soil samples S014, S021 and S027, respectively) are indicated on Figures A-7 and A-8. The gamma direct measurements for these locations ranged from

approximately 7,000 to 73,000 cpm on the surface and from approximately 8,400 to 220,000 cpm at 30 cm depth.

## 8.4 RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES

### 8.4.1 RSS Soil Samples

The summary data for the two SUs are presented in Table 2. The data for the radionuclide concentrations in individual samples are provided in Table B-2. The gamma count rate data used for selecting the appropriate sample locations are shown in Table B-1.

**TABLE 2:**
**RADIONUCLIDE CONCENTRATIONS IN RSS SOIL SAMPLES**
**SUMMARY RESULTS**

| Survey Units | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Th-230 | Th-228 | Th-232 | Natural Th[a] |
| **Survey Unit 1** | -11.6 to 10.5 | 0.20 to 3.61 | 0.21 to 3.40 | 0.41 to 7.01 |
| *Mean Concentration* | *-1.0* | *0.8* | *0.8* | *1.5* |
| **Survey Unit 2** | -12.8 to 18.5 | 0.31 to 6.46 | 0.29 to 6.63 | 0.61 to 13.09 |
| *Mean Concentration* | *-1.4* | *0.9* | *0.9* | *1.8* |
| *Site RSS Mean* | *-1.2* | *0.8* | *0.8* | *1.7* |
| *Site RSS Median* | *-0.3* | *0.4* | *0.4* | *0.8* |

[a]Natural Thorium = Th-228 + Th-232 concentrations.

### 8.4.2 Judgmental Soil Samples

Eleven (eight surface and three subsurface) judgmental soil samples were collected from locations identified as having elevated gamma radiation levels during the gamma surface scans. The radionuclide concentrations in these samples are provided in Table B-3. The summary data for the judgmental soil samples are presented in Table 3. The elevated areas within SU1 were approximately 0.25 $m^2$ each for Samples S025 and S026 and approximately 0.5 $m^2$ for the area associated with Samples S027, S032 and S035. The elevated areas within SU2 were approximately 0.1 $m^2$ for Samples S014 and its associated subsurface sample (S033) and approximately 7.0 $m^2$ for the area associated with Sample S021 (subsurface S034), and Samples S028 through S031.

| TABLE 3: RADIONUCLIDE CONCENTRATIONS IN JUDGMENTAL SOIL SAMPLES SUMMARY RESULTS | | | | |
|---|---|---|---|---|
| **Survey Units** | **Radionuclide Concentrations (pCi/g)** | | | |
| | **Th-230** | **Th-228** | **Th-232** | **Natural Th[a]** |
| Survey Unit 1 | 1.2 to 206 | 0.02 to 78.7 | 0.11 to 80.3 | 0.13 to 160 |
| Survey Unit 2 | 2.8 to 23.4 | 0.51 to 8.08 | 0.49 to 8.35 | 1.0 to 16.4 |

[a]Natural Thorium = Th-228 + Th-232 concentrations.

### 8.4.3 Background Soil Samples

The radionuclide concentrations in background soil samples, collected during a previous site visit to the adjacent AAR facility, are presented in Table B-4 (ORISE 2004). A summary of the background soil sample results is provided in Table 4. These data are provided for informational purposes only. Site sample results have not been modified to account for natural background contributions.

| TABLE 4: RADIONUCLIDE CONCENTRATIONS IN BACKGROUND SOIL SAMPLES SUMMARY RESULTS | | | | |
|---|---|---|---|---|
| **Range/Average** | **Radionuclide Concentrations (pCi/g)** | | | |
| | **Th-230** | **Th-228** | **Th-232** | **Natural Th[a]** |
| Range | 0.42 to 0.84 | 0.18 to 0.36 | 0.19 to 0.37 | 0.37 to 0.73 |
| Average | 0.55 | 0.27 | 0.32 | 0.59 |

[a]Natural Thorium = Th-228 + Th-232 concentrations.

## 9.0 SUMMARY

During the period of September 20 through 21, 2010, ORISE performed radiological survey activities on a portion of the CSX Transportation property adjacent and south of the AAR Manufacturing facility near Inkster Road in Livonia, Michigan. The radiological survey results demonstrate that residual soil contamination is present along the fence line at several locations. An elevated measurement comparison was not performed for either SU as area factor values are not available.

## 10.0 REFERENCES

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# APPENDIX A
# FIGURES

**Figure A-1: Location of the CSX Transportation Property in Livonia, Michigan**

**Figure A-2: Site Layout Map Indicating Survey Units for the CSX Transportation Property in Livonia, Michigan**

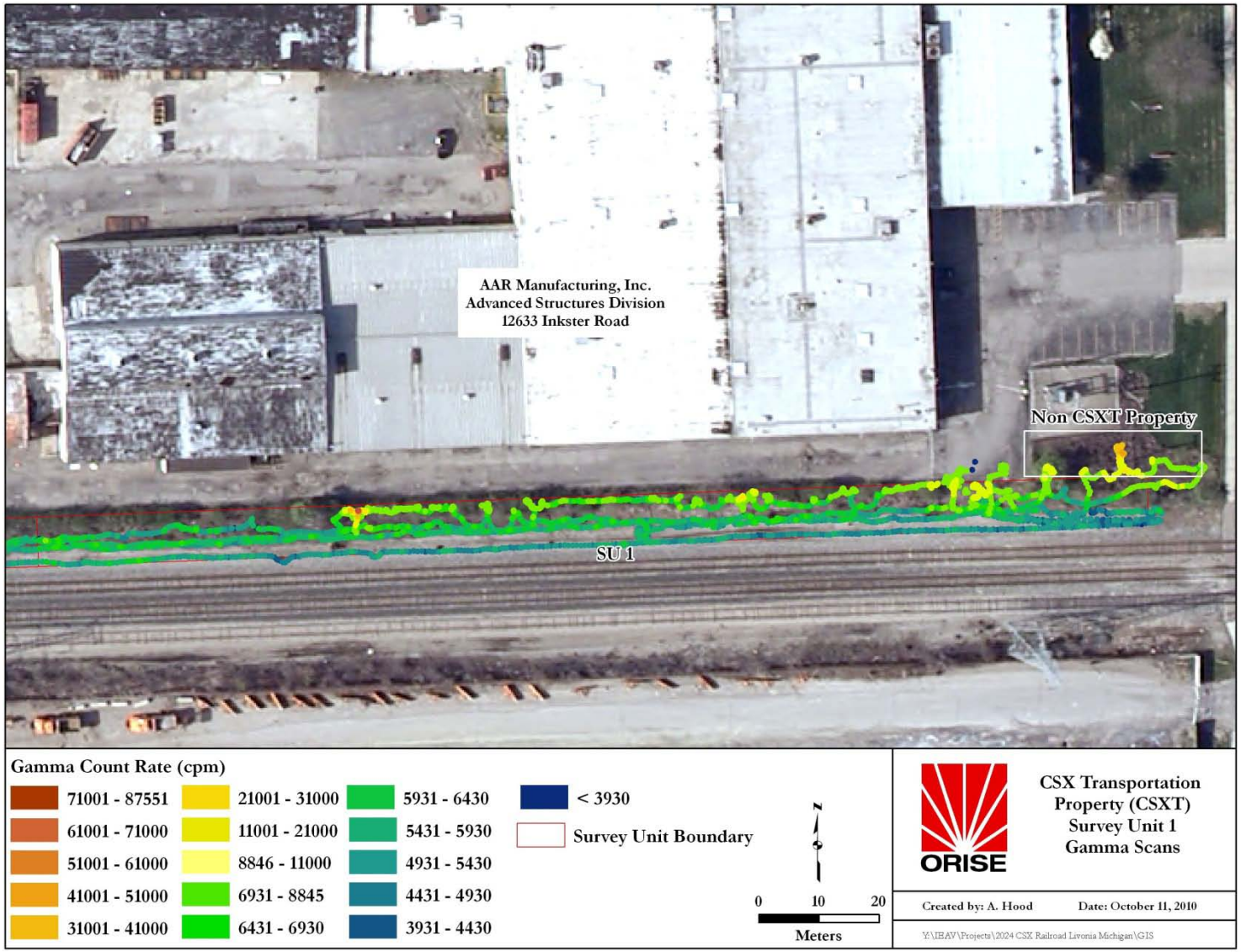


**Figure A-3: Survey Unit 1 - Gamma Scan Count Rates**

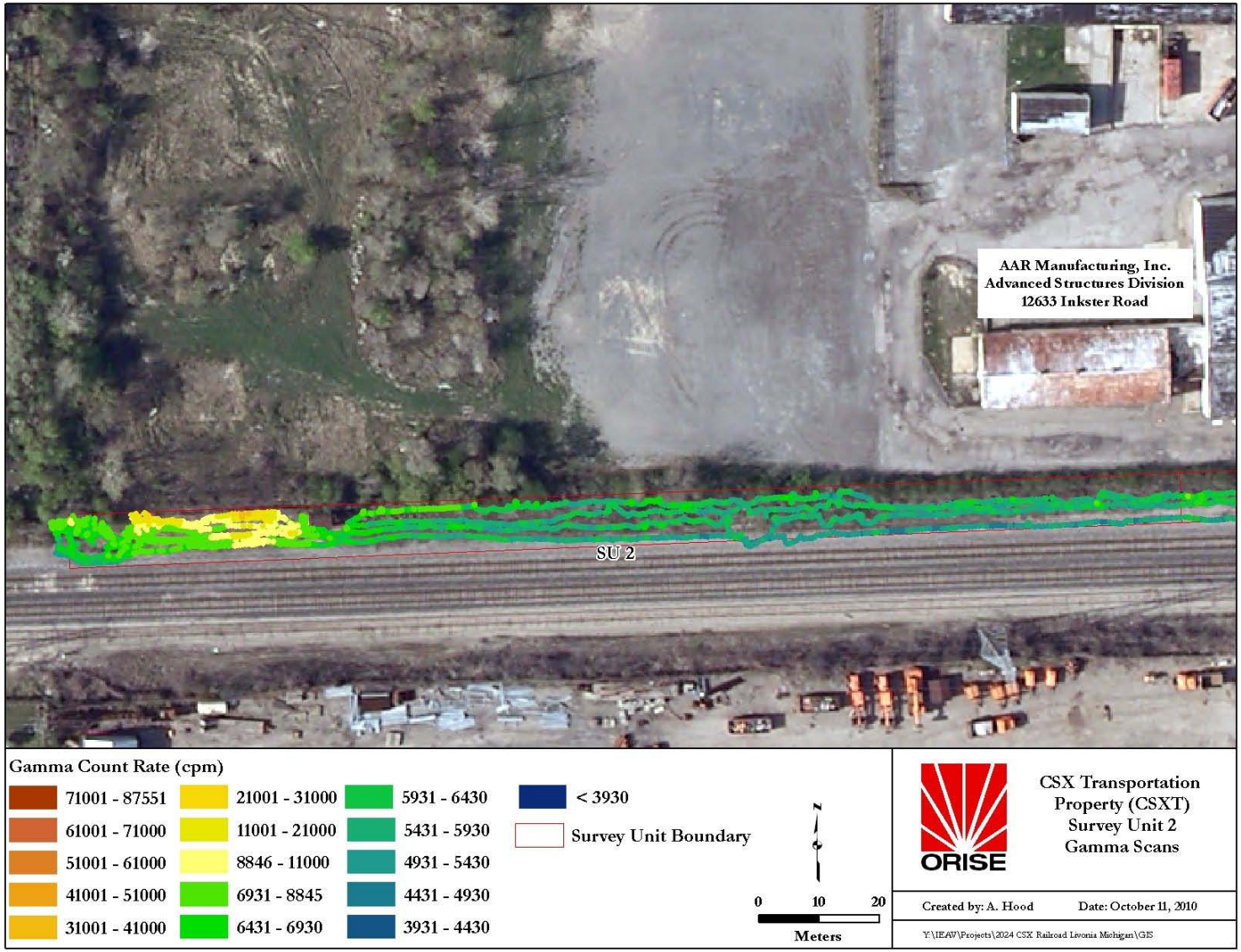


**Figure A-4: Survey Unit 2 - Gamma Scan Count Rates**

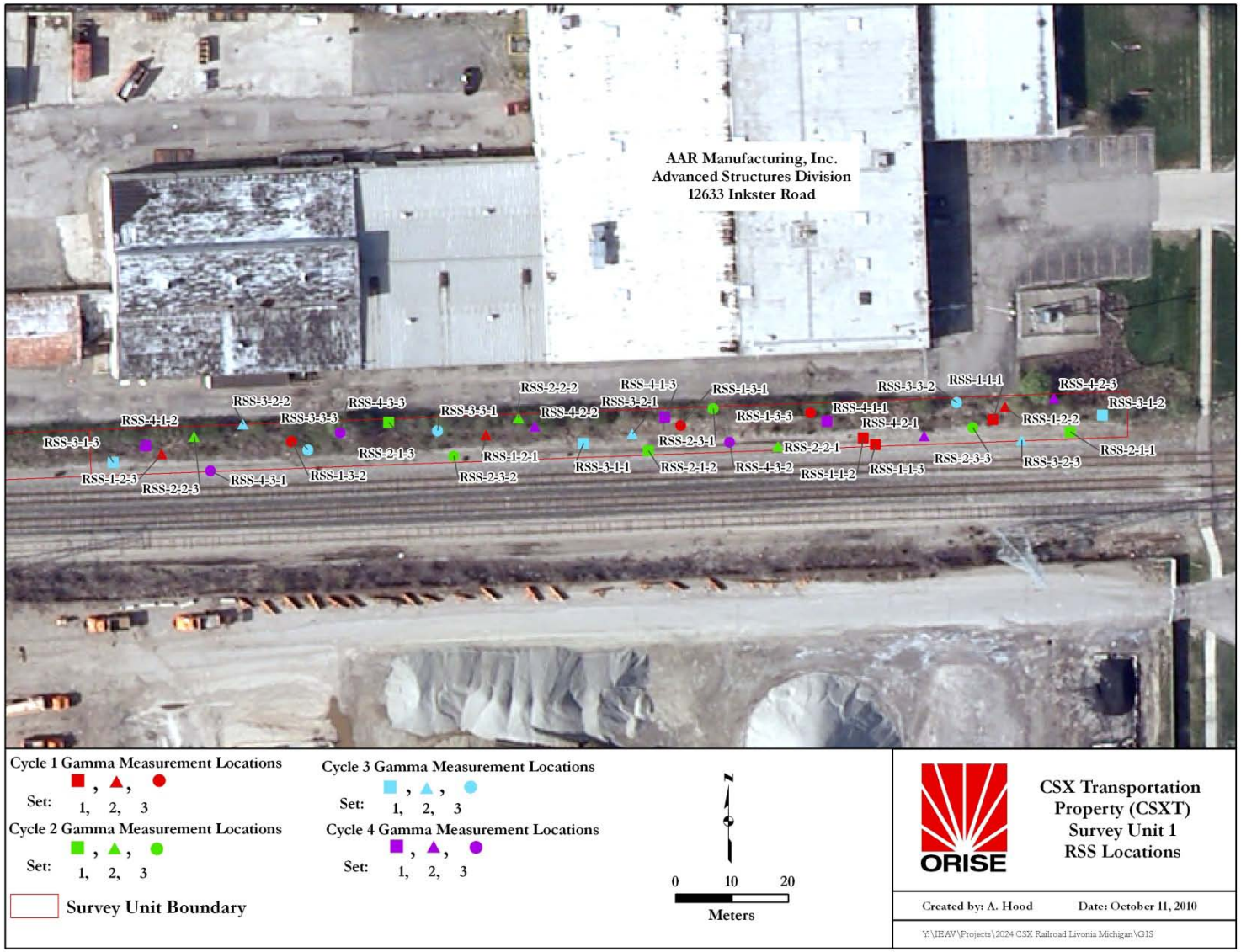


**Figure A-5: Survey Unit 1 - Ranked Set Sampling Gamma Measurement Locations**

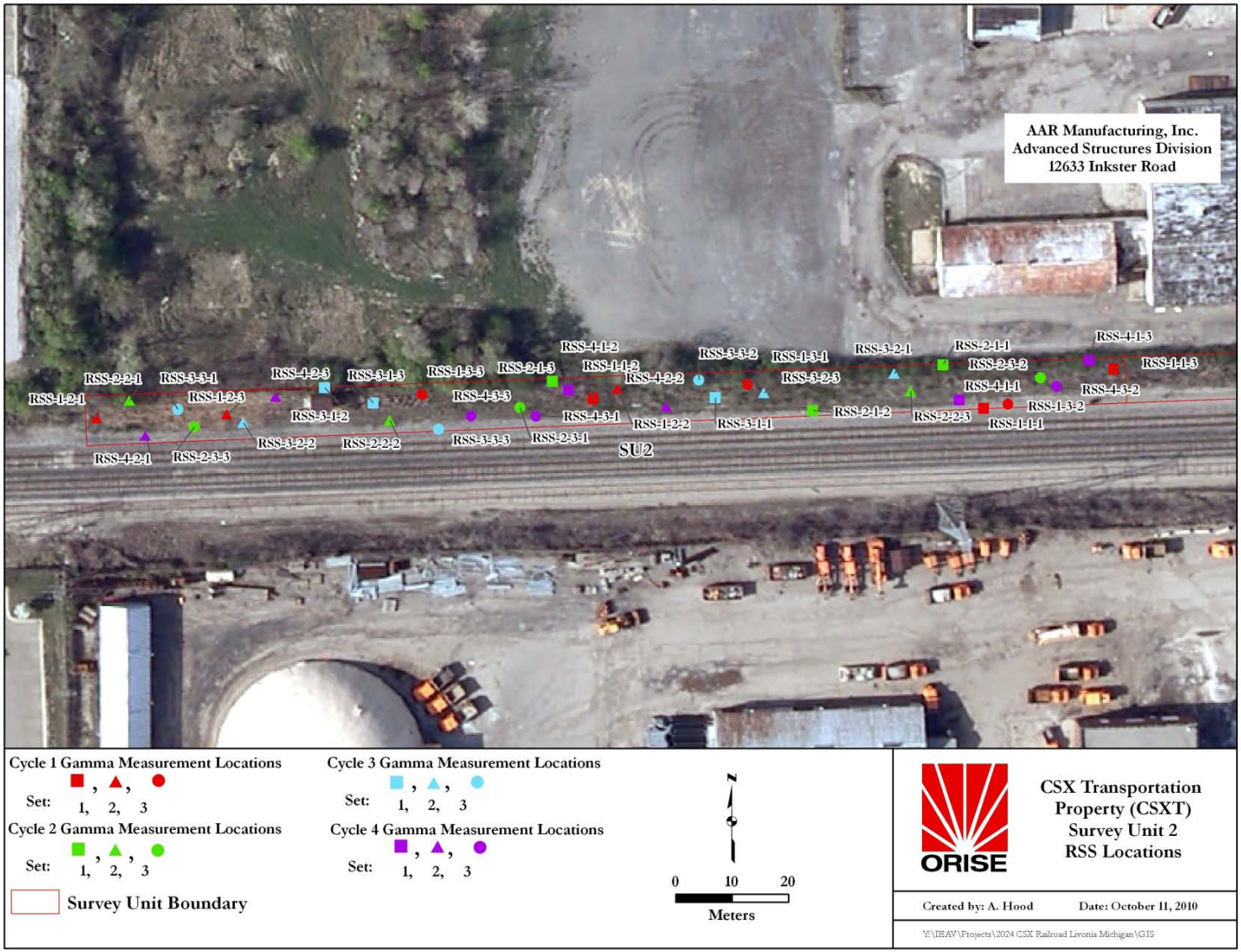


**Figure A-6: Survey Unit 2 - Ranked Set Sampling Gamma Measurement Locations**

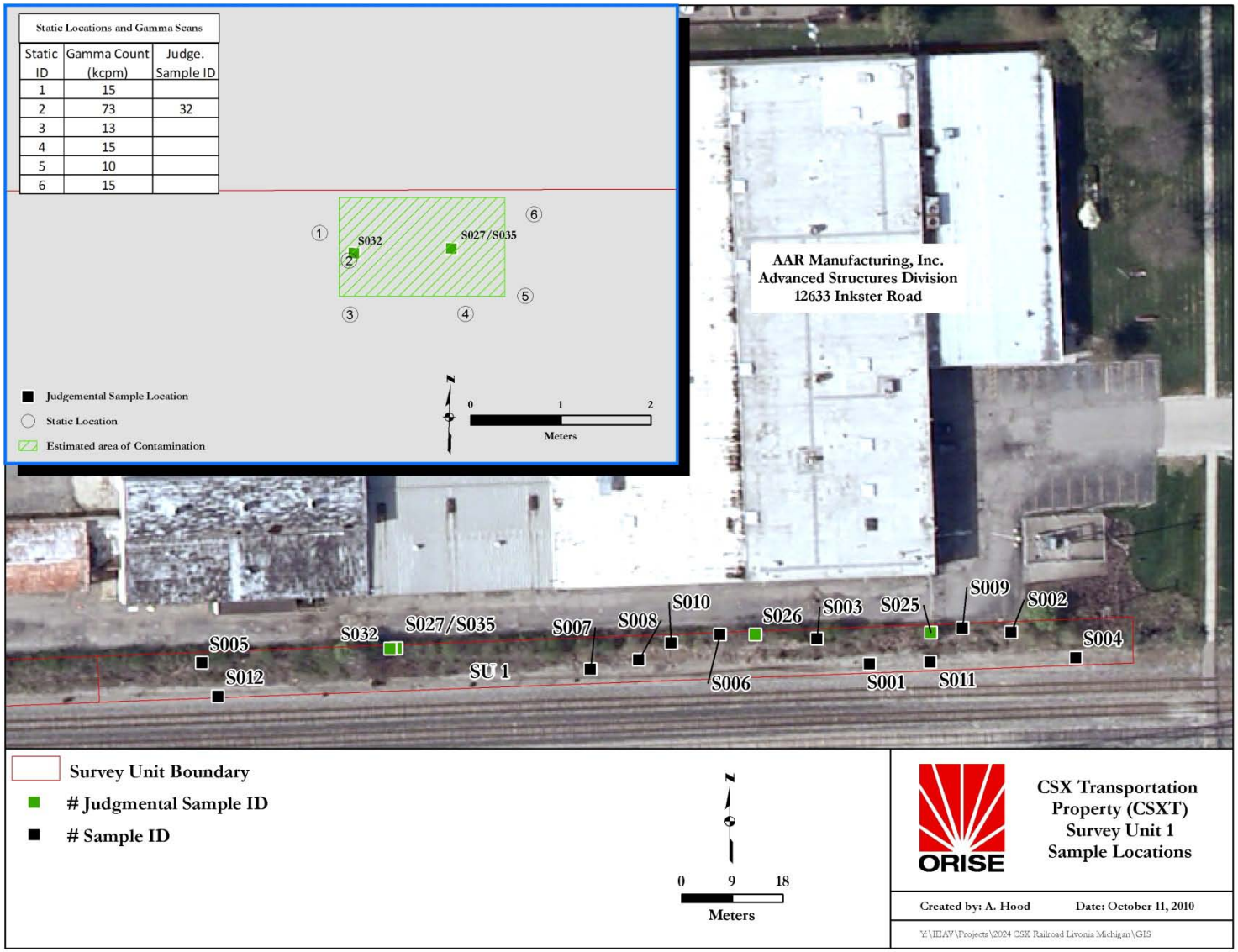


**Figure A-7: Survey Unit 1 - Soil Sampling Locations**

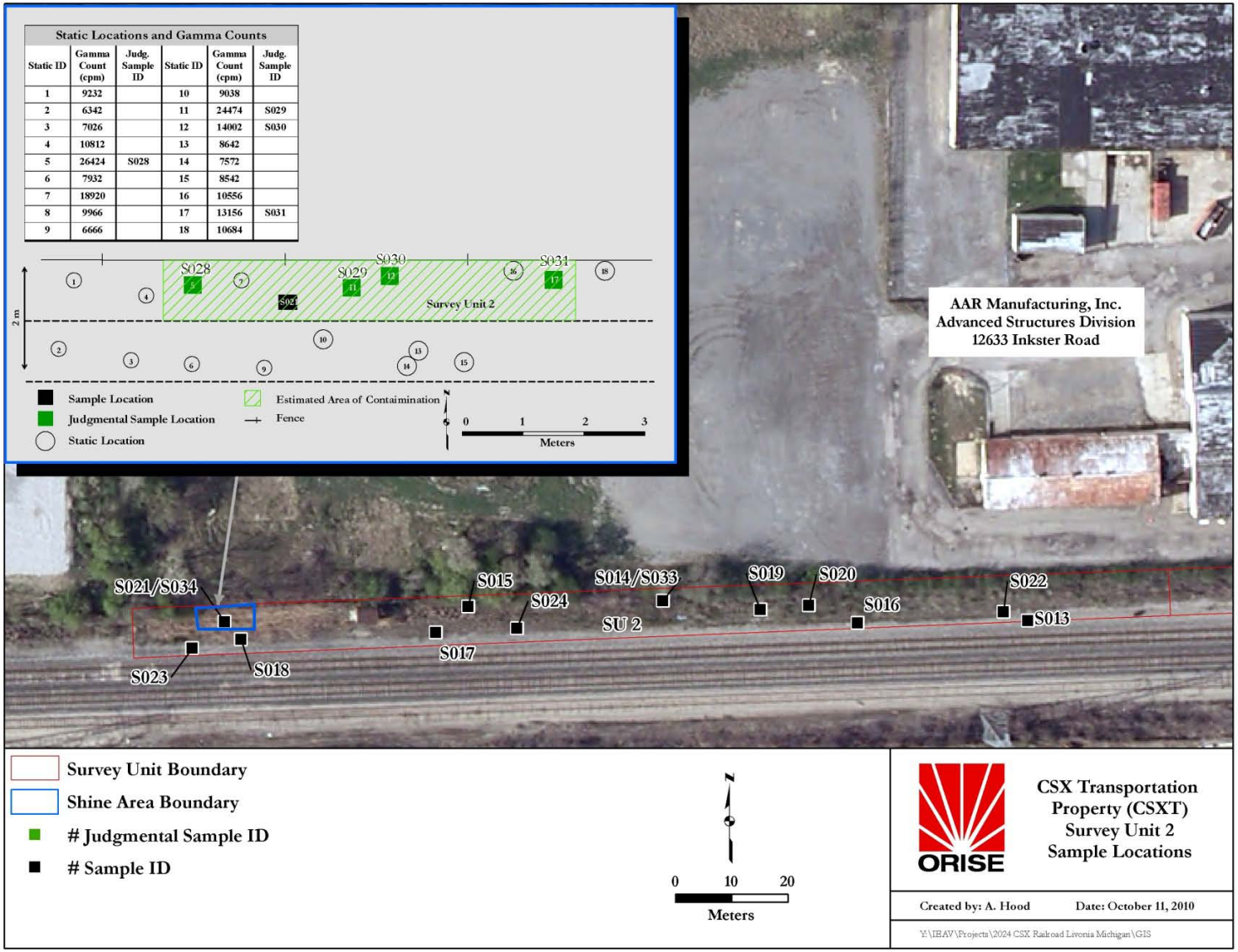


**Figure A-8: Survey Unit 2 - Soil Sampling Locations**

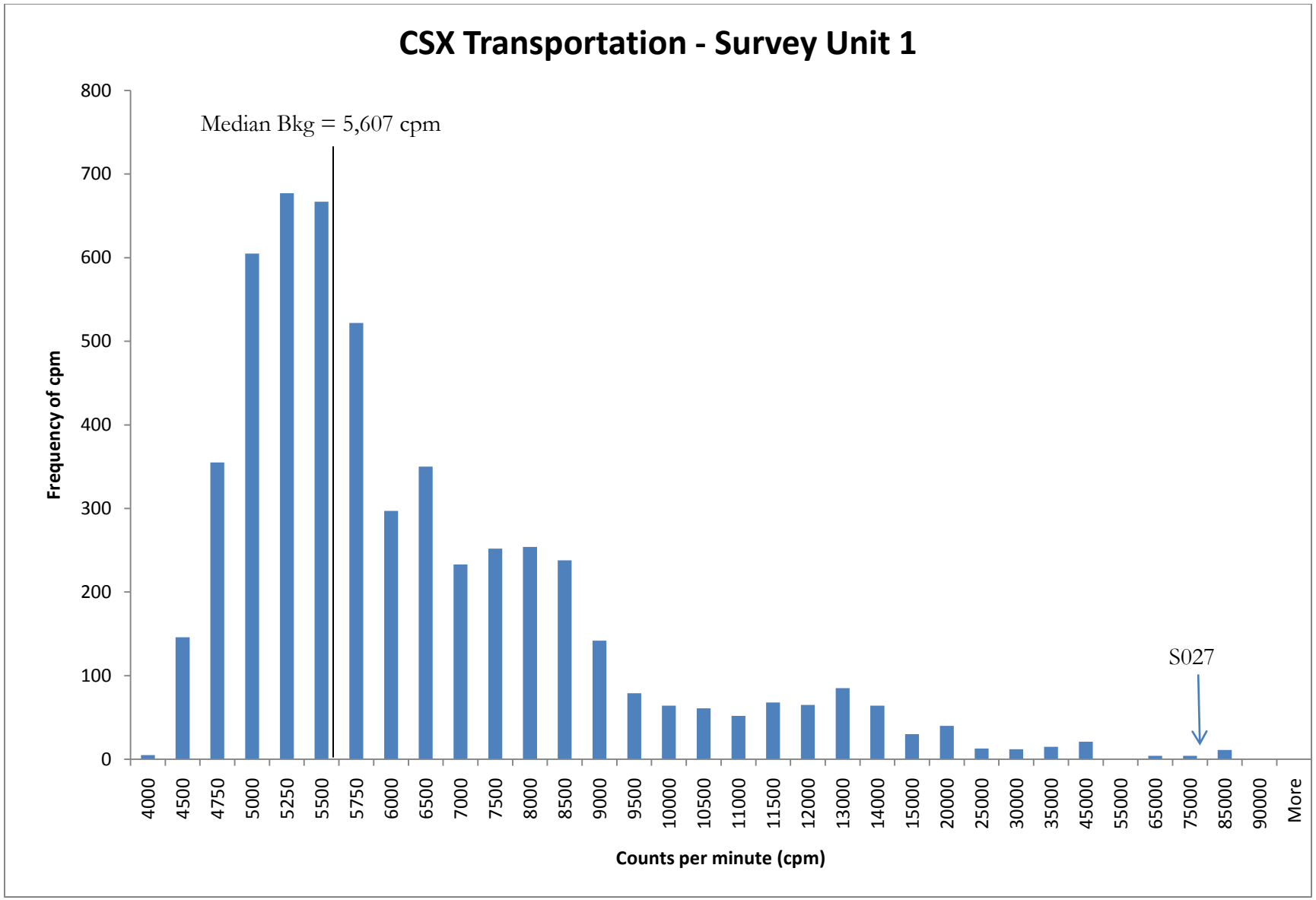


**Figure A-9: Survey Unit 1 - Gamma Scan Count Rate Distribution**

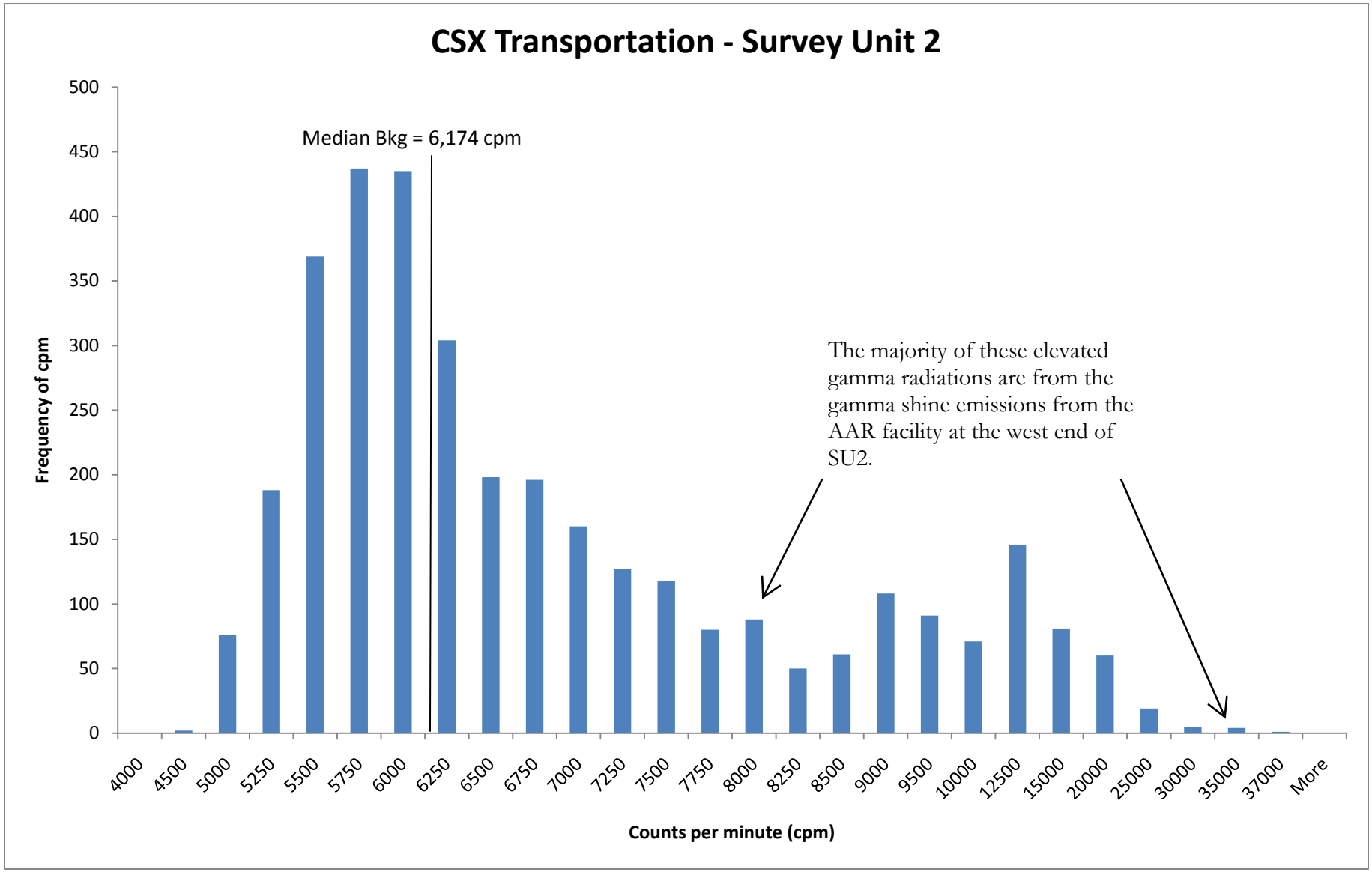


**Figure A-10: Survey Unit 2 - Gamma Scan Count Rate Distribution**

# APPENDIX B
# TABLES

**TABLE B-1:**
**RANKED SET SAMPLING GAMMA MEASUREMENTS**
**CSX TRANSPORTATION PROPERTY**
**LIVONIA, MICHIGAN**

| East (m) | North (m) | RSS Measurement Location[a] | | | | Gamma Count (cpm)[b] | Code[c] | Surface Soil Sample # | Subsurface Gamma Count (cpm) | Subsurface Soil Sample # (Gamma Count cpm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cycle | Set | # | Symbol | | | | | |
| **Survey Unit 1[d]** | | | | | | | | | | |
| 309449.0 | 4694255.7 | 1 | 1 | 1 | ■ | 5,845 | L | ---[e] | --- | --- |
| 309426.0 | 4694252.4 | 1 | 1 | 2 | ■ | 5,680 | **L** | **S001** | 5,780 | --- |
| 309428.1 | 4694251.2 | 1 | 1 | 3 | ■ | 5,855 | L | --- | --- | --- |
| 309359.0 | 4694252.9 | 1 | 2 | 1 | ▲ | 6,494 | M | --- | --- | --- |
| 309451.2 | 4694258.0 | 1 | 2 | 2 | ▲ | 6,461 | **M** | **S002** | 7,284 | --- |
| 309301.4 | 4694249.6 | 1 | 2 | 3 | ▲ | 6,187 | M | --- | --- | --- |
| 309393.6 | 4694254.6 | 1 | 3 | 1 | ● | 6,275 | H | --- | --- | --- |
| 309324.4 | 4694251.8 | 1 | 3 | 2 | ● | 6,248 | H | --- | --- | --- |
| 309416.6 | 4694256.8 | 1 | 3 | 3 | ● | 7,269 | **H** | **S003** | 7,916 | --- |
| 309462.7 | 4694253.5 | 2 | 1 | 1 | ■ | 5,070 | **L** | **S004** | 5,300 | --- |
| 309387.8 | 4694250.1 | 2 | 1 | 2 | ■ | 5,491 | L | --- | --- | --- |
| 309341.7 | 4694255.2 | 2 | 1 | 3 | ■ | 68,201 | **L** | **S027[f]** | 105,354 | **S035 (215,887)** |
| 309410.8 | 4694250.9 | 2 | 2 | 1 | ▲ | 5,540 | M | --- | --- | --- |
| 309364.8 | 4694255.9 | 2 | 2 | 2 | ▲ | 9,293 | M | --- | --- | --- |
| 309307.2 | 4694252.5 | 2 | 2 | 3 | ▲ | 6,037 | **M** | **S005** | 6,065 | --- |
| 309399.3 | 4694257.6 | 2 | 3 | 1 | ● | 7,125 | **H** | **S006** | 6,947 | --- |
| 309353.2 | 4694249.2 | 2 | 3 | 2 | ● | 5,577 | H | --- | --- | --- |
| 309445.4 | 4694254.2 | 2 | 3 | 3 | ● | 5,460 | H | --- | --- | --- |

**TABLE B-1:**
**RANKED SET SAMPLING GAMMA MEASUREMENTS**
**CSX TRANSPORTATION PROPERTY**
**LIVONIA, MICHIGAN**

| East (m) | North (m) | RSS Measurement Location[a] | | | | Gamma Count (cpm)[b] | Code[c] | Surface Soil Sample # | Subsurface Gamma Count (cpm) | Subsurface Soil Sample # (Gamma Count cpm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cycle | Set | # | Symbol | | | | | |
| **Survey Unit 1[d]-continued** | | | | | | | | | | |
| 309376.3 | 4694251.4 | 3 | 1 | 1 | ■ | 5,737 | **L** | **S007** | 5,798 | --- |
| 309468.4 | 4694256.5 | 3 | 1 | 2 | ■ | 5,970 | L | --- | --- | --- |
| 309292.8 | 4694248.1 | 3 | 1 | 3 | ■ | 6,685 | L | --- | --- | --- |
| 309384.9 | 4694253.1 | 3 | 2 | 1 | ▲ | 6,103 | **M** | **S008** | 6,704 | --- |
| 309315.8 | 4694254.8 | 3 | 2 | 2 | ▲ | 6,448 | M | --- | --- | --- |
| 309454.0 | 4694252.0 | 3 | 2 | 3 | ▲ | 5,645 | M | --- | --- | --- |
| 309350.4 | 4694253.7 | 3 | 3 | 1 | ● | 6,518 | H | --- | --- | --- |
| 309442.5 | 4694258.7 | 3 | 3 | 2 | ● | 14,688 | **H** | **S009** | 14,910 | --- |
| 309327.3 | 4694250.3 | 3 | 3 | 3 | ● | 5,828 | H | --- | --- | --- |
| 309419.5 | 4694255.3 | 4 | 1 | 1 | ■ | 6,226 | L | --- | --- | --- |
| 309298.5 | 4694251.1 | 4 | 1 | 2 | ■ | 6,449 | L | --- | --- | --- |
| 309390.7 | 4694256.1 | 4 | 1 | 3 | ■ | 6,002 | **L** | **S010** | 6,235 | --- |
| 309436.8 | 4694252.7 | 4 | 2 | 1 | ▲ | 5,664 | **M** | **S011** | 6,103 | --- |
| 309367.6 | 4694254.4 | 4 | 2 | 2 | ▲ | 6,415 | M | --- | --- | --- |
| 309459.8 | 4694259.5 | 4 | 2 | 3 | ▲ | 5,569 | M | --- | --- | --- |
| 309310.0 | 4694246.6 | 4 | 3 | 1 | ● | 5,778 | **H** | **S012** | 5,612 | --- |
| 309402.2 | 4694251.6 | 4 | 3 | 2 | ● | 5,601 | H | --- | --- | --- |
| 309333.1 | 4694253.3 | 4 | 3 | 3 | ● | 5,716 | H | --- | --- | --- |

**TABLE B-1:**
**RANKED SET SAMPLING GAMMA MEASUREMENTS**
**CSX TRANSPORTATION PROPERTY**
**LIVONIA, MICHIGAN**

| East (m) | North (m) | RSS Measurement Location[a] | | | | Gamma Count (cpm)[b] | Code[c] | Surface Soil Sample # | Subsurface Gamma Count (cpm) | Subsurface Soil Sample # (Gamma Count cpm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cycle | Set | # | Symbol | | | | | |
| **Survey Unit 2[d]** | | | | | | | | | | |
| 309263.6 | 4694244.7 | 1 | 1 | 1 | ■ | 5,996 | **L** | **S013** | 6,200 | --- |
| 309194.3 | 4694246.4 | 1 | 1 | 2 | ■ | 6,583 | L | --- | --- | --- |
| 309286.6 | 4694251.7 | 1 | 1 | 3 | ■ | 6,172 | L | --- | --- | --- |
| 309106.3 | 4694242.9 | 1 | 2 | 1 | ▲ | 6,925 | M | --- | --- | --- |
| 309198.6 | 4694248.2 | 1 | 2 | 2 | ▲ | 6,995 | **M** | **S014** | 8,388 | **S033 (8,763)** |
| 309129.4 | 4694243.7 | 1 | 2 | 3 | ▲ | 9,239 | M | --- | --- | --- |
| 309221.7 | 4694248.9 | 1 | 3 | 1 | ● | 6,569 | H | --- | --- | --- |
| 309267.9 | 4694245.4 | 1 | 3 | 2 | ● | 5,898 | H | --- | --- | --- |
| 309164.0 | 4694247.2 | 1 | 3 | 3 | ● | 6,995 | **H** | **S015** | 6,700 | --- |
| 309256.3 | 4694252.4 | 2 | 1 | 1 | ■ | 5,967 | L | --- | --- | --- |
| 309233.3 | 4694244.3 | 2 | 1 | 2 | ■ | 5,950 | **L** | **S016** | 6,400 | --- |
| 309187.1 | 4694249.5 | 2 | 1 | 3 | ■ | 6,956 | L | --- | --- | --- |
| 309112.1 | 4694246.0 | 2 | 2 | 1 | ▲ | 8,133 | M | --- | --- | --- |
| 309158.2 | 4694242.5 | 2 | 2 | 2 | ▲ | 6,771 | **M** | **S017** | 6,900 | --- |
| 309250.6 | 4694247.8 | 2 | 2 | 3 | ▲ | 6,248 | M | --- | --- | --- |
| 309181.3 | 4694244.8 | 2 | 3 | 1 | ● | 6,168 | H | --- | --- | --- |
| 309273.7 | 4694250.1 | 2 | 3 | 2 | ● | 5,999 | H | --- | --- | --- |
| 309123.6 | 4694241.3 | 2 | 3 | 3 | ● | 7,823 | **H** | **S018** | 7,000 | --- |

**TABLE B-1:**
**RANKED SET SAMPLING GAMMA MEASUREMENTS**
**CSX TRANSPORTATION PROPERTY**
**LIVONIA, MICHIGAN**

| East (m) | North (m) | RSS Measurement Location[a] | | | | Gamma Count (cpm)[b] | Code[c] | Surface Soil Sample # | Subsurface Gamma Count (cpm) | Subsurface Soil Sample # (Gamma Count cpm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cycle | Set | # | Symbol | | | | | |
| **Survey Unit 2[d]-continued** | | | | | | | | | | |
| 309216.0 | 4694246.6 | 3 | 1 | 1 | ■ | 5,991 | **L** | **S019** | 6,400 | --- |
| 309146.7 | 4694248.4 | 3 | 1 | 2 | ■ | 8,197 | L | --- | --- | --- |
| 309155.4 | 4694245.6 | 3 | 1 | 3 | ■ | 6,463 | L | --- | --- | --- |
| 309247.7 | 4694250.9 | 3 | 2 | 1 | ▲ | 6,127 | M | --- | --- | --- |
| 309132.3 | 4694242.1 | 3 | 2 | 2 | ▲ | 7,716 | M | --- | --- | --- |
| 309224.6 | 4694247.4 | 3 | 2 | 3 | ▲ | 6,236 | **M** | **S020** | 6,800 | --- |
| 309120.7 | 4694244.5 | 3 | 3 | 1 | ● | 17,924 | **H** | **S021** | 13,000 | **S034 (NA)** |
| 309213.1 | 4694249.7 | 3 | 3 | 2 | ● | 6,441 | H | --- | --- | --- |
| 309166.9 | 4694241.0 | 3 | 3 | 3 | ● | 6,781 | H | --- | --- | --- |
| 309259.2 | 4694246.2 | 4 | 1 | 1 | ■ | 6,180 | **L** | **S022** | 6,500 | --- |
| 309190.0 | 4694248.0 | 4 | 1 | 2 | ■ | 6,600 | L | --- | --- | --- |
| 309282.3 | 4694253.2 | 4 | 1 | 3 | ■ | 6,945 | L | --- | --- | --- |
| 309115.0 | 4694239.8 | 4 | 2 | 1 | ▲ | 6,893 | **M** | **S023** | 7,400 | --- |
| 309207.3 | 4694245.0 | 4 | 2 | 2 | ▲ | 6,267 | M | --- | --- | --- |
| 309138.1 | 4694246.8 | 4 | 2 | 3 | ▲ | 9,463 | M | --- | --- | --- |
| 309184.2 | 4694243.3 | 4 | 3 | 1 | ● | 6,358 | H | --- | --- | --- |
| 309276.5 | 4694248.5 | 4 | 3 | 2 | ● | 6,340 | H | --- | --- | --- |
| 309172.7 | 4694243.3 | 4 | 3 | 3 | ● | 6,618 | **H** | **S024** | 6,800 | --- |

[a]RSS description, color and symbol codes explanation provided in Appendix E.
[b]Gamma counts represent the one-minute gamma count rate at the soil surface for the location.
[c]Sample select code specifies which location is sampled for a given cycle/set based on the gamma count rate.
[d]For Survey Unit 1 refer to Figure A-5 and for Survey Unit 2, refer to Figure A-6.
[e]Measurement/sample not required.
[f]Although RSS location 2-1-3 in SU1 was in the L (low) cycle, a judgmental sample was collected at this location due to the presence of elevated gamma radiation.

**TABLE B-2:**
**RADIONUCLIDE CONCENTRATIONS IN RSS SOIL SAMPLES**
**CSX TRANSPORTATION PROPERTY**
**LIVONIA, MICHIGAN**

| Sample #[a] | Sample Location[a] | | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|---|---|
| | East (m) | North (m) | Th-230 | Th-228 | Th-232 | Natural Thorium[b] |
| **Survey Unit 1** | | | | | | |
| S001 | 309426.0 | 4694252.4 | -1.9 ± 2.3[c] | 0.20 ± 0.02 | 0.21 ± 0.04 | 0.41 ± 0.05 |
| S002 | 309451.2 | 4694258.0 | 2.4 ± 1.1 | 1.02 ± 0.08 | 1.08 ± 0.13 | 2.10 ± 0.15 |
| S003 | 309416.6 | 4694256.8 | 3.6 ± 1.3 | 1.10 ± 0.08 | 1.06 ± 0.12 | 2.16 ± 0.14 |
| S004 | 309462.7 | 4694253.5 | -11.6 ± 2.7 | 0.21 ± 0.02 | 0.25 ± 0.04 | 0.46 ± 0.05 |
| S005 | 309307.2 | 4694252.5 | 1.4 ± 1.9 | 0.37 ± 0.03 | 0.39 ± 0.05 | 0.76 ± 0.06 |
| S006 | 309399.3 | 4694257.6 | 2.6 ± 2.2 | 0.64 ± 0.05 | 0.67 ± 0.09 | 1.31 ± 0.10 |
| S007 | 309376.3 | 4694251.4 | 0.8 ± 2.4 | 0.38 ± 0.03 | 0.36 ± 0.05 | 0.74 ± 0.06 |
| S008 | 309384.9 | 4694253.1 | -10.7 ± 3.0 | 0.45 ± 0.04 | 0.48 ± 0.06 | 0.93 ± 0.07 |
| S009 | 309442.5 | 4694258.7 | 10.5 ± 2.1 | 3.61 ± 0.26 | 3.40 ± 0.34 | 7.01 ± 0.43 |
| S010 | 309390.7 | 4694256.1 | -9.9 ± 3.1 | 0.55 ± 0.05 | 0.64 ± 0.08 | 1.19 ± 0.09 |
| S011 | 309436.8 | 4694252.7 | 1.0 ± 1.6 | 0.28 ± 0.02 | 0.31 ± 0.04 | 0.59 ± 0.05 |
| S012 | 309310.0 | 4694246.6 | 0.1 ± 1.8 | 0.28 ± 0.03 | 0.32 ± 0.05 | 0.60 ± 0.06 |
| ***Survey Unit 1 Mean Concentrations*** | | | *-1.0* | *0.8* | *0.8* | *1.5* |

**TABLE B-2:**
**RADIONUCLIDE CONCENTRATIONS IN RSS SOIL SAMPLES**
**CSX TRANSPORTATION PROPERTY**
**LIVONIA, MICHIGAN**

| Sample #[a] | Sample Location[a] | | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|---|---|
| | East (m) | North (m) | Th-230 | Th-228 | Th-232 | Natural Thorium[b] |
| **Survey Unit 2** | | | | | | |
| S013 | 309263.6 | 4694244.7 | 0.3 ± 1.7 | 0.32 ± 0.03 | 0.29 ± 0.04 | 0.61 ± 0.05 |
| S014 | 309198.6 | 4694248.2 | -9.5 ± 2.9 | 0.47 ± 0.04 | 0.50 ± 0.06 | 0.97 ± 0.07 |
| S015 | 309164.0 | 4694247.2 | -7.8 ± 3.6 | 0.41 ± 0.04 | 0.52 ± 0.07 | 0.93 ± 0.08 |
| S016 | 309233.3 | 4694244.3 | -1.1 ± 1.8 | 0.31 ± 0.03 | 0.35 ± 0.05 | 0.66 ± 0.06 |
| S017 | 309158.2 | 4694242.5 | -1.2 ± 2.0 | 0.40 ± 0.03 | 0.44 ± 0.06 | 0.84 ± 0.07 |
| S018 | 309123.6 | 4694241.3 | -2.4 ± 2.0 | 0.32 ± 0.03 | 0.35 ± 0.05 | 0.67 ± 0.06 |
| S019 | 309216.0 | 4694246.6 | -12.8 ± 3.5 | 0.37 ± 0.03 | 0.36 ± 0.06 | 0.73 ± 0.07 |
| S020 | 309224.6 | 4694247.4 | 1.2 ± 2.0 | 0.41 ± 0.03 | 0.40 ± 0.05 | 0.81 ± 0.06 |
| S021 | 309120.7 | 4694244.5 | 18.5 ± 3.1 | 6.46 ± 0.46 | 6.63 ± 0.66 | 13.09 ± 0.80 |
| S022 | 309259.2 | 4694246.2 | -0.7 ± 1.8 | 0.35 ± 0.03 | 0.31 ± 0.05 | 0.66 ± 0.06 |
| S023 | 309115.0 | 4694239.8 | 0.5 ± 1.9 | 0.36 ± 0.03 | 0.39 ± 0.05 | 0.75 ± 0.06 |
| S024 | 309172.7 | 4694243.3 | -1.9 ± 2.4 | 0.33 ± 0.03 | 0.35 ± 0.05 | 0.68 ± 0.06 |
| ***Survey Unit 2 Mean Concentrations*** | | | *-1.4* | *0.9* | *0.9* | *1.8* |

[a]Refer to Figures A-7 and A-8.
[b]Natural Thorium is calculated by Th-228 + Th-232.
[c]Uncertainties are total propagated uncertainties, based on the 95% confidence interval.

**TABLE B-3:**
**RADIONUCLIDE CONCENTRATIONS IN JUDGMENTAL SOIL SAMPLES**
**CSX TRANSPORTATION PROPERTY**
**LIVONIA, MICHIGAN**

| Sample #[a] | Sample Location[a] | | Estimated Area of Contamination ($m^2$) | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|---|---|---|
| | East (m) | North (m) | | Th-230 | Th-228 | Th-232 | Natural Thorium[b] |
| **Survey Unit 1-Elevated Gamma Areas, Surface and Subsurface Soil Samples** | | | | | | | |
| S025 | 309436.8 | 4694257.9 | 0.25 | 11.0 ± 2.3[c] | 4.21 ± 0.31 | 4.05 ± 0.40 | 8.26 ± 0.51 |
| S026 | 309405.6 | 4694257.5 | 0.25 | 1.6 ± 2.1 | 0.02 ± 0.02 | 0.11 ± 0.06 | 0.13 ± 0.06 |
| S027[d] | 309341.7 | 4694255.2 | 0.5 | 141 ± 13 | 52.1 ± 3.7 | 54.8 ± 5.6 | 106.9 ± 6.7 |
| S032[d,e] | 309340.7 | 4694255.2 | 0.5 | 1.2 ± 2.4 | 0.52 ± 0.04 | 0.50 ± 0.07 | 1.02 ± 0.08 |
| S035[d]/27 | 309341.7 | 4694255.2 | 0.5 | 206 ± 16 | 78.7 ± 5.4 | 80.3 ± 8.4 | 160 ± 10 |
| **Survey Unit 2-Elevated Gamma Areas, Surface and Subsurface Soil Samples** | | | | | | | |
| S014[f] | 309198.6 | 4694248.2 | 0.1 | -9.5 ± 2.9 | 0.47 ± 0.04 | 0.50 ± 0.06 | 0.97 ± 0.07 |
| S033/14 | 309198.6 | 4694248.2 | 0.1 | 2.8 ± 1.2 | 0.51 ± 0.04 | 0.49 ± 0.07 | 1.00 ± 0.08 |
| S021[f,g] | 309120.7 | 4694244.5 | 7.0 | 18.5 ± 3.1 | 6.46 ± 0.46 | 6.63 ± 0.66 | 13.09 ± 0.80 |
| S034[g]/21 | 309120.7 | 4694244.5 | 7.0 | 7.9 ± 2.1 | 1.84 ± 0.14 | 1.89 ± 0.20 | 3.73 ± 0.24 |
| S028[g] | 309119.0 | 4694245.0 | 7.0 | 23.4 ± 4.0 | 8.08 ± 0.57 | 8.35 ± 0.87 | 16.4 ± 1.0 |
| S029[g] | 309121.5 | 4694245.0 | 7.0 | 15.0 ± 3.2 | 5.51 ± 0.39 | 5.91 ± 0.62 | 11.42 ± 0.73 |
| S030[g] | 309122.3 | 4694245.2 | 7.0 | 12.7 ± 2.4 | 4.70 ± 0.33 | 4.58 ± 0.47 | 9.28 ± 0.57 |
| S031[g] | 309124.9 | 4694245.2 | 7.0 | 3.4 ± 1.2 | 1.26 ± 0.09 | 1.33 ± 0.15 | 2.59 ± 0.17 |

[a]Refer to Figures A-7 and A-8. For double sample numbers, the first sample number is the subsurface (15 to 30 cm) sample number and the second is the corresponding surface (0 to 15 cm) sample number location.
[b]Natural Thorium is calculated by Th-228 + Th-232.
[c]Uncertainties are total propagated uncertainties, based on the 95% confidence interval.
[d]Same elevated gamma radiation area within SU1.
[e]Sample depth hit refusal for subsurface sample; however, the gamma count rate increased from 73 kcpm to 101 kcpm. This location is in adjacent to Sample S027 and its subsurface Sample S035.
[f]Samples S014 and S021 were RSS samples and are not judgmental soil samples. However, the RSS location for S021 did exhibit elevated gamma radiation levels and thorium concentrations.
[g]Same elevated gamma radiation area within SU2.

| TABLE B-4: RADIONUCLIDE CONCENTRATIONS IN BACKGROUND SOIL SAMPLES[a] SAMPLES COLLECTED DURING AAR SURVEY ACTIVITIES LIVONIA, MICHIGAN | | | | |
|---|---|---|---|---|
| **Sample #** | **Th-230[b]** | **Th-228** | **Th-232** | **Natural Thorium[c]** |
| 1 | 0.42 ± 0.06[d] | 0.18 ± 0.02 | 0.19 ± 0.04 | 0.37 ± 0.04 |
| 2 | 0.55 ± 0.08 | 0.36 ± 0.03 | 0.37 ± 0.06 | 0.73 ± 0.07 |
| 3 | 0.57 ± 0.08 | 0.28 ± 0.03 | 0.32 ± 0.05 | 0.60 ± 0.06 |
| 4 | 0.84 ± 0.09 | 0.28 ± 0.03 | 0.34 ± 0.05 | 0.62 ± 0.06 |
| 5 | 0.44 ± 0.07 | 0.24 ± 0.03 | 0.32 ± 0.07 | 0.56 ± 0.08 |
| 6 | 0.47 ± 0.07 | 0.29 ± 0.04 | 0.37 ± 0.10 | 0.66 ± 0.11 |
| *BKG Avg* | *0.55* | *0.27* | *0.32* | *0.59* |

[a]Background soil samples collected during previous survey activities at the adjacent AAR facility in August 2003 (ORISE 2004).
[b]Th-230 concentrations determined by alpha spectroscopy.
[c]Natural thorium calculated by Th-228 + Th-232.
[d]Uncertainties are total propagated uncertainties, based on the 95% confidence interval.

# APPENDIX C
# MAJOR INSTRUMENTATION

# 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 x 2 in
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to:
Trimble GeoXH Receiver and 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)

# APPENDIX D
# SURVEY AND ANALYTICAL PROCEDURES

# 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 (JHA). All survey and laboratory activities were conducted in accordance with ORISE health and safety and radiation protection procedures (ORISE 2008 and 2010d).

Pre-survey activities included the evaluation and identification of potential health and safety issues. Survey work was performed per the ORISE generic health and safety plans and a site-specific Integrated Safety Management (ISM) pre-job hazard checklist. CSXT and ARCADIS personnel also provided site-specific safety awareness training. An ORISE safety walk down of the site indicated that the land clearing activities (to cut down brush, small trees and tall grasses) by CSXT personnel left stumps up to one foot high along the cleared area. This safety issue was discussed with the ORISE and NRC personnel.

## 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 ORISE documents:

- Survey Procedures Manual (May 2008)
- Laboratory Procedures Manual (October 2010c)
- Quality Program Manual (June 2009)

The procedures contained in these manuals were developed to meet the requirements of 10 CFR 830 Subpart A, *Quality Assurance Requirements*, Department of Energy Order 414.1C *Quality Assurance*, and the U.S. Nuclear Regulatory Commission *Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards* and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment

- Operation is within acceptable statistical fluctuations.
- Participation in Mixed-Analyte Performance Evaluation Program (MAPEP), NIST Radiochemistry Intercomparison Testing Program (NRIP), and Intercomparison Testing Program (ITP) 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

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 (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 95$^{th}$ percentile.

ORISE Survey Procedures (ORISE 2008) 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. A review of the gamma scan walkover data points relative to the scan area coverage indicate that the scan speed was less than 0.7 m/s (5000 data points within an approximately 3100 m$^2$ area with one data point recorded each second). The scan minimum detectable concentrations 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. Any audible increase in radiation levels were investigated by ORISE. It is standard procedure for the ORISE 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 ORISE survey procedures.

The RSS samples were collected as individual samples from the randomly selected soil sample locations as determined by VSP. 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 (TAP) associated with the ROCs were reviewed for consistency of activity. TAPs used for determining the activities of ROCs and the typical associated minimum detectable concentration (MDCs) for a four-hour count time were:

| RADIONUCLIDE | TAP[a] (MeV) | MDC (pCi/g) |
|---|---|---|
| Th-230 | 0.067 | 5.00 |
| 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.4.2 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.4.3 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 E
# ORISE STATISTICAL SURVEY DESIGN FOR THE CSX TRANSPORTATION PROPERTY ADJACENT TO AAR MANUFACTURING, INC. INKSTER ROAD, LIVONIA, MICHIGAN

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# ORISE STATISTICAL SURVEY DESIGN FOR THE CSX TRANSPORTATION PROPERTY ADJACENT TO AAR MANUFACTURING, INC. INKSTER ROAD, LIVONIA, MICHIGAN

## E.0 SURVEY DESIGN SUMMARY

ORISE used available pre-final status survey data to develop a defensible statistical sampling and survey design for the CSX Transportation property adjacent to the AAR facility near Inkster Road in Livonia, Michigan. The selected VSP 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). A Ranked Set Sampling (RSS) design was selected using associated statistical assumptions as well as general guidelines for conducting post-sampling data analysis. The sampling plan components included how many sampling locations to choose and where within the sampling area to collect those samples.

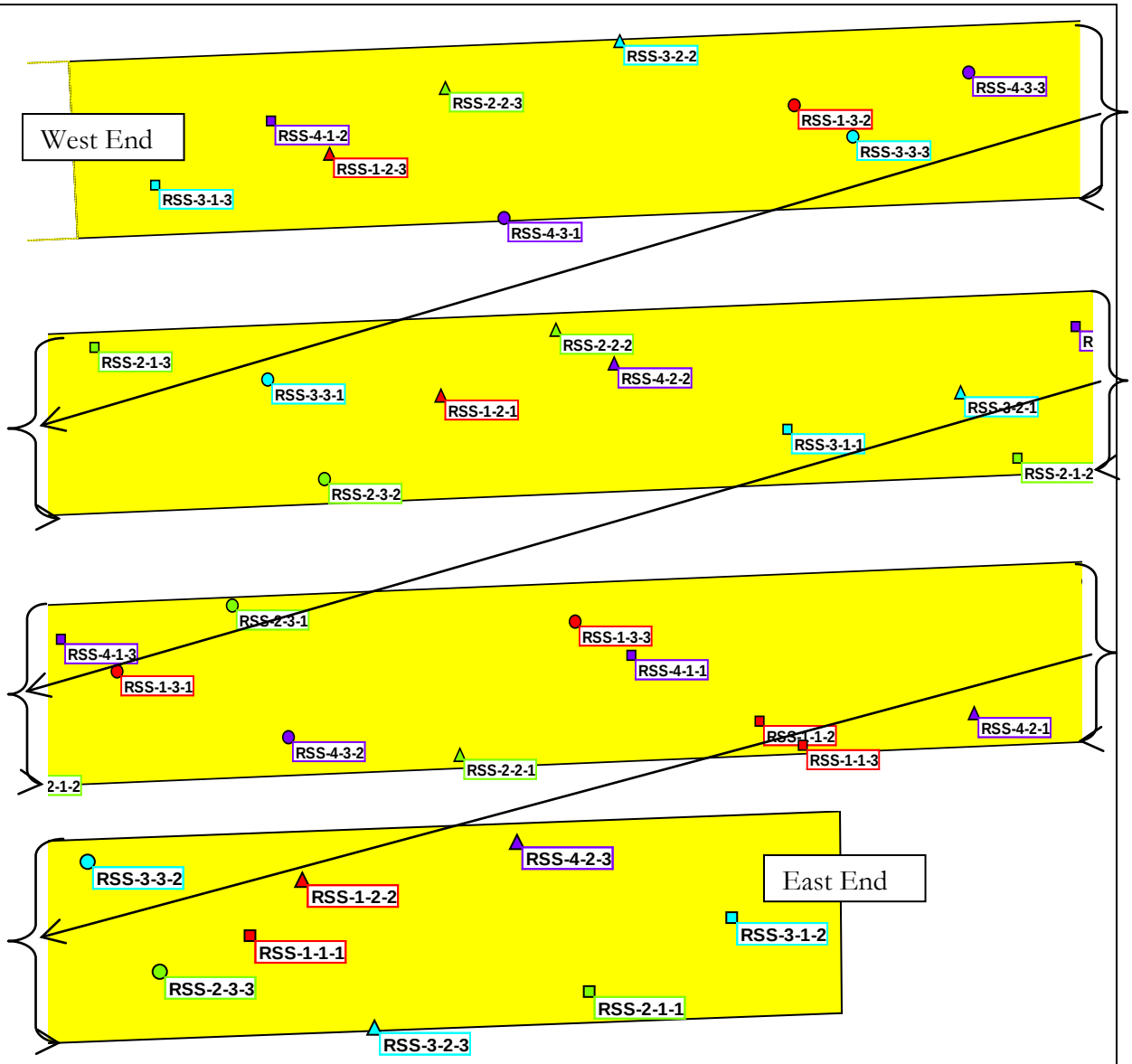
The following table summarizes the balanced RSS design developed.

| SUMMARY OF SAMPLING DESIGN FOR EACH AREA | |
|---|---|
| **Primary Objective of Design** | **Estimate the population mean** |
| Sample Placement (Location) in the Field | Quasi-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) | 4 |
| Number of Samples to Analyze (m x r) | 12 |
| Number of Field Locations to Rank($m^2$ x r) | 36 |
| Number of selected sample areas[a] | 2 |
| Specified sampling area [b] | 3077.6 $m^2$ |

aThe 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.

bThe sampling area is the total surface area of the selected colored sample areas on the map of the site.

Figure E-1 demonstrates the detailed VSP measurement locations in the field for Survey Unit 1 and Figure E-2 demonstrates the VSP generated measurement locations for both survey units. There were 36 RSS measurement locations within each survey unit from which twelve samples were collected from each survey unit.




Refer to Figures A-3 and E-2.

| Cycle 1 Gamma Measurement Locations | Cycle 2 Gamma Measurement Locations | Cycle 3 Gamma Measurement Locations | Cycle 4 Gamma Measurement Locations |
|---|---|---|---|
| ■, ▲, ● | ■, ▲, ● | ■, ▲, ● | ■, ▲, ● |
| Set: 1, 2, 3 | Set: 1, 2, 3 | Set: 1, 2, 3 | Set: 1, 2, 3 |

**Figure E-1: Example of the RSS Measurement/Sampling Plan for Survey Unit 1**

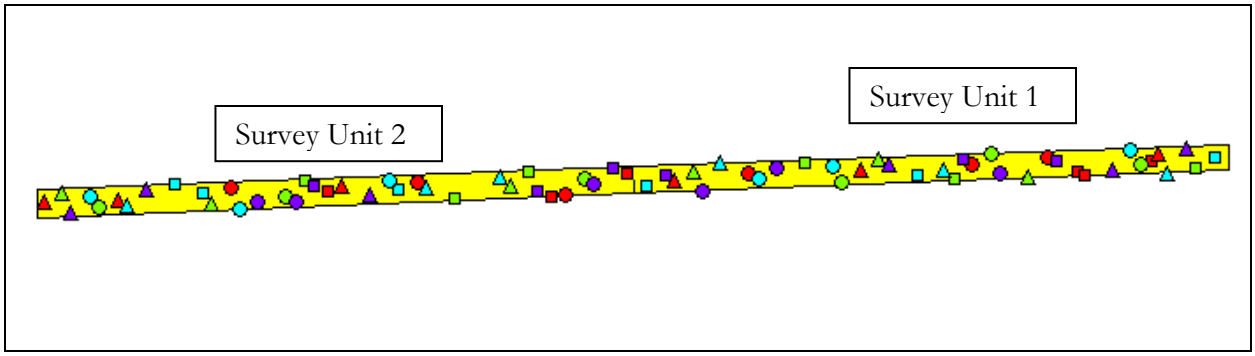



**Figure E-2: Visual Sample Plan Generated Measurement Locations for the Two Survey Units**

Table B-1 lists the sampling coordinates generated by VSP that were identified in the field.