OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
Shaping the Future of Science

January 10, 2020

Ms. Marlayna Doell
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Decommissioning, Uranium Recovery, and Waste Programs
Reactor Decommissioning Branch
Mail Stop: T-5A10
11555 Rockville Pike
Rockville, MD 20852

SUBJECT: CONTRACT NO. DE-SC0014664
INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN
RFTA No. 18-003; DCN 5299-SR-05-0

Dear Ms. Doell:

The Oak Ridge Institute for Science and Education (ORISE) is pleased to provide the enclosed final report, which describes the procedures and results of the confirmatory survey for the remaining land areas at the La Crosse Boiling Water Reactor in Genoa, Wisconsin. The U.S. Nuclear Regulatory Commission's (NRC's) comments on the draft report have been addressed in this final version.

Please feel free to contact me at 865.574.6273 or Erika Bailey at 865.576.6659 if you have any comments or concerns.

Sincerely,

Nick A. Altic, CHP
Health Physicist/Project Manager
ORISE

NAA:tb

electronic distribution:	K. Conway, NRC	P. Lee, NRC
	M. Kunowski, NRC	E. Bailey, ORISE
	D. Hagemeyer, ORISE	File/5299

OAK RIDGE INSTITUTE
FOR SCIENCE AND EDUCATION
Shaping the Future of Science

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN

K. M. Engel
ORISE

FINAL REPORT

Prepared for the
U.S. Nuclear Regulatory Commission

JANUARY 2020

NOTICES

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN

FINAL REPORT

Prepared by

K. M. Engel

ORISE

JANUARY 2020

Prepared for the
U.S. Nuclear Regulatory Commission

This document was prepared for the U.S. Nuclear Regulatory Commission by the Oak Ridge Institute for Science and Education (ORISE) through interagency agreement number 31310018N0014 with the U.S. Department of Energy (DOE). ORISE is managed by Oak Ridge Associated Universities (ORAU) under DOE contract number DE-SC0014664.

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN

Prepared by:	K. M. Engel, Health Physicist ORISE	Date:	01/10/2020
Reviewed by:	N. A. Altic, CHP, Health Physicist/Project Manager ORISE	Date:	1/10/2020
Reviewed by:	P. H. Benton, Quality Manager ORISE	Date:	1/10/2020
Reviewed by:	W. F. Smith, Senior Chemist ORISE	Date:	1/10/2020
Reviewed and approved for release by:	E. N. Bailey, Survey and Technical Projects Group Manager ORISE	Date:	1/10/2020

FINAL REPORT

JANUARY 2020

CONTENTS

FIGURES

TABLES

ACRONYMS

AA	alternative action
cm	centimeter
cpm	counts per minute
CU	confirmatory unit
DCGL	derived concentration guideline level
$DCGL_{BC}$	base case derived concentration guideline level
$DCGL_{Op}$	operational derived concentration guideline level
DPC	Dairyland Power Cooperative
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
DQO	data quality objective
DS	decision statement
FESW	Fuel Element Storage Well
FSS	final status survey
GPS	global positioning system
ISFSI	Independent Spent Fuel Storage Installation
LACBWR	La Crosse Boiling Water Reactor
LTP	License Termination Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
mrem/yr	millirem per year
NaI(Tl)	thallium-doped sodium iodide
NORM	naturally occurring radioactive material
NRC	U.S. Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocurie per gram
PSQs	principal study questions
Q	quantile
REAL	Radiological and Environmental Analytical Laboratory
ROC	radionuclide of concern
SOF	sum-of-fractions
SU	survey unit
TEDE	total effective dose equivalent
VSP	Visual Sample Plan

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN

EXECUTIVE SUMMARY

The La Crosse Boiling Water Reactor (LACBWR), a 50-megawatt electric boiling water reactor located in Genoa, Wisconsin, was originally a demonstration plant funded by the U.S. Atomic Energy Commission. LACBWR achieved initial criticality on July 11, 1967, and operated for 19 years until being permanently shut down on April 30, 1987. A License Termination Plan (LTP) submitted by LACBWR requesting the removal of all remaining open land and structures, except for the fenced area surrounding the Independent Spent Fuel Storage Installation, from License DPR-45 (LS 2018) was approved by the U.S. Nuclear Regulatory Commission (NRC) on May 21, 2019 (NRC 2019). LACBWR has subjected all remaining land areas and structures to a final status survey (FSS) to demonstrate compliance with federal radiological release criteria. NRC staff requested that the Oak Ridge Institute for Science and Education (ORISE) perform confirmatory survey activities within these remaining impacted land areas of the site.

ORISE performed independent assessment activities during the period of September 23–26, 2019. Confirmatory survey activities included gamma walkover scanning, gamma direct measurements, and soil sampling. The areas investigated included the remaining open-land areas of Class 1, 2, or 3 designation. A total of 46 soil samples were collected across all survey units: 20 random samples and 26 judgmental samples. A graphical comparison of the confirmatory and FSS data indicated that, overall, the confirmatory sum-of-fraction (SOF) results are lower than the FSS SOF results for both the random and judgmental data sets. All confirmatory radionuclide of concern (ROC) concentrations were less than the respective operational derived concentration guideline levels ($DCGL_{Op}$s), and the maximum SOF for the confirmatory data was 0.107. The ROC concentrations for the two samples collected deeper than 15 centimeters (cm) were less than the respective minimum detectable concentrations (MDCs). For all samples, the ROC concentrations were less than 50% of the respective $DCGL_{Op}$s, thus confirming the FSS survey unit (SU) classification.

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR REMAINING LAND AREAS AT THE LA CROSSE BOILING WATER REACTOR, GENOA, WISCONSIN

1. INTRODUCTION

The La Crosse Boiling Water Reactor (LACBWR), a 50-megawatt electric boiling water reactor located in Genoa, Wisconsin, was originally a demonstration plant funded by the U.S. Atomic Energy Commission. The plant was later sold to Dairyland Power Cooperative (DPC) with a provisional operating license. The LACBWR achieved initial criticality on July 11, 1967, and operated for 19 years until being permanently shut down on April 30, 1987. Consequently, DPC's authority to operate LACBWR under Provisional Operating License DPR-45 (issued by the U.S. Nuclear Regulatory Commission [NRC] on August 28, 1973) was amended via License Amendment 56 (August 4, 1987) to possession-only authority (LS 2018).

Dismantlement of plant-related systems and subsequent waste disposal operations began in 1994. The reactor pressure vessel (head, internals, and 29 control rods sealed with concrete), stored waste in the Fuel Element Storage Well (FESW), and other Class B/C wastes were shipped offsite for disposal in June 2007. Other systems and components—such as spent fuel storage racks, gaseous waste disposal systems (excluding the underground gas storage tanks), condensate and feed water systems (excluding condensate storage tank and condenser), the turbine and generator, and various components located in the Turbine Building (e.g., cooling water system pumps, heat exchangers, piping)—also have been removed. In September 2012, 333 spent fuel assemblies from the FESW were packaged in five dry casks and transferred to the Independent Spent Fuel Storage Installation (ISFSI) for storage (LS 2018). In May 2016, NRC consented to having the possession, maintenance, and decommissioning authorities of the LACBWR site transferred from DPC to LaCrosse*Solutions*, LLC.

A License Termination Plan (LTP) submitted by LACBWR requesting the removal of all remaining open-land and structures, except for the fenced area surrounding the ISFSI, from License DPR-45 (LS 2018) was approved by the NRC on May 21, 2019 (NRC 2019). Per the LTP, the Waste Gas Tank Vault and the Reactor Building structures were demolished and removed to a depth of three feet below grade, which corresponds to the 636-foot elevation. LACBWR has subjected all remaining land areas and structures to a final status survey (FSS) to demonstrate compliance with federal radiological release criteria.

NRC staff requested that the Oak Ridge Institute for Science and Education (ORISE) perform confirmatory survey activities within the impacted land areas of the site in order to use the confirmatory survey data for their evaluation of the adequacy and accuracy of LACWR's FSS data.

2. SITE DESCRIPTION

The LACBWR site enclosure is a 0.61 hectare (1.5 acre) land area within the 66.2-hectare (160 acre) licensed site located approximately 1.6 kilometers (1 mile) south of the Village of Genoa, Wisconsin, on the eastern shore of the Mississippi River. The licensed site is shared with the non-nuclear Genoa-3 Fossil Station. The operational fossil plant's buildings and structures were classified as non-impacted and are not subject to the release surveys specified in the LTP (LS 2018). Figure 2.1 provides an aerial view of the licensed site and illustrates remaining land area survey unit (SU) boundaries and radiological contamination classifications based on the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC 2000). The total area of all the land area FSS SUs is approximately 9 hectares (22 acres).

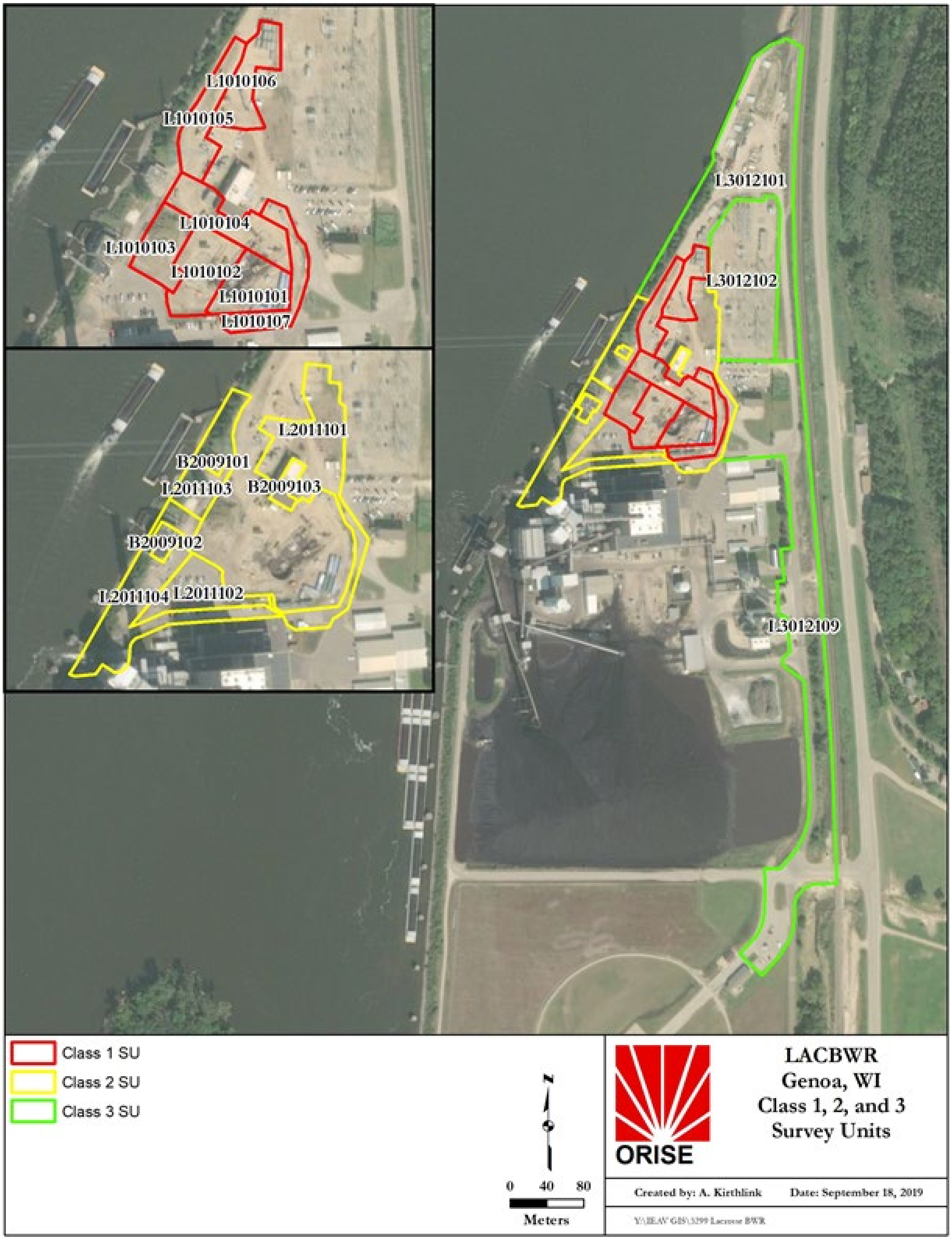

Figure 2.1. LACBWR Remaining Land Survey Area Boundaries and Classifications

3. DATA QUALITY OBJECTIVES

The data quality objectives (DQOs) described herein are consistent with the *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA 2006) and provided a formalized method for planning radiation surveys, improving survey efficiency and effectiveness, and ensuring that the type, quality, and quantity of data collected were adequate for the intended decision applications. The seven steps in the DQO process were as follows:

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

3.1 STATE THE PROBLEM

The first step in the DQO process defined the problem that necessitated the study, identified the planning team, and examined the project budget and schedule. The planning team, project budget, and schedule are presented in the project-specific plan and are not repeated here. LACBWR is requesting approval from NRC to remove the remaining open land and structures not associated with the ISFSI facility from its 10 *Code of Federal Regulations* Part 50 license. NRC staff requested that ORISE perform confirmatory surveys of the remaining land areas at LACBWR to provide independent radiological data to assist NRC staff in their evaluation of the adequacy and accuracy of LACBWR's FSS results. Therefore, the problem statement was as follows:

> Confirmatory surveys are necessary to generate independent radiological data for NRC staff's consideration in the evaluation of the FSS design, implementation, and results for demonstrating compliance with the release criteria.

3.2 IDENTIFY THE DECISION

The second step in the DQO process identified the principal study questions (PSQs) and alternative actions (AAs), developed a decision statement, and organized multiple decisions, as appropriate.

This was done by specifying AAs that could result from a "yes" response to the PSQs and combining the PSQs and AAs into a decision statement. Given that the problem statement introduced in Section 3.1 was fairly broad, multiple PSQs arose. PSQs, AAs, and combined decision statements (DSs) were organized based on the survey unit type (i.e., the associated FSS methodology), and are presented in Table 3.1.

Table 3.1. LACBWR Confirmatory Survey Decision Process

Principal Study Questions	Alternate Actions
PSQ1: Do confirmatory survey results agree with the FSS data for the remaining land areas and are residual radioactivity concentrations associated with the remaining land areas below applicable limits?	**Yes:** Compile confirmatory data and report results to NRC staff for their decision making. Provide independent interpretation that confirmatory field surveys did not identify anomalous areas of residual radioactivity, quantitative field and laboratory data satisfied the NRC-approved decommissioning criteria, and/or that statistical sample population examination/assessment conditions were met. **No:** Compile confirmatory data and report results to NRC staff for their decision making. Provide independent interpretation of confirmatory survey results identifying any anomalous field or laboratory data and/or when statistical sample population examination/assessment conditions were not satisfied for NRC staff's determination of the adequacy and accuracy of the FSS data.
PSQ2: Do the confirmatory results support the MARSSIM classification of the FSS SUs?	**Yes:** Confirmatory results support the classification of the FSS SUs. Compile confirmatory survey data and present results to NRC staff for their decision making. **No:** Confirmatory results do not support the classification of the FSS SUs. Summarize the discrepancies and provide technical comments to NRC staff for their decision making.
Decision Statements	
Determine if anomalous confirmatory survey results or other conditions preclude the FSS data from demonstrating compliance with the release criteria are present. Determine if confirmatory survey results support the FSS SUs MARSSIM classification.	

3.3 IDENTIFY INPUTS TO THE DECISION

The third step in the DQO process identified both the information needed and the sources of this information, determined the basis for action levels, and identified sampling and analytical methods that met data requirements. For this effort, information inputs included the following:

- LACBWR FSS data for remaining soils
- Derived concentration guideline levels (DCGLs), further discussed in subsection 3.3.1
- ORISE confirmatory survey results for surface radiation scans
- ORISE volumetric sample analysis results for soil

3.3.1 Radionuclides of Concern and Release Guidelines

The primary radionuclides of concern (ROCs) identified for LACBWR are beta-gamma emitters—fission and activation products—resulting from reactor operations. LACBWR developed site-specific DCGLs that correspond to a residual radioactive contamination level above background, which could result in a total effective dose equivalent (TEDE) of 25 millirem per year (mrem/yr) to an average member of the critical group. These DCGLs—defined in LACBWR's LTP as base case DCGLs ($DCGL_{BC}$s)—are radionuclide-specific and independently correspond to a TEDE of 25 mrem/yr for each source term. The initial suite of ROCs present at LACBWR has been reduced based on an insignificant dose contribution from a number of radionuclides. As such, the $DCGL_{BC}$s have been reduced to account for the dose from these insignificant radionuclides.

In order to ensure that total dose from all site-related source terms—basement structures, soils, buried piping, and groundwater—is less than the NRC's release criteria, the $DCGL_{BC}$s are further reduced to operational DCGLs ($DCGL_{Op}$s). The $DCGL_{Op}$s represent the expected dose from prior investigations, and are used for remediation and FSS/remedial action design purposes. Base case and operational DCGLs for surface soil, accounting for insignificant dose contributors, are provided in Table 3.2. Note that LACBWR did not identify H-3 and Ni-63 as primary ROCs. However H-3 and Ni-63 were included as part of this study, as requested by NRC staff.

Table 3.2. DCGLs for Surface Soil		
ROC	**Base Case DCGL (pCi/g)** [a]	**Operational DCGL (pCi/g)**
Co-60	10.6	3.83
Sr-90	5,470	1970.45
Cs-137	48.3	17.39
Eu-152	23.6	8.51
Eu-154	21.9	7.89

[a] pCi/g = picocurie per gram

Because each individual $DCGL_{BC}$ corresponds to the TEDE criterion, the sum-of-fractions (SOF) approach must be used to evaluate the total dose from the SU and demonstrate compliance with the dose limit. Since no areas of elevated activity exceeded the DCGLs, Equation 4-3 from MARSSIM was used for SOF calculations:

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

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

3.4 Define the Study Boundaries

The fourth step in the DQO process defined target populations and spatial boundaries, determined the timeframe for collecting data and making decisions, addressed practical constraints, and determined the smallest subpopulations, area, and time for which separate decisions must be made.

Confirmatory surveys activities were conducted September 23–26, 2019, in the land area SUs illustrated in Figure 2.1. The physical boundaries were defined by fencing, the Mississippi River, and areas that ORISE personnel were able to access safely. During the survey, individual SUs were combined into larger confirmatory units (CUs) based on classification, resulting in a Class 1 CU, Class 2 CU, and Class 3 CU. Field investigations were limited to surface soil (0- to 15- centimeters [cm] in depth), though, in some cases, deeper soil was investigated when measurements indicated the possibility of subsurface contamination. All Class 1 SUs contained backfill soil, and confirmatory statistical evaluations were not planned for SUs subject to backfill, because residual radioactivity above background was not anticipated.

3.5 DEVELOP A DECISION RULE

The fifth step in the DQO process specified appropriate population parameters (e.g., mean, median), confirmed action levels were above detection limits, and developed an "if…then…" decision rule statement. For this survey effort, the parameter of interest was the SOF for the confirmatory and FSS soil data. For assessing the data, the project-specific plan included comparing the mean/median ROC concentrations of the confirmatory soil data set against the FSS soil data set via a two-sample statistical test. This statistical test was not performed as the population of results were at or below the minimum detectable concentration (MDC). Comparing populations at these levels (i.e. background concentrations) yields inconclusive results due to the presence of non-detected values. Furthermore, this evaluation is unnecessary when the DCGLs are large relative to the results, as a small difference in the populations would not alter the decision to release the SU. Instead a graphical analysis of confirmatory and FSS data was performed, along with a comparison of the confirmatory survey sample results directly to the $DCGL_{Op}$s. As such, the decision rule was reformulated as follows:

> If confirmatory data and FSS data are similar and each individual sample result is below the $DCGL_{Op}$, then conclude that the FSS data are acceptable for demonstrating compliance with the release criterion; otherwise, perform further evaluation(s) and provide technical comments/recommendations to NRC for their evaluation and decision making.

The classification of the SUs also was assessed as part of the confirmatory survey process based on the requirements outlined in the LTP and primarily relates to Class 2 and Class 3 SUs, as well as non-impacted areas, as a Class 1 SU will not receive higher classification. FSS investigation levels—for surface scans and quantitative measurements such as soil sample analytical results—that trigger additional evaluations were established and are presented in Section 5.6.4.6 of the LTP. These investigation levels are reproduced in Table 3.3. The site may perform additional remediation and/or reclassify and resurvey all or a portion of the SUs. For confirmatory surveys, ORISE focused on identifying locations that potentially exceeded the soil sample investigation levels. These locations were used to confirm whether the SU should have been reclassified as part of the FSS process. The decision rule related to SU classification was stated as follows:

If soil concentrations indicate that a Class 2 or Class 3 should be reclassified to a higher classification, then summarize confirmatory data for NRC staff's evaluation and decision making.

Table 3.3. LACBWR Investigation Levels [a]

SU Classification	Soil Surface Scanning Investigation Levels	Soil Sample Investigation Levels
Class 1	> $DCGL_{Op}$ or > MDC_{SCAN}[b] if the MDC_{SCAN} is greater than the $DCGL_{Op}$	> $DCGL_{Op}$
Class 2		
Class 3		> 50% of $DCGL_{Op}$

[a] Recreated from LS 2018.
[b] MDC_{SCAN} = scan minimum detectable concentration

3.6 Specify Limits on Decision Errors

The sixth step in the DQO process established bounds of decision errors. Decision errors were controlled by optimizing the confirmatory field measurement and laboratory analytical MDCs. Field scanning and analytical MDCs were minimized by following the procedures referenced in Sections 4 and 5, respectively. Typical laboratory MDCs were a fraction of the $DCGL_{Op}$s and were sufficient for decision making.

3.7 Optimize the Design for Obtaining Data

The seventh step in the DQO process was used to review DQO outputs, develop data collection design alternatives, formulate mathematical expressions for each design, select the sample size to satisfy DQOs, decide on the most resource-effective design of agreed alternatives, and document requisite details. Specific survey procedures are presented in Section 4.

4. PROCEDURES

The ORISE survey team performed visual inspections, measurements, and sampling activities within the accessible portions of Class 1, 2, and 3 SUs during the period of September 23–26, 2019. Survey activities were performed in accordance with the project-specific confirmatory survey plan, the *Oak Ridge Associated Universities (ORAU) Radiological and Environmental Survey Procedures Manual,* and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORISE 2019, ORAU

2016a, ORAU 2019a). Appendices C and D provide additional information regarding survey instrumentation and related processes discussed within this section.

4.1 REFERENCE SYSTEM

ORISE referenced confirmatory measurement/sampling locations to global positioning system (GPS) coordinates, specifically the Wisconsin South 4803 state plane NAD 1987, as well as other prominent site features. Measurement and sampling locations were documented on detailed survey maps.

4.2 SURFACE SCANS

Surface scans were performed with Ludlum Model 44-10 2-inch by 2-inch thallium-doped sodium iodide (NaI[Tl]) scintillation detectors coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. Ratemeter-scalers were also coupled to GPS systems that enabled real time gamma count rate and geo-referenced data capture. Locations of elevated response that were audibly distinguishable from localized background levels, suggesting the presence of residual contamination, were marked for further investigation. Scan density was commensurate with LACBWR's SU classification, as specified in Table 4.1. Surface scans in Class 2 or 3 SUs first focused on judgmentally selected areas based on the potential for run-off accumulation, migration pathways, and/or other indications of residual contamination as well as SU boundaries that separated areas with different classifications. Surface scans in these units also focused on vegetative areas, with only moderate attention paid to roadways and parking lots. Scan coverage in Class 2 and 3 SUs was increased, as time allowed, relative to what was originally planned.

Table 4.1. Surface Scan Density

MARSSIM Classification	Scan Coverage
Class 1	High Density (up to 100%)
Class 2	Medium to High Density (50% to 100%)
Class 3	Low Density (10%)

4.3 SOIL SAMPLING AND LOCATIONS

Soil samples were collected from both randomly and judgmentally selected locations. Because Class 1 survey units consisted of backfilled soil, only judgmental samples were collected in these areas, dependent upon detector response and after initial examination of the scan data. The confirmatory measurement locations were determined using Visual Sample Plan (VSP), version 7.11b. The FSS data were used as VSP inputs to generate the confirmatory sample population size: 10 locations randomly placed throughout the Class 2 and Class 3 CUs, respectively. As mentioned in Section 4.2, judgmental sample locations were selected based on the results of the surface scans. Table 4.2 provides a summary of the samples collected.

Table 4.2. Summary of Collected Soil Samples

Area	Random Samples	Judgmental Samples
Class 1 CU	0	11[a]
Class 2 CU	10	6
Class 3 CU	10	9[a]
Total	20	26

[a] One of the judgmental samples was collected at a 15- to 30-cm depth.

Soil samples were collected from a depth of 0- to 15- cm using hand trowels. Sampling equipment was decontaminated in the field after the collection of each sample to prevent cross-contamination. One-minute static gamma counts were performed at each sample location pre- and post-sample collection to assess if there was a potential for contamination at depth greater than 15 cm. Based on the 1-minute static gamma counts, two soil samples were collected from a 15- to 30-cm depth: one sample from the Class 1 CU and one sample from the Class 3 CU, both from judgmental locations.

5. SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data collected on site were transferred to the ORISE facility for analysis and interpretation. Sample custody was transferred to the Radiological and Environmental Analytical Laboratory (REAL) in Oak Ridge, Tennessee. Sample analyses were performed in accordance with the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2019b). Soil samples were crushed and homogenized and then analyzed by gamma spectrometry for gamma emitting fission and activation products. Per NRC staff direction, nine soil samples were analyzed for Sr-90, Ni-63, and H-3. Three samples were selected based on the gamma spectrometry results; the other six were randomly selected to complete a batch. Analytical results are reported in units of picocurie per gram (pCi/g).

Scan data and random soil sample results were graphed in quantile (Q) plots for assessment and are discussed further in Section 6. The Q-plot is a graphical tool for assessing the distribution of a dataset. For the following Q-plots, the Y-axis represents the NaI(Tl) detector response in units of counts per minute (cpm) in Figure 6.1, the SOF results in Figures 6.2 and 6.3, and the naturally occurring radioactive material (NORM) concentrations (pCi/g) in Figure 6.4. The X-axis represents the data quantiles about the mean value. Values less than the mean are represented in the negative quantiles; the values greater than the mean are represented in the positive quantiles. A normal distribution (i.e., a background population) that is not skewed by outliers will appear as a straight line, with the slope of the line subject to the degree of variability among the data population. More than one distribution, such as background plus contamination or other outliers, will appear as a step function. Additionally, the FSS data were plotted along with the confirmatory data on a Q-plot to evaluate for biases. Biases—positive or negative—would be indicated by diverging data groupings. Select soil sample analytical results were also plotted using strip charts, often referred to as one-dimensional scatter plots and are further discussed in Section 6 as well.

6. FINDINGS AND RESULTS

The results of the confirmatory survey are discussed in the following subsections.

6.1 SURFACE SCANS

Gamma walkover presenting NaI(Tl) detector response ranges for each CU are illustrated in Figures A.1 through A.4 in Appendix A. Table 6.1 provides a summary of these data. Q-plots of the walkover data for each CU are provided in Figure 6.1 below.

Table 6.1. Summary of Gamma Walkover Data	
Area	**Gamma Scan Ranges (cpm)**
Class 1 CU	2,600 to 14,000
Class 2 CU	2,200 to 10,000
Class 3 CU	2,400 to 20,000

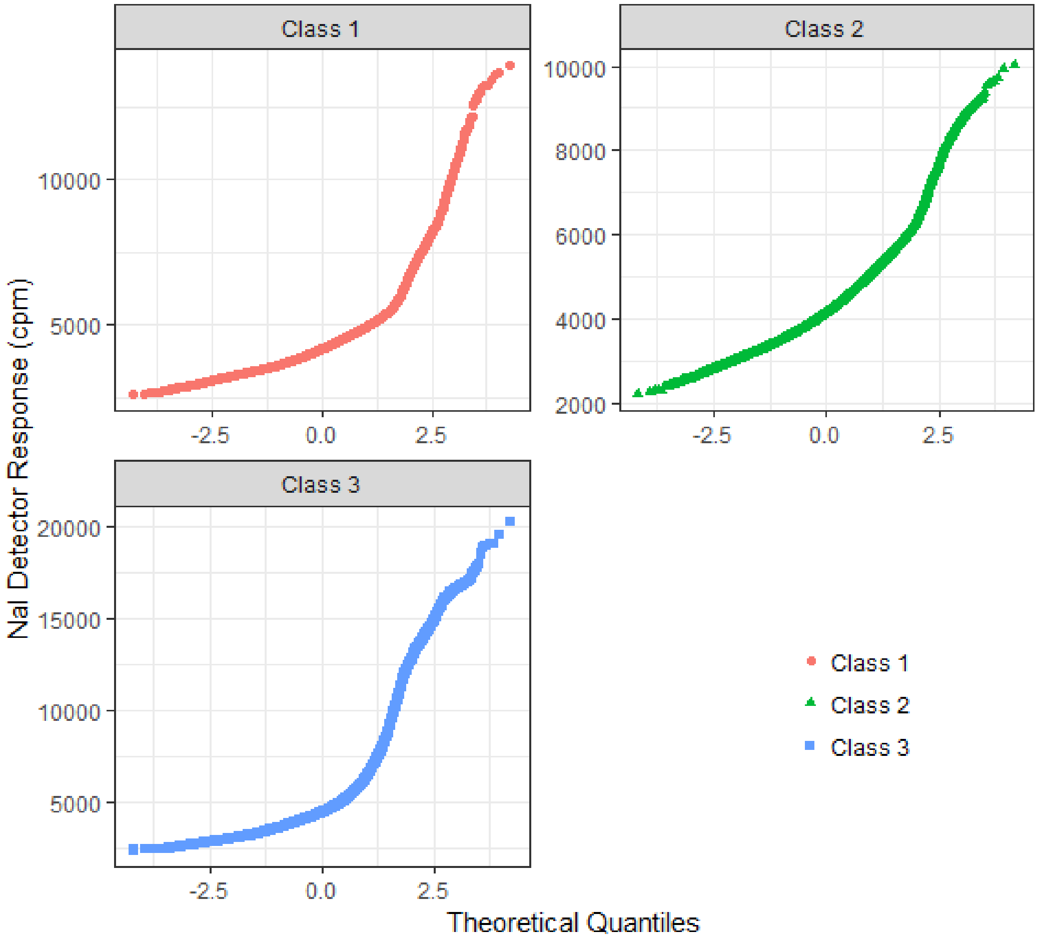

Figure 6.1. Quantile Plots for the Gamma Walkover Survey

As indicated by the shape of the Q-plots, data sets are not normally distributed and indicate multiple background populations. Gamma scanning data identified multiple locations of elevated detector response relative to background. Some of the elevated detector responses could be attributed to fluctuations in material background (e.g., asphalt, brick, soil porcelain/ceramic). For example, detector responses were higher near the brick building and along the roadway where red rock-type gravel was present. In these cases, the elevated detector response was over a wide-spread area (see Figures A.1, A.2, and A.4 in Appendix A). In other cases, the elevated detector response was more localized (see Figures A.1, A.2, and A.3). Regardless of the suspected source, areas of elevated gamma response were flagged for further investigation and judgmental soil samples were collected at a majority of the locations.

6.2 SOIL SAMPLING

Figures A.1 through A.4 in Appendix A display the locations for each of the soil samples collected from the Class 1, Class 2, and Class 3 CUs. Soil sample coordinates and pre- and post-sample static gamma counts are presented in Tables B.1, B.2, and B.3 in Appendix B. Analytical results for the site ROC concentrations in individual soil samples are presented in Tables B.4, B.6, and B.8. Analytical results for NORM concentrations for all samples are provided in Tables B.5, B.7, and B.9. H-3 and Ni-63 concentrations for nine samples (one sample from each CU with the highest Cs-137 concentration and six random samples) are presented in Table B.10. A summary of the results is provided in Tables 6.2, 6.3, and 6.4.

Table 6.2. Range of ROC Concentrations in Judgmental Samples (pCi/g)

ROC	Class 1 CU		Class 2 CU		Class 3 CU	
	Min	Max	Min	Max	Min	Max
Co-60	-0.007	0.063	-0.005	0.013	-0.025	0.013
Sr-90	-0.06	0.18	--	0.08	--	-0.03
Cs-137	-0.021	1.58	-0.008	0.466	-0.020	0.024
Eu-152	-0.079	0.038	-0.036	0.033	-0.065	-0.004
Eu-154	-0.113	-0.025	-0.137	-0.02	-0.22	-0.011
SOF	0.000	0.107	0.000	0.031	0.000	0.004

Table 6.3. Descriptive Statistics for ROC Concentrations in Random Soil Samples (pCi/g)

ROC	Class 2 CU					Class 3 CU				
	Mean	Median	St. Dev.	Min	Max	Mean	Median	St. Dev.	Min	Max
Co-60	0.002	0.002	0.007	-0.008	0.013	0.005	0.004	0.01	-0.010	0.027
Sr-90	--	--	--	--	--	0.05	0.05	0.03	0.03	0.07
Cs-137	0.04	0.04	0.04	0.003	0.125	0.07	0.03	0.1	-0.001	0.360
Eu-152	-0.006	-0.008	0.02	-0.027	0.023	-0.003	-0.002	0.02	-0.036	0.021
Eu-154	-0.069	-0.063	0.038	-0.153	-0.020	-0.03	-0.03	0.02	-0.085	0.009
SOF	0.003	0.003	0.006	0.001	0.010	0.005	0.003	0.008	0.000	0.021

Table 6.4. Range of H-3 and Ni-63 Concentrations in Select Soil Samples (pCi/g)

ROC	Min	Max
H-3	-0.8	0.6
Ni-63	0.17	1.26

Figure 6.2 below provides Q-plots of the SOF results for the confirmatory (ORISE) and FSS (LACBWR) random data sets. The plots shown in Figure 6.2 illustrate that the ORISE population is shifted down from the LACBWR population indicating that, overall, the ORISE SOF results are lower than the LACBWR SOF results. There were two noted differences between the FSS and confirmatory data related to the calculation of the SOF: FSS gamma-emitting ROC concentrations were reported based on highest abundance energy line (only when the ROC was not detected), and the Sr-90 concentration was calculated using a surrogate approach. The REAL reported activity concentrations by gamma spectrometry based on the activity from a specific total absorption peak (listed in Table D.1 in Appendix D). This difference in radionuclide concentration reporting potentially accounts, in part, for the bias seen between the FSS and ORISE data. Additionally, the FSS SOF results include the contribution from Sr-90 whereas the ORISE reported SOF results do not. This additional fraction due to Sr-90 is small relative to the overall SOF for the FSS data. Thus, the former mentioned reporting difference is likely the more significant source of bias. Additional investigation would be needed to resolve the differences, however, since all SOF results for both data sets are a fraction unity—based on the $DCGL_{Op}$s and provided the large number of non-detects in each data set—further investigation into the difference is unwarranted.

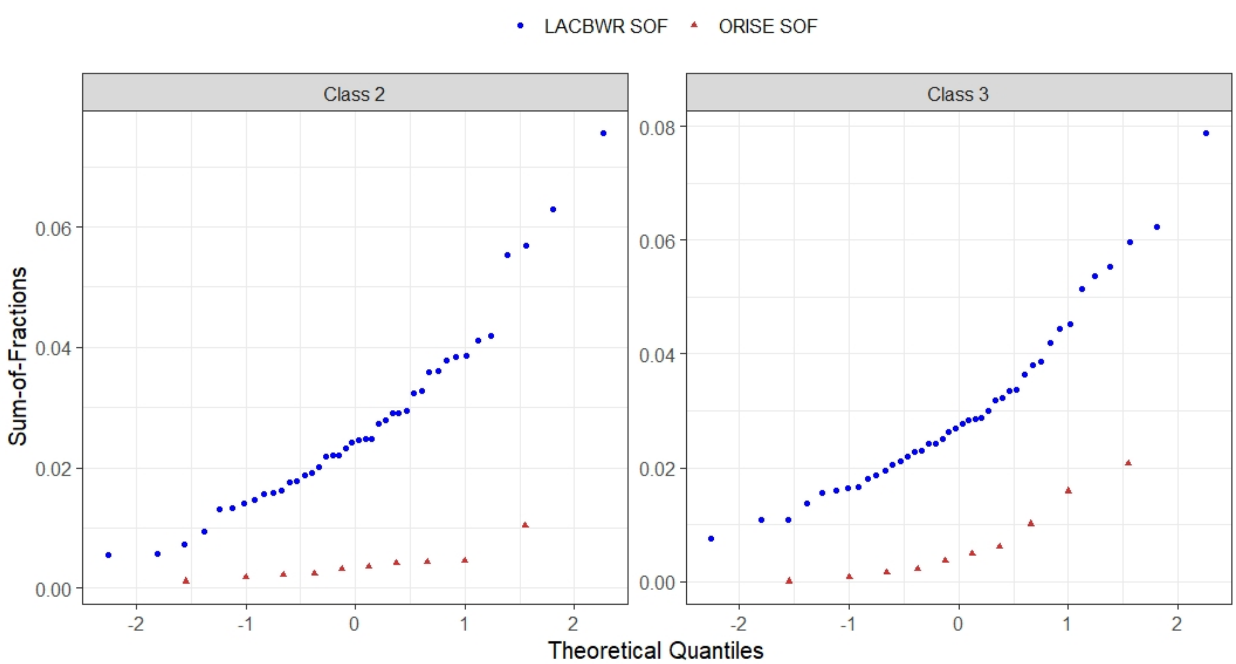

Figure 6.2. Quantile Plots for the ORISE and LACBWR Random Sample SOF

Figure 6.3 provides strip charts of the SOF results for the confirmatory and FSS surface judgmental data sets. As with the random populations, the ORISE SOF results are lower than the LACBWR SOF results. See previous discussion on differences between SOF calculations between the FSS data and confirmatory data. All SOF results for both data sets are less than 1; and all individual concentrations are less than the respective $DCGL_{Op}$s. All ROC concentrations for the two samples collected from the 15- to 30-cm depth (5299S0039 and 5299S0045) are less than the respective MDCs.

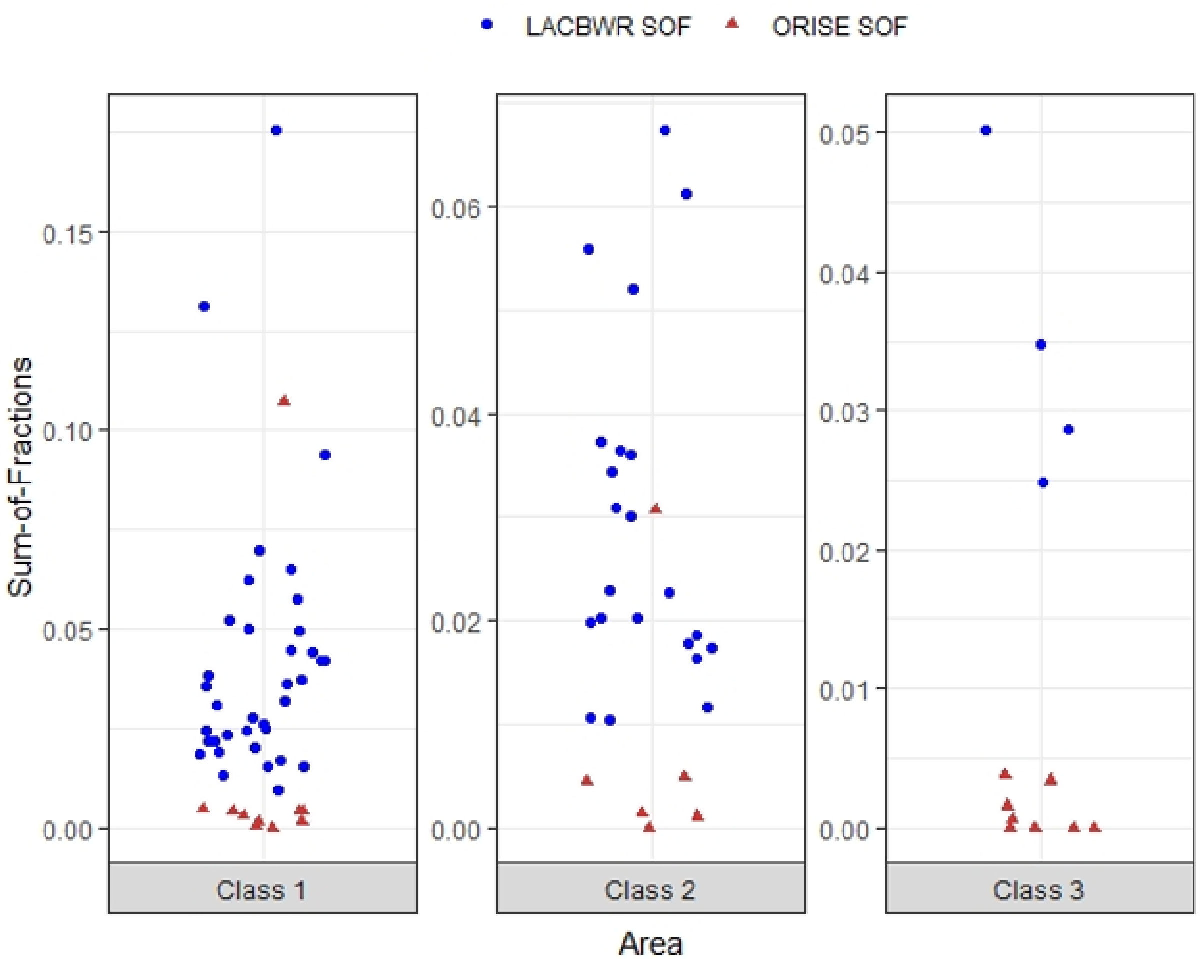

Figure 6.3. Strip Charts for the ORISE and LACBWR Judgmental Sample SOF

Figure 6.4 provides strip charts of the NORM concentrations for ORISE random and ORISE judgmental samples. The highest NORM concentrations are from judgmental samples. All 26 judgmental samples had K-40, Ra-226, and Th-232 concentrations greater than the respective analytical MDCs. In general, judgmental samples, which were selected based on increased gamma radiation responses, also exhibited higher NORM concentrations than the random samples. For example, the judgmental soil sample that exhibited the highest static gamma measurement of 23,000 cpm (5299S0045) had the following NORM concentrations: 11.91 pCi/g, 5.10 pCi/g, 2.07 pCi/g, and 3.5 pCi/g for K-40, Ra-226, Th-232, and U-238, respectively. Additionally, the highest K-40 concentrations (27.2 and 52.3 pCi/g) were found in two samples collected from a location also identified by the site during scans. ORISE collected both a surface and subsurface sample at this location: samples 5299S0038 and 5299S0039, respectively. The elevated direct gamma radiation prompting the collection of judgmental samples was attributed to the presence of NORM.

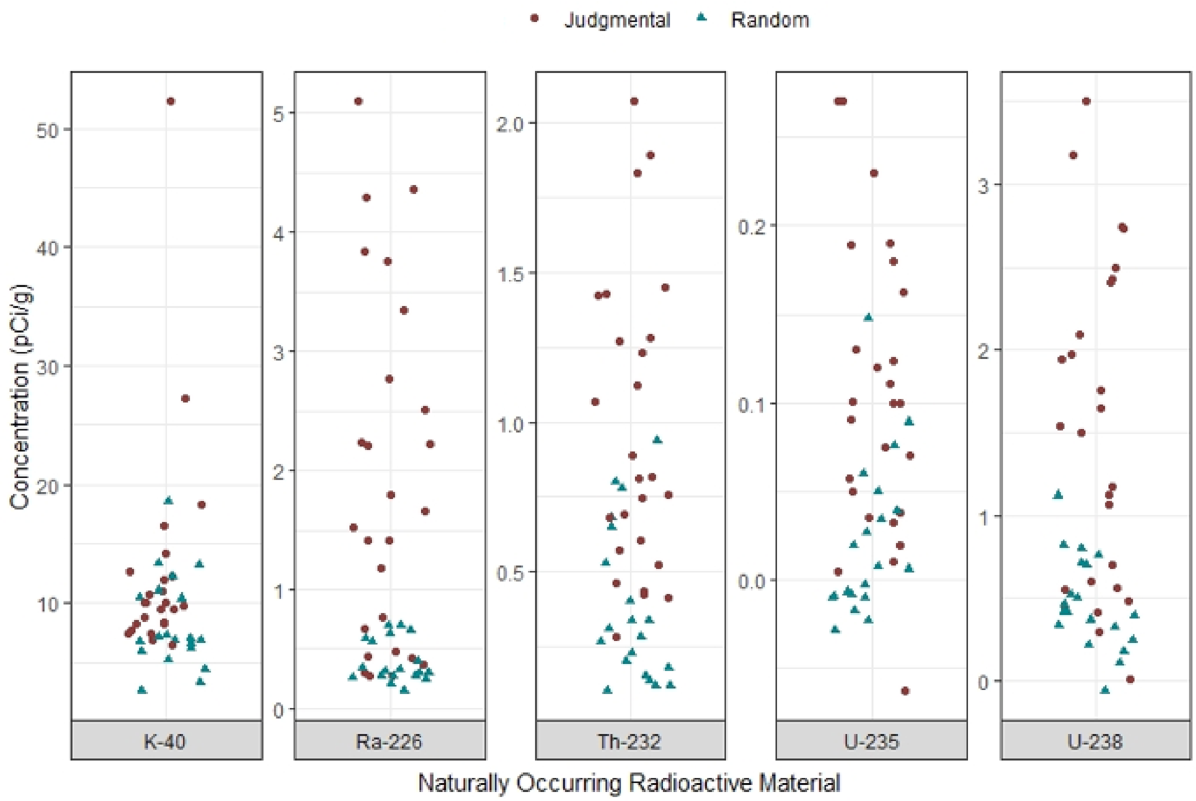

Figure 6.4. Strip Charts for the ORISE Random and Judgmental Sample NORM Concentrations

The confirmatory data was compared against the investigation levels presented in Table 3.3. None of the ROC concentrations exceeded 50% of the respective $DCGL_{Op}$s, thus confirming the FSS SU classification.

7. SUMMARY

At the request of the NRC, ORISE performed independent confirmatory survey activities of surface soils associated with the remaining land areas at the LACBWR in Genoa, Wisconsin, during the period of September 23–26, 2019. The confirmatory surveys consisted of gamma surface scan, gamma direct measurements, and soil sampling.

Gamma scans of the Class 1, 2, and 3 CUs identified multiple areas of elevated radiation distinguishable from background. Based on the results of the scanning, 26 soil samples were collected from judgmentally-selected locations. All soil samples were collected from the surface (0- to 15-cm) except for two samples, which were collected from the 15- to 30-cm depth based on results of the 1-minute, post-sample gamma count. In addition to the judgmental samples, 10 soil samples were collected from randomly selected locations in each of the Class 2 and 3 CUs, resulting in 20 total random samples. Only judgmental samples were collected in the Class 1 CU because that area had been backfilled.

A graphical comparison of the confirmatory and FSS data indicated that, overall, the confirmatory SOF results are lower than the FSS SOF results for both the random and judgmental data sets. All confirmatory ROC concentrations were less than the respective $DCGL_{Op}$s, and the maximum SOF for the confirmatory data was 0.107. The ROC concentrations for the two samples collected deeper than 15 cm were less than their respective MDCs. For all samples, the ROC concentrations were less than 50% of the respective $DCGL_{Op}$s, thus confirming the FSS SU classification.

8. REFERENCES

EPA 2006. *Guidance on Systematic Planning Using the Data Quality Objectives Process*. EPA QA/G-4. U.S. Environmental Protection Agency. Washington, D.C. February.

LS 2018. *La Crosse Boiling Water Reactor License Termination Plan*. Revision 1. LaCrosse*Solutions*. Genoa, Wisconsin. May.

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

NRC 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*. NUREG-1575. Rev. 1. U.S. Nuclear Regulatory Commission. Washington, D.C. August.

NRC 2019. *La Crosse Boiling Water Reactor – Issuance of License Amendment No. 75 to Approve the LaCrosseSolutions, LLC License Termination Plan (CAC NO. 000083; EPID-L-2017-DTP-0008)*. U.S. Nuclear Regulatory Commission. Washington, D.C. May.

ORAU 2014. *ORAU Radiation Protection Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. October.

ORAU 2016a. *ORAU Radiological and Environmental Survey Procedures Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. November 10.

ORAU 2016b. *ORAU Health and Safety Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. January.

ORAU 2019a. *ORAU Environmental Services and Radiation Training Quality Program Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. April 30.

ORAU 2019b. *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual*. Oak Ridge Associated Universities. Oak Ridge, Tennessee. June 27.

ORISE 2019. *Project-Specific Plan for the Confirmatory Survey Activities of Remaining Land Areas at the La Crosse Boiling Water Reactor, Genoa, Wisconsin*. Oak Ridge Institute for Science and Education. Oak Ridge, Tennessee. September 20.

APPENDIX A: FIGURES

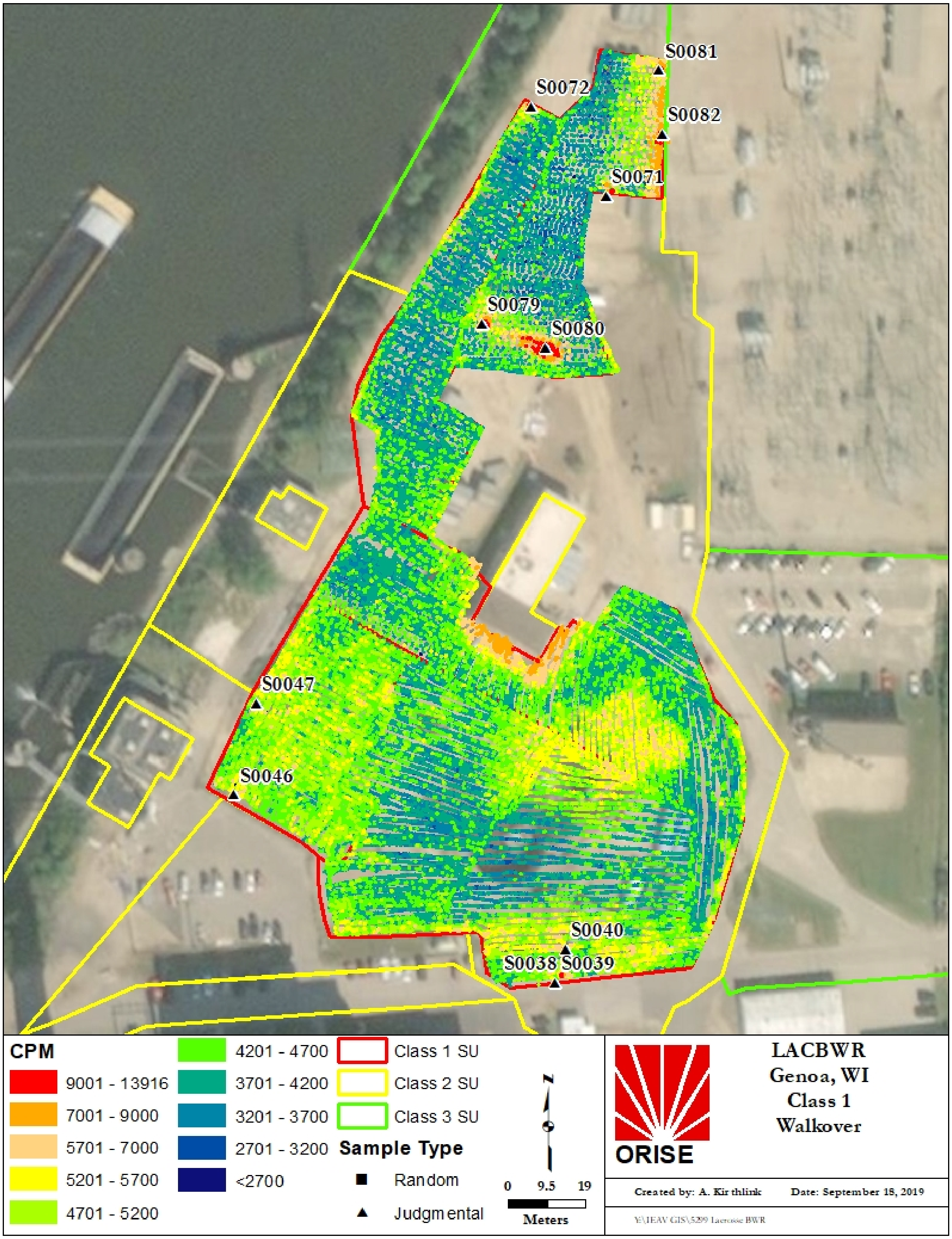

Figure A.1. Gamma Walkover Data for Class 1 Survey Units

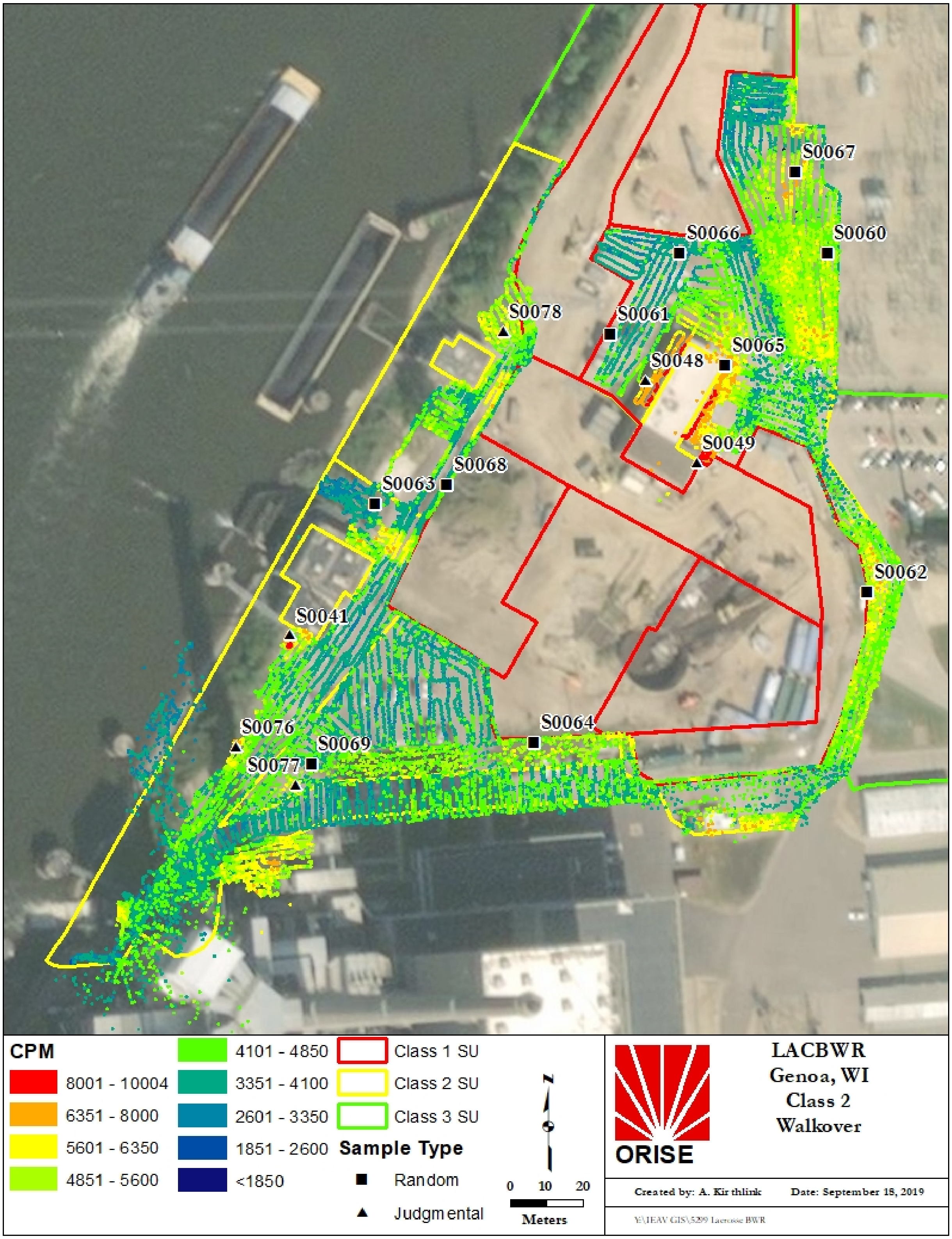

Figure A.2. Gamma Walkover Data for Class 2 Survey Units

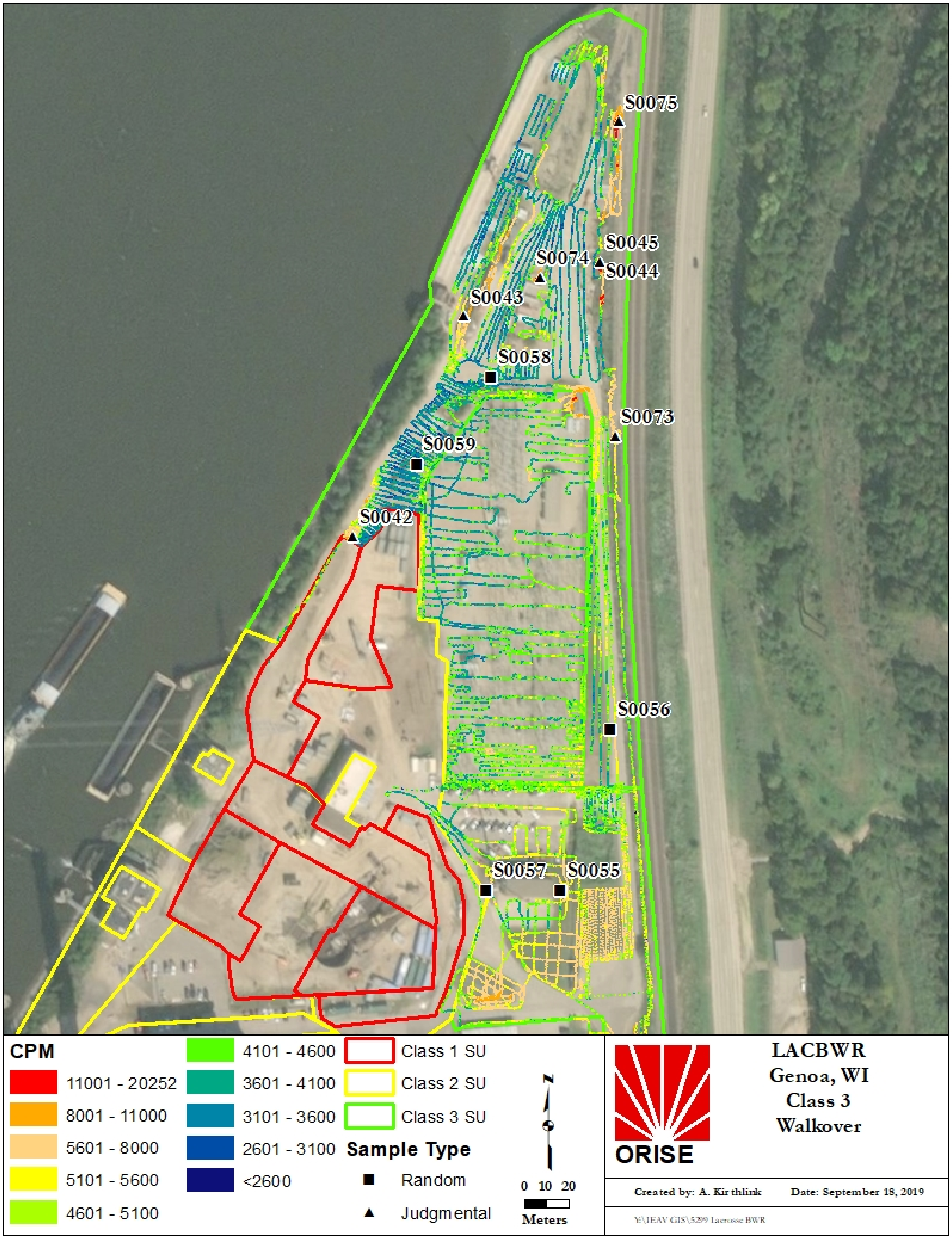

Figure A.3. Gamma Walkover Data for the Northern Region of Class 3 Survey Units

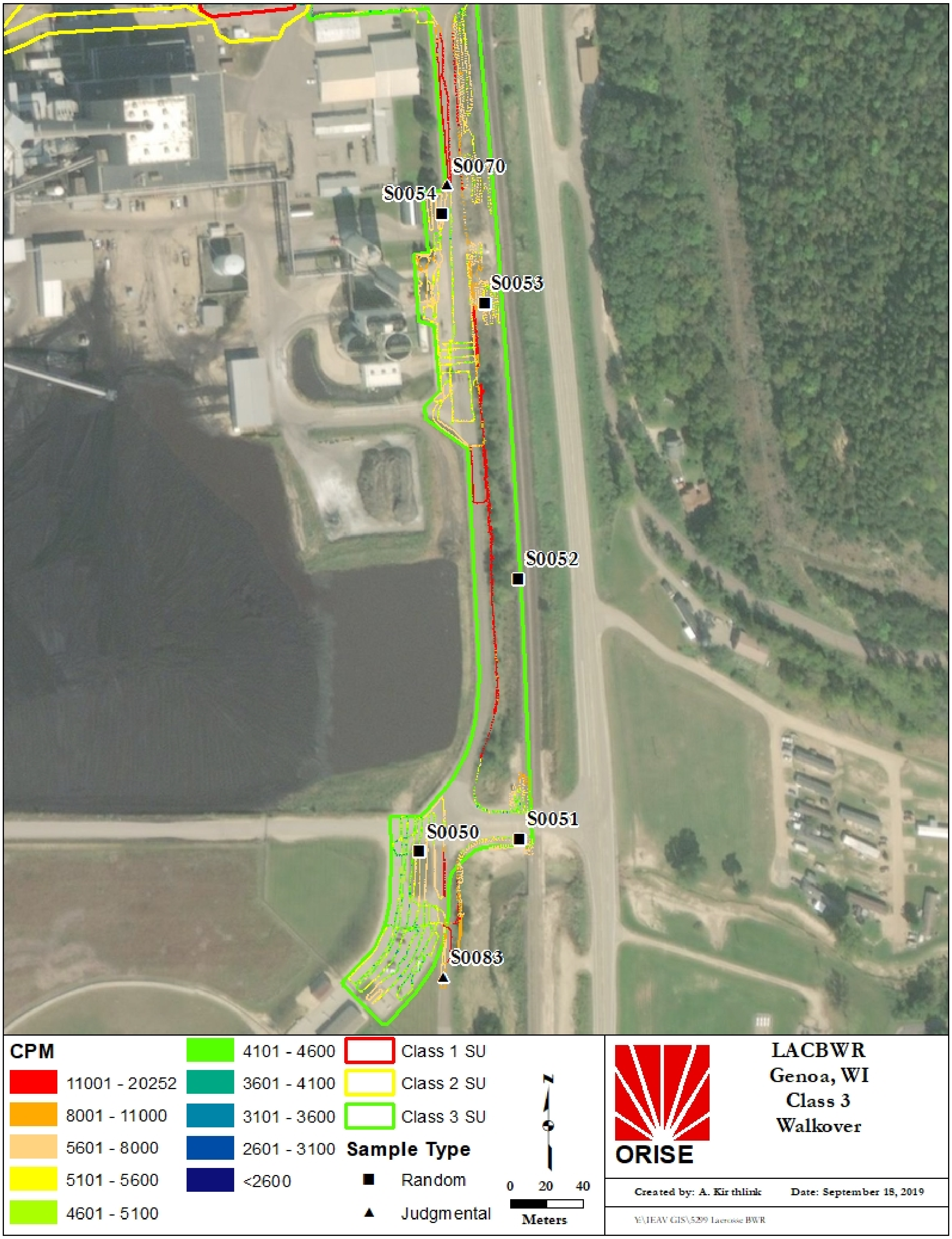

Figure A.4. Gamma Walkover Data for the Southern Region of Class 3 Survey Units

APPENDIX B: DATA TABLES

Table B.1. Class 1 CU Soil Sample Locations and Gamma Measurements						
Sample ID	Survey Unit	Coordinates (ft)		Gamma Measurement (cpm)		Sample Depth (cm)
		Northing	Easting	Pre-Sample	Post-Sample	
Judgmental Samples						
5299S0038	L1010107	570859	1642153	12,000	16,000	0-15
5299S0039	L1010107	570859	1642153	16,000	18,000	15-30
5299S0040	L1010107	570886	1642161	10,000	13,000	0-15
5299S0046	L1010103	571012	1641892	5,800	7,300	0-15
5299S0047	L1010103	571086	1641910	4,800	4,900	0-15
5299S0071	L1010106	571498	1642194	9,500	14,000	0-15
5299S0072	L1010105	571571	1642133	7,900	7,400	0-15
5299S0079	L1010106	571394	1642093	10,000	11,000	0-15
5299S0080	L1010106	571375	1642145	13,000	16,000	0-15
5299S0081	L1010106	571601	1642237	8,100	11,000	0-15
5299S0082	L1010106	571549	1642240	7,800	8,600	0-15

Table B.2. Class 2 CU Soil Sample Locations and Gamma Measurements						
Sample ID	Survey Unit	Coordinates (ft)		Gamma Measurement (cpm)		Sample Depth (cm)
		Northing	Easting	Pre-Sample	Post-Sample	
Random Samples						
5299S0060	L2011101	571338	1642271	4,600	5,200	0-15
5299S0061	L2011101	571264	1642074	3,500	3,600	0-15
5299S0062	L2011101	571031	1642307	5,700	6,900	0-15
5299S0063	L2011104	571111	1641860	3,600	3,900	0-15
5299S0064	L2011102	570894	1642005	4,700	5,400	0-15
5299S0065	L2011101	571237	1642178	7,900	9,100	0-15
5299S0066	L2011101	571338	1642137	3,100	3,300	0-15
5299S0067	L2011101	571412	1642242	5,100	5,400	0-15
5299S0068	L2011103	571127	1641926	4,000	4,200	0-15
5299S0069	L2011102	570875	1641802	3,900	4,300	0-15
Judgmental Samples						
5299S0041	L2011104	570991	1641783	9,000	13,000	0-15
5299S0048	L2011101	571222	1642105	7,900	8,500	0-15
5299S0049	L2011101	571147	1642152	9,200	10,000	0-15
5299S0076	L2011104	570889	1641733	5,900	7,100	0-15
5299S0077	L2011102	570854	1641788	6,700	9,700	0-15
5299S0078	L2011103	571266	1641976	6,300	7,500	0-15

Table B.3. Class 3 CU Soil Sample Locations and Gamma Measurements						
Sample ID	**Survey Unit**	**Coordinates (ft)**		**Gamma Measurement (cpm)**		**Sample Depth (cm)**
		Northing	**Easting**	**Pre-Sample**	**Post-Sample**	
Random Samples						
5299S0050	L3012109	569338	1642495	6,300	6,600	0-15
5299S0051	L3012109	569360	1642677	7,200	7,700	0-15
5299S0052	L3012109	569833	1642675	9,000	9,300	0-15
5299S0053	L3012109	570336	1642613	6,100	6,400	0-15
5299S0054	L3012109	570498	1642536	6,300	7,000	0-15
5299S0055	L3012109	571055	1642449	5,500	6,000	0-15
5299S0056	L3012101	571293	1642523	5,100	6,300	0-15
5299S0057	L3012101	571056	1642340	3,500	3,700	0-15
5299S0058	L3012101	571811	1642347	3,300	3,300	0-15
5299S0059	L3012101	571682	1642237	3,200	3,500	0-15
Judgmental Samples						
5299S0042	L3012101	571576	1642143	9,100	12,000	0-15
5299S0043	L3012101	571900	1642307	12,000	16,000	0-15
5299S0044	L3012101	571980	1642506	14,000	23,000	0-15
5299S0045	L3012101	571980	1642506	23,000	27,000	15-30
5299S0070	L3012109	570549	1642544	12,000	17,000	0-15
5299S0073	L3012101	571723	1642529	9,600	13,000	0-15
5299S0074	L3012101	571957	1642419	16,000	19,000	0-15
5299S0075	L3012101	572187	1642534	13,000	18,000	0-15
5299S0083	L3012109	569109	1642538	12,000	17,000	0-15

Table B.4. ROC Sample Concentrations from Class 1 CU																
Sample ID	**Co-60 (pCi/g)**			**Sr-90 (pCi/g)**			**Cs-137 (pCi/g)**			**Eu-152 (pCi/g)**			**Eu-154 (pCi/g)**			**SOF**
	Conc.	**TPU[a]**	**MDC[b]**	**Conc.**	**TPU**	**MDC**	**Conc.**	**TPU**	**MDC**	**Conc.**	**TPU**	**MDC**	**Conc.**	**TPU**	**MDC**	
Judgmental Samples																
5299S0038	0.004	0.023	0.048	0.04	0.16	0.29	**0.049**[c]	0.017	0.034	-0.010	0.040	0.087	-0.113	0.099	0.185	0.004
5299S0039[d]	0.010	0.025	0.053	--	--	--	0.015	0.020	0.046	0.038	0.045	0.109	-0.052	0.072	0.201	--
5299S0040	**0.063**	0.021	0.040	-0.05	0.16	0.31	**1.58**	0.12	0.03	-0.003	0.046	0.101	-0.045	0.058	0.163	0.107
5299S0046	-0.007	0.021	0.041	--	--	--	**0.052**	0.013	0.031	-0.010	0.038	0.084	-0.056	0.057	0.161	0.003
5299S0047	0.010	0.010	0.023	-0.06	0.16	0.31	0.013	0.011	0.026	0.008	0.017	0.068	-0.025	0.039	0.105	0.004
5299S0071	-0.006	0.023	0.046	--	--	--	-0.010	0.027	0.056	-0.050	0.064	0.137	-0.105	0.094	0.259	0.000
5299S0072	0.002	0.030	0.064	--	--	--	-0.009	0.022	0.055	-0.026	0.066	0.143	-0.077	0.092	0.258	0.001
5299S0079	0.006	0.029	0.062	0.07	0.17	0.29	0.000	0.023	0.066	-0.079	0.075	0.160	-0.092	0.100	0.276	0.002
5299S0080	-0.005	0.025	0.050	--	--	--	-0.021	0.020	0.049	0.013	0.059	0.140	-0.092	0.065	0.213	0.002
5299S0081	0.010	0.032	0.069	--	--	--	0.025	0.021	0.048	0.000	0.068	0.151	-0.091	0.099	0.268	0.004
5299S0082	0.012	0.025	0.054	0.18	0.18	0.29	0.024	0.012	0.041	-0.071	0.058	0.130	-0.030	0.076	0.211	0.005

[a] Uncertainties are based on total propagated uncertainties reported at the 95% confidence level.
[b] MDC = minimum detectable concentration.
[c] Results greater than MDC are bolded.
[d] Sample collected from a 15- to 30-cm depth.

Table B.5. NORM Sample Concentrations from Class 1 CU															
Sample ID	**K-40 (pCi/g)**			**Ra-226 by Pb-214 (pCi/g)[a]**			**Th-232 by Ac-228(pCi/g)**			**U-235 (pCi/g)**			**U-238 by Th-234(pCi/g)**		
	Conc.	**TPU[b]**	**MDC[c]**	**Conc.**	**TPU**	**MDC**	**Conc.**	**TPU**	**MDC**	**Conc.**	**TPU**	**MDC**	**Conc.**	**TPU**	**MDC**
Judgmental Samples															
5299S0038	**27.2**	2.1	0.4	**0.272**	0.032	0.056	**0.417**	0.086	0.150	0.038	0.072	0.171	0.41	0.21	0.45
5299S0039	**52.3[d]**	3.5	0.6	**0.421**	0.049	0.077	**0.75**	0.11	0.17	0.10	0.11	0.27	0.01	0.48	1.15
5299S0040	**16.5**	1.3	0.3	**0.280**	0.037	0.059	**0.434**	0.071	0.130	0.019	0.075	0.177	0.43	0.23	0.49
5299S0046	**12.2**	1.0	0.4	**0.484**	0.048	0.057	**0.604**	0.094	0.133	0.033	0.072	0.169	**0.56**	0.24	0.46
5299S0047	**7.41**	0.63	0.46	**0.297**	0.034	0.045	**0.282**	0.056	0.088	0.035	0.076	0.180	0.55	0.33	0.70
5299S0071	**8.74**	0.85	0.52	**1.79**	0.12	0.09	**1.83**	0.19	0.16	0.09	0.11	0.27	**1.97**	0.62	0.99
5299S0072	**6.92**	0.77	0.61	**2.77**	0.18	0.10	**0.82**	0.14	0.20	0.13	0.11	0.25	**1.94**	0.64	1.05
5299S0079	**10.06**	0.97	0.70	**4.36**	0.26	0.10	**1.23**	0.16	0.22	0.27	0.14	0.31	**2.74**	0.75	0.99
5299S0080	**10.72**	0.89	0.61	**4.29**	0.25	0.10	**1.45**	0.16	0.17	0.19	0.13	0.30	**2.41**	0.94	1.77
5299S0081	**12.6**	1.2	0.6	**2.24**	0.16	0.10	**1.07**	0.16	0.21	0.10	0.11	0.25	**2.09**	0.66	1.04
5299S0082	**18.3**	1.5	0.7	**2.51**	0.16	0.09	**0.81**	0.13	0.18	0.12	0.12	0.27	**2.5**	1.1	2.1

[a] Ra-226 by Pb-214 values are estimated due to non-equilibrium state before counting.

[b] Uncertainties are based on total propagated uncertainties reported at the 95% confidence level.

[c] MDC = minimum detectable concentration.

[d] Results greater than MDC are bolded.

Table B.6. ROC Sample Concentrations from Class 2 CU																
Sample ID	Co-60 (pCi/g)			Sr-90 (pCi/g)			Cs-137 (pCi/g)			Eu-152 (pCi/g)			Eu-154 (pCi/g)			SOF
	Conc.	TPU[a]	MDC[b]	Conc.	TPU	MDC	Conc.	TPU	MDC	Conc.	TPU	MDC	Conc.	TPU	MDC	
Random Samples																
5299S0060	0.000	0.013	0.032	--	--	--	0.020	0.009	0.027	-0.004	0.032	0.071	-0.087	0.069	0.145	0.001
5299S0061	0.013	0.012	0.031	--	--	--	0.003	0.010	0.015	0.000	0.030	0.072	-0.037	0.038	0.105	0.004
5299S0062	0.002	0.022	0.048	--	--	--	**0.125**[c]	0.026	0.041	0.023	0.038	0.107	-0.081	0.078	0.189	0.010
5299S0063	-0.004	0.013	0.025	--	--	--	**0.049**	0.011	0.022	0.003	0.026	0.063	-0.020	0.036	0.103	0.003
5299S0064	-0.008	0.018	0.035	--	--	--	**0.041**	0.016	0.032	-0.022	0.036	0.076	-0.042	0.051	0.143	0.002
5299S0065	-0.007	0.019	0.037	--	--	--	**0.076**	0.015	0.029	-0.027	0.039	0.089	-0.153	0.071	0.150	0.004
5299S0066	0.002	0.006	0.014	--	--	--	0.005	0.011	0.026	0.011	0.029	0.070	-0.046	0.055	0.110	0.002
5299S0067	0.004	0.019	0.042	--	--	--	**0.053**	0.020	0.039	-0.017	0.041	0.101	-0.072	0.086	0.203	0.004
5299S0068	0.008	0.019	0.042	--	--	--	**0.044**	0.014	0.025	-0.012	0.031	0.069	-0.093	0.073	0.144	0.005
5299S0069	0.005	0.011	0.024	--	--	--	0.008	0.009	0.020	-0.016	0.024	0.055	-0.054	0.050	0.108	0.002
Judgmental Samples																
5299S0041	0.013	0.019	0.044	--	--	--	0.015	0.014	0.044	0.001	0.045	0.101	-0.102	0.076	0.181	0.004
5299S0048	-0.005	0.012	0.031	--	--	--	0.025	0.009	0.026	-0.021	0.035	0.075	-0.090	0.062	0.144	0.001
5299S0049	-0.001	0.011	0.044	--	--	--	**0.084**	0.017	0.034	-0.031	0.044	0.100	-0.137	0.081	0.173	0.005
5299S0076	-0.000	0.017	0.036	--	--	--	0.019	0.009	0.028	-0.011	0.022	0.094	-0.059	0.056	0.152	0.001
5299S0077	-0.003	0.022	0.045	--	--	--	-0.008	0.017	0.047	-0.036	0.051	0.109	-0.052	0.077	0.211	0.000
5299S0078	-0.004	0.008	0.047	0.08	0.17	0.29	**0.466**	0.046	0.029	0.033	0.035	0.087	-0.020	0.038	0.124	0.031

[a] Uncertainties are based on total propagated uncertainties reported at the 95% confidence level.
[b] MDC = minimum detectable concentration.
[c] Results greater than MDC are bolded.

Table B.7. NORM Sample Concentrations from Class 2 CU															
Sample ID	**K-40 (pCi/g)**			**Ra-226 by Pb-214 (pCi/g)[a]**			**Th-232 by Ac-228(pCi/g)**			**U-235 (pCi/g)**			**U-238 by Th-234(pCi/g)**		
	Conc.	**TPU[b]**	**MDC[c]**	**Conc.**	**TPU**	**MDC**	**Conc.**	**TPU**	**MDC**	**Conc.**	**TPU**	**MDC**	**Conc.**	**TPU**	**MDC**
Random Samples															
5299S0060	**6.93[d]**	0.70	0.34	**0.204**	0.032	0.048	**0.266**	0.072	0.125	-0.009	0.060	0.140	0.41	0.22	0.44
5299S0061	**4.34**	0.50	0.49	**0.272**	0.038	0.053	**0.104**	0.049	0.097	0.089	0.081	0.197	0.70	0.45	0.95
5299S0062	**12.2**	1.1	0.5	**0.582**	0.062	0.068	**0.68**	0.12	0.15	0.147	0.093	0.229	**0.76**	0.34	0.66
5299S0063	**6.55**	0.59	0.39	**0.250**	0.033	0.047	**0.153**	0.047	0.085	-0.017	0.071	0.164	0.41	0.34	0.76
5299S0064	**7.34**	0.72	0.32	**0.306**	0.040	0.054	**0.338**	0.074	0.113	0.027	0.068	0.161	0.22	0.24	0.56
5299S0065	**13.3**	1.1	0.5	**0.700**	0.062	0.067	**0.78**	0.11	0.12	0.06	0.11	0.25	0.82	0.55	1.20
5299S0066	**3.35**	0.39	0.48	**0.265**	0.033	0.048	**0.138**	0.046	0.089	-0.029	0.073	0.168	0.11	0.31	0.73
5299S0067	**10.38**	0.99	0.38	**0.567**	0.059	0.062	**0.53**	0.10	0.15	-0.003	0.088	0.205	0.50	0.30	0.64
5299S0068	**6.83**	0.68	0.33	**0.338**	0.040	0.047	**0.310**	0.067	0.097	-0.007	0.064	0.150	0.34	0.23	0.50
5299S0069	**6.19**	0.56	0.37	**0.148**	0.026	0.042	**0.230**	0.052	0.083	-0.023	0.068	0.158	0.33	0.31	0.71
Judgmental Samples															
5299S0041	**6.50**	0.66	0.40	**1.179**	0.087	0.066	**0.525**	0.094	0.140	0.075	0.067	0.156	**1.12**	0.35	0.54
5299S0048	**8.18**	0.75	0.33	**0.433**	0.043	0.048	**0.427**	0.075	0.106	0.005	0.053	0.128	**0.48**	0.22	0.45
5299S0049	**14.1**	1.1	0.6	**0.773**	0.067	0.071	**0.89**	0.11	0.15	0.01	0.12	0.27	0.70	0.56	1.27
5299S0076	**9.73**	0.80	0.55	**0.678**	0.060	0.066	**0.573**	0.087	0.122	0.070	0.075	0.176	0.60	0.49	1.11
5299S0077	**7.39**	0.76	0.52	**1.52**	0.11	0.07	**0.68**	0.11	0.16	0.10	0.11	0.26	**1.65**	0.50	0.76
5299S0078	**10.99**	0.90	0.47	**0.371**	0.044	0.062	**0.463**	0.081	0.112	-0.063	0.096	0.221	0.30	0.49	1.16

[a] Ra-226 by Pb-214 values are estimated due to non-equilibrium state before counting.
[b] Uncertainties are based on total propagated uncertainties reported at the 95% confidence level.
[c] MDC = minimum detectable concentration.
[d] Results greater than MDC are bolded.

Table B.8. ROC Sample Concentrations from Class 3 CU																
Sample ID	Co-60 (pCi/g)			Sr-90 (pCi/g)			Cs-137 (pCi/g)			Eu-152 (pCi/g)			Eu-154 (pCi/g)			SOF
	Conc.	TPU[a]	MDC[b]	Conc.	TPU	MDC	Conc.	TPU	MDC	Conc.	TPU	MDC	Conc.	TPU	MDC	
Random Samples																
5299S0050	-0.005	0.020	0.040	0.03	0.15	0.27	-0.001	0.017	0.042	-0.003	0.042	0.093	-0.046	0.059	0.185	0.000
5299S0051	-0.002	0.019	0.039	--	--	--	**0.037**[c]	0.011	0.034	-0.036	0.040	0.090	-0.085	0.077	0.170	0.002
5299S0052	0.027	0.021	0.051	--	--	--	**0.125**	0.026	0.046	0.014	0.049	0.118	-0.010	0.072	0.201	0.016
5299S0053	0.002	0.013	0.029	--	--	--	0.004	0.005	0.016	-0.005	0.028	0.066	-0.018	0.044	0.107	0.001
5299S0054	-0.010	0.020	0.038	--	--	--	**0.054**	0.013	0.030	0.005	0.040	0.094	0.009	0.049	0.157	0.005
5299S0055	0.007	0.016	0.036	--	--	--	**0.101**	0.019	0.029	0.021	0.033	0.077	-0.028	0.045	0.143	0.010
5299S0056	-0.002	0.014	0.029	0.07	0.16	0.28	**0.360**	0.040	0.026	-0.019	0.034	0.078	-0.029	0.051	0.123	0.021
5299S0057	0.022	0.015	0.041	--	--	--	0.005	0.014	0.032	0.000	0.033	0.074	-0.027	0.039	0.128	0.006
5299S0058	0.006	0.010	0.024	--	--	--	0.000	0.009	0.023	-0.009	0.024	0.057	-0.029	0.040	0.100	0.001
5299S0059	0.006	0.014	0.031	--	--	--	0.024	0.013	0.028	0.005	0.030	0.068	-0.035	0.058	0.114	0.004
Judgmental Samples																
5299S0042	-0.011	0.024	0.047	--	--	--	-0.007	0.013	0.051	-0.038	0.051	0.111	-0.017	0.041	0.218	0.000
5299S0043	0.013	0.017	0.038	-0.03	0.18	0.33	-0.020	0.016	0.038	-0.009	0.046	0.107	-0.065	0.065	0.169	0.003
5299S0044	0.006	0.028	0.059	--	--	--	-0.006	0.012	0.061	-0.015	0.067	0.147	-0.046	0.096	0.270	0.002
5299S0045[d]	-0.025	0.029	0.054	--	--	--	-0.008	0.019	0.052	-0.056	0.065	0.147	-0.115	0.071	0.232	--
5299S0070	0.002	0.019	0.039	--	--	--	0.002	0.013	0.043	-0.004	0.043	0.095	-0.011	0.056	0.176	0.001
5299S0073	0.009	0.017	0.037	--	--	--	0.024	0.010	0.033	-0.033	0.040	0.100	-0.063	0.060	0.160	0.004
5299S0074	-0.009	0.029	0.058	--	--	--	-0.004	0.020	0.058	-0.065	0.071	0.151	-0.22	0.11	0.24	0.000
5299S0075	0.000	0.024	0.049	--	--	--	0.000	0.018	0.047	-0.011	0.056	0.130	-0.045	0.051	0.193	0.000
5299S0083	-0.010	0.028	0.057	--	--	--	-0.002	0.030	0.063	-0.027	0.065	0.141	-0.18	0.10	0.27	0.000

[a] Uncertainties are based on total propagated uncertainties reported at the 95% confidence level.
[b] MDC = minimum detectable concentration.
[c] Results greater than MDC are bolded.
[d] Sample collected from a 15- to 30-cm depth.

Table B.9. NORM Sample Concentrations from Class 3 CU															
Sample ID	K-40 (pCi/g)			Ra-226 by Pb-214 (pCi/g)[a]			Th-232 by Ac-228(pCi/g)			U-235 (pCi/g)			U-238 by Th-234(pCi/g)		
	Conc.	TPU[b]	MDC[c]	Conc.	TPU	MDC	Conc.	TPU	MDC	Conc.	TPU	MDC	Conc.	TPU	MDC
Random Samples															
5299S0050	**10.5**[d]	1.0	0.4	**0.395**	0.050	0.062	**0.404**	0.090	0.133	0.034	0.082	0.195	0.52	0.40	0.89
5299S0051	**13.2**	1.1	0.5	**0.633**	0.061	0.069	**0.80**	0.11	0.13	0.05	0.11	0.27	1.12	0.65	1.37
5299S0052	**18.6**	1.5	0.6	**0.694**	0.069	0.085	**0.94**	0.14	0.17	-0.01	0.11	0.26	0.80	0.74	1.67
5299S0053	**6.70**	0.61	0.41	**0.301**	0.036	0.046	**0.337**	0.062	0.080	0.008	0.064	0.155	-0.06	0.38	0.77
5299S0054	**11.07**	0.93	0.49	**0.659**	0.061	0.067	**0.65**	0.10	0.13	0.020	0.080	0.193	0.71	0.56	1.24
5299S0055	**7.08**	0.68	0.31	**0.328**	0.039	0.052	**0.284**	0.074	0.135	0.006	0.062	0.144	**0.46**	0.22	0.44
5299S0056	**7.05**	0.63	0.51	**0.309**	0.039	0.058	**0.200**	0.049	0.107	0.076	0.085	0.203	0.18	0.34	0.80
5299S0057	**5.94**	0.65	0.37	**0.275**	0.038	0.047	**0.179**	0.060	0.104	-0.010	0.061	0.143	0.37	0.21	0.43
5299S0058	**5.25**	0.50	0.37	**0.269**	0.033	0.043	**0.118**	0.041	0.075	-0.008	0.070	0.163	0.39	0.40	1.00
5299S0059	**2.58**	0.35	0.34	**0.329**	0.037	0.041	**0.120**	0.039	0.089	0.039	0.042	0.099	0.25	0.16	0.35
Judgmental Samples															
5299S0042	**7.71**	0.73	0.46	**2.22**	0.14	0.07	**0.76**	0.11	0.17	0.111	0.088	0.205	**1.50**	0.43	0.60
5299S0043	**8.35**	0.71	0.55	**2.21**	0.14	0.08	**1.12**	0.12	0.13	0.057	0.096	0.229	**1.76**	0.66	1.20
5299S0044	**9.51**	0.87	0.57	**3.76**	0.22	0.09	**1.42**	0.16	0.18	0.19	0.10	0.24	**3.18**	0.78	0.77
5299S0045	**11.91**	0.95	0.66	**5.10**	0.30	0.11	**2.07**	0.19	0.18	0.27	0.14	0.32	**3.5**	1.1	1.6
5299S0070	**8.30**	0.76	0.38	**1.417**	0.096	0.058	**0.695**	0.098	0.128	0.162	0.088	0.213	**1.17**	0.37	0.59
5299S0073	**9.54**	0.80	0.48	**1.414**	0.098	0.072	**1.27**	0.14	0.13	0.124	0.095	0.222	1.07	0.63	1.35
5299S0074	**10.01**	0.93	0.58	**3.35**	0.21	0.10	**1.28**	0.16	0.22	0.18	0.12	0.29	**2.73**	0.73	0.91
5299S0075	**10.66**	0.88	0.54	**3.84**	0.22	0.09	**1.43**	0.14	0.16	0.23	0.12	0.28	**2.43**	0.91	1.68
5299S0083	**9.99**	0.96	0.54	**1.66**	0.12	0.09	**1.89**	0.20	0.16	0.05	0.11	0.27	**1.54**	0.57	1.05

[a] Ra-226 by Pb-214 values are estimated due to non-equilibrium state before counting.
[b] Uncertainties are based on total propagated uncertainties reported at the 95% confidence level.
[c] MDC = minimum detectable concentration.
[d] Results greater than MDC are bolded.

Table B.10. H-3 and Ni-63 Sample Concentrations								
Sample ID	Area	Sample Type	H-3 (pCi/g)			Ni-63 (pCi/g)		
			Conc.	TPU[a]	MDC[b]	Conc.	TPU	MDC
5299S0038	Class 1 CU	Judgmental	0.3	1.4	2.4	0.99	0.81	1.35
5299S0040[c]	Class 1 CU	Judgmental	-0.7	1.3	2.3	1.15	0.82	1.35
5299S0047	Class 1 CU	Judgmental	-0.1	1.4	2.5	1.22	0.82	1.35
5299S0079	Class 1 CU	Judgmental	0.0	1.6	2.7	0.84	0.74	1.23
5299S0082	Class 1 CU	Judgmental	0.6	2.0	3.4	0.36	0.80	1.36
5299S0078[c]	Class 2 CU	Judgmental	0.5	1.1	1.9	1.26	0.85	1.40
5299S0050	Class 3 CU	Random	-0.3	1.7	2.9	0.17	0.71	1.23
5299S0056[c]	Class 3 CU	Random	-0.1	1.4	2.4	1.13	0.81	1.34
5299S0043	Class 3 CU	Judgmental	-0.8	1.5	2.6	1.05	0.79	1.31

[a] Uncertainties are based on total propagated uncertainties reported at the 95% confidence level.

[b] MDC = minimum detectable concentration.

[c] Samples selected based on gamma spectroscopy results. Other samples randomly selected for analysis.

APPENDIX C: MAJOR INSTRUMENTATION

C.1. SCANNING AND MEASUREMENT INSTRUMENT/ DETECTOR COMBINATIONS

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.1.1 GAMMA

Ludlum NaI(Tl) Scintillation Detector Model 44-10, Crystal: 5.1 cm × 5.1 cm
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to: Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to: Trimble Geo 7X
(Trimble Navigation Limited, Sunnyvale, CA)

C.2. LABORATORY ANALYTICAL INSTRUMENTATION

Low-Background Gas Proportional Counter
Series 5 XLB
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Eclipse Software
Dell Workstation
(Canberra, Meriden, Connecticut)

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

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. GMX-45200-5
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation

(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. GMX-30P4
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation
(Canberra, Meriden, Connecticut)

High-Purity, Intrinsic Detector
EG&G ORTEC Model No. CDG-SV-76/GEM-MX5970-S
Canberra Lynx ® Multichannel Analyzer
Canberra Gamma-Apex Software
(Canberra, Meriden, Connecticut)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, Tennessee) and
Dell Workstation
(Canberra, Meriden, Connecticut)

Liquid Scintillation Counter
Perkin Elmer Tricarb 5110TR
(Perkin Elmer, Waltham, Massachusetts)

APPENDIX D: SURVEY AND ANALYTICAL PROCEDURES

D.1. PROJECT HEALTH AND SAFETY

ORISE performed all survey activities in accordance with the *ORAU Radiation Protection Manual*, the *ORAU Radiological and Environmental Survey Procedures Manual,* and the *ORAU Health and Safety Manual* (ORAU 2014, ORAU 2016a, and ORAU 2016b). Prior to on-site activities, a Work-Specific Hazard Checklist was completed for the project and discussed with field personnel. The planned activities were discussed thoroughly with site personnel prior to implementation to identify hazards present. Additionally, prior to performing work, a pre-job briefing and walk down of the survey areas were completed with field personnel to identify hazards present and discuss safety concerns. Should ORISE have identified a hazard not covered in the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2016a) or the project's Work-Specific Hazard Checklist for the planned survey and sampling procedures, work would not have been initiated or continued until the hazard was addressed by an appropriate job hazard analysis and hazard controls.

D.2. CALIBRATION AND QUALITY ASSURANCE

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

Field survey activities were conducted in accordance with procedures from the following documents:

- ORAU *Radiological and Environmental Survey Procedures Manual* (ORAU 2016a)
- ORAU *Environmental Services and Radiation Training Quality Program Manual* (ORAU 2019a)
- ORAU *Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2019b)

The procedures contained in these manuals were developed to meet the requirements of U.S. Department of Energy (DOE) Order 414.1D and the U.S. Nuclear Regulatory Commission (NRC) *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 the DOE Mixed-Analyte Performance Evaluation Program and the NRC Intercomparison Testing Program laboratory quality assurance programs
- Training and certification of all individuals performing procedures
- Periodic internal and external audits

D.3. SURVEY PROCEDURES

D.3.1 SURFACE SCANS

Gamma scans were performed using a hand-held thallium-doped sodium iodide (NaI[Tl]) scintillation detector with a 2-inch by 2-inch crystal. Scans for elevated gamma radiation were performed by passing the detector slowly over the surface. The NaI(Tl) detectors were used solely as a qualitative means to identify elevated radiation levels in excess of local background. Identifications of elevated radiation levels that could exceed the background were determined based on an increase in the audible signal from the indicating instrument and/or were identified after initial examination of the scan data while the team was still at the site.

D.3.2 SOIL SAMPLING

Soil samples (approximately 0.5 kilogram each) were collected by ORISE personnel using a clean garden trowel to transfer soil into a new sample container. The container was then labeled and security sealed in accordance with ORISE procedures. ORISE shipped samples under chain-of-custody to the ORISE laboratory for analysis.

D.4. RADIOLOGICAL ANALYSIS

D.4.1 GAMMA SPECTROSCOPY

Samples were analyzed as received and mixed, crushed, and/or homogenized, as necessary, and a portion sealed in a size appropriate Marinelli beaker. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined, and the samples were counted using intrinsic, high-purity, germanium detectors coupled to a pulse-height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using computer capabilities inherent in the analyzer system. All total absorption peaks (TAPs) associated with the radionuclides of concern (ROC) were reviewed for consistency of activity. Spectra also were reviewed for other identifiable TAPs. TAPs used for determining the activities of ROCs and the typical associated minimum detectable concentrations (MDCs) for a 1-hour count time were:

Table D.1. Typical MDCs and TAPs for ROCs		
ROC	**TAP (MeV)**	**MDC (pCi/g)**
Co-60	1.332	0.06
Cs-137	0.662	0.05
Eu-152	0.344	0.10
Eu-154	0.723	0.15

D.4.2 Sr-90 Analysis

Strontium-90 (Sr-90) concentrations were quantified by total sample dissolution followed by radiochemical separation and counted on a low background gas proportional counter.

Samples were homogenized and dissolved by a combination of potassium hydrogen fluoride and pyrosulfate fusions. The fusion cakes were dissolved, and strontium was coprecipitated on lead sulfate. The strontium was separated from residual calcium and lead by reprecipitating strontium sulfate from Ethylenediaminetetraacetic acid (EDTA) at a pH of 4.0. Strontium was separated from barium by complexing the strontium in Diethylenetriaminepentaacetic acid (DTPA) while precipitating barium as barium chromate. The strontium ultimately was converted to strontium carbonate and counted on a low-background gas proportional counter. The typical MDC for a 1 gram sample and a 60-minute count time was 0.3 picocurie per gram (pCi/g).

D.4.3 H-3 Analysis

Tritium (H-3) analysis for the soil samples was performed using a material oxidizer and counted by liquid scintillation. The material oxidizer combusts samples in a stream of oxygen gas and passes the products, including H-3 as water vapor through a series of catalysts. The H-3 is then captured by a trapping scintillation cocktail specific to water. The typical MDC for a 60-minute count time using this procedure is approximately 3.5 pCi/g, depending on sample quantity.

D.4.4 Ni-63 Analysis

Nickel-63 (Ni-63) in environmental samples was precipitated as a nickel/dimethylglyoxime precipitate on an extraction chromatographic resin. Iron was removed from soil samples prior to the nickel separation using anion exchange chromatography. Samples that contain sufficient amounts of radioactive cobalt were processed through an anion exchange column prior to passing the samples through the nickel resin. Other potential interfering elements were removed from the nickel cartridge with a buffered ammonium citrate solution. Nickel was eluted off the column with dilute nitric acid. The Ni-63 activity was determined via liquid scintillation counting. The typical MDC is approximately 1.3 pCi/g for a 1 gram soil sample using a 60-minute count.

D.4.5 Detection Limits

Detection limits, referred to as MDCs, were based on a 95% confidence level. 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.