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August 31, 2015

Mr. John Hickman
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Decommissioning, Uranium Recovery, and Waste Programs
Reactor Decommissioning Branch
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SUBJECT: FINAL REPORT—INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE CRIB HOUSE AND NON-IMPACTED OPEN LAND AREAS AT THE ZION NUCLEAR POWER STATION, ZION, ILLINOIS (RFTA NO. 15-005); DCN 5271-SR-01-0

Dear Mr. Hickman:

ORAU is pleased to provide the enclosed final report detailing the independent confirmatory survey activities of the Crib House and the non-impacted open land areas at the Zion Nuclear Power Station in Zion, Illinois. This report provides the summary and results of activities performed by ORAU, under the Oak Ridge Institute for Science and Education (ORISE) contract, during the period of July 6–9, 2015.

You may contact me at 865.576.6659 or Tim Vitkus at 865.576.5073 if you have any questions.

Sincerely,

Erika Bailey

Erika N. Bailey
Survey Projects Manager, Health Physicist
ORAU

ENB:EMH:fs

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE CRIB HOUSE AND NON-IMPACTED OPEN LAND AREAS AT THE ZION NUCLEAR POWER STATION, ZION, ILLINOIS

FINAL REPORT

Prepared by
Erika N. Bailey

AUGUST 2015

Prepared for the
U.S. Nuclear Regulatory Commission

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

ORAU

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE CRIB HOUSE AND NON-IMPACTED OPEN LAND AREAS AT THE ZION NUCLEAR POWER STATION, ZION, ILLINOIS

1. INTRODUCTION

The Zion Nuclear Power Station (ZNPS) was operated by Exelon Generation Company (Exelon) and is currently being decommissioned by a division of Energy*Solutions* called Zion*Solutions*, LLC (ZS). The ZNPS operated commercially from 1973 to 1997. Cessation of nuclear operations was certified in 1998 after both reactor units had been defueled and the fuel assemblies had been placed in the spent fuel pools. Both units were then placed in a SAFSTOR condition until final decommissioning and dismantlement began in 2010. At that time, the U.S. Nuclear Regulatory Commission (NRC) operating license was transferred from Exelon to the decommissioning company, ZS. Decommissioning activities are expected to be completed by 2020. Upon successful completion of decommissioning activities, control and responsibility for the site will be transferred back to Exelon (EC 2015).

The NRC is responsible for oversight of permitted license activities that are currently being conducted at the ZNPS. The NRC requested that ORAU, under the Oak Ridge Institute for Science and Education (ORISE) contract, perform confirmatory surveys of the remaining portions of the Crib House and assess the radiological status of the non-impacted open land areas.

2. SITE DESCRIPTION

The ZNPS is located in Lake County, Illinois on the easternmost portion of the city of Zion. It is approximately 40 miles north of Chicago, Illinois and 42 miles south of Milwaukee, Wisconsin (Figure A-1). The overall site is comprised of approximately 200 acres and is situated between the northern and southern parts of Illinois Beach State Park on the western shore of Lake Michigan (EC 2015 and ZS 2014).

While ZNPS was operational, the Crib House contained the pump housings for six circulatory pumps that provided cooling water, drawn from Lake Michigan, to Turbine Building heat exchangers and condensers, as well as sumps and sump system components. The majority of the Crib House has already undergone dismantlement. The remaining portion of the Crib House

consists of the below-grade structure (i.e., basement) which spans between 588 feet and 532 feet above sea level. Historical contamination was not identified in the remaining structures and based upon use and the historical results, ZS designated the sub-grade structures as Class 3 for final status survey.

A large majority of the site footprint is comprised of open land areas that have been classified as non-impacted. Most of the non-impacted land area survey units are located to the west of Radiologically Restricted Area (RRA) fence, although there are small areas north and southwest of the fence. Lake Michigan forms the eastern boundary to the RRA fence. Figure 2.1 shows the non-impacted land area survey units as green-shaded areas.

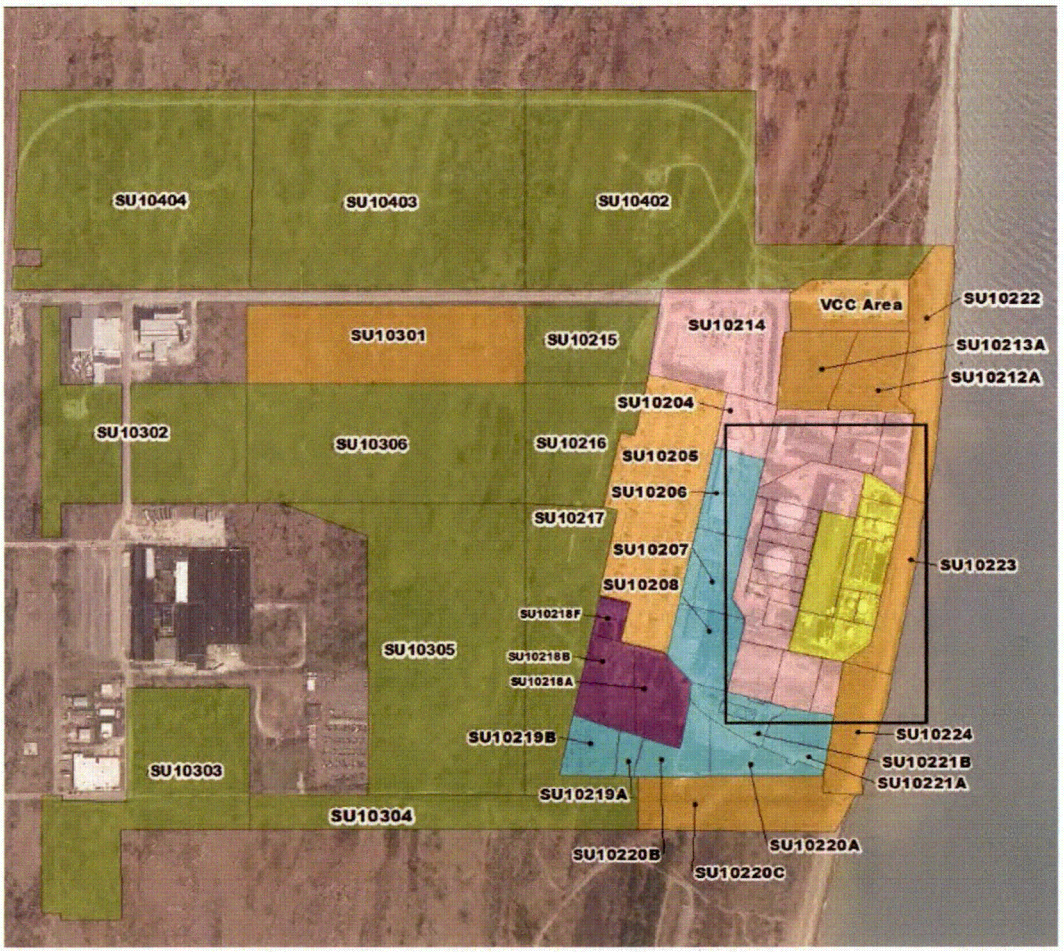

Figure 2.1. ZNPS Land Area Survey Units

3. OBJECTIVES

The objectives of the confirmatory survey activities were to provide independent contractor field data reviews and to generate independent radiological data for use by the NRC in evaluating the accuracy and adequacy of the licensee's procedures and results.

4. APPLICABLE SITE GUIDELINES

The primary radionuclides of concern (ROCs) at the ZNPS are beta-gamma emitters—fission and activation products—resulting from reactor operation. Licensee documentation states that five specific ROCs accounted for 99.5% of the total activity at ZNPS (ZS 2015). Specific building surface activity guidelines are not applicable for the Crib House because the above-grade structure has been demolished and the debris will not remain on site. Instead, the remaining building surfaces were evaluated based on maximum inventory levels per square meter area that corresponded to a total dose of 25 millirem per year (mrem/year). Table 4.1 provides the per square meter maximum inventories for each of the five ROCs.

Table 4.1. Crib House Inventory Levels

ROC	Inventory Limit (pCi/m^2)
Co-60	9.28E+07
Cs-134	3.58E+07
Cs-137	4.95E+07
Ni-63	5.64E+09
Sr-90	1.94E+06

The volumetric soil and buried pipe derived concentration guideline levels ($DCGL_W$s) for impacted areas of the site are listed in Table 4.2. However, ORAU notes that these $DCGL_W$s are not applicable to survey units assigned a non-impacted designation—the focus of ORAU's confirmatory activities during this site visit. Any positive identification of site ROCs not expected to be present in background in a non-impacted area would require reclassification as impacted.

Table 4.2. Radionuclide Soil and Buried Pipe DCGLs[a]			
ROC	**Surface Soil (pCi/g)**	**Subsurface Soil (pCi/g)**	**Buried Pipe (dpm/100 cm^2)**
Co-60	4.7	3.8	3.60E+04
Cs-134	7.5	4.9	6.33E+04
Cs-137	15.7	8.5	1.50E+05
Ni-63	3988	847	1.31E+08
Sr-90	14.3	1.8	3.49E+05

[a]From Chapter 5 in the license termination plan (ZS 2014b)

Each radionuclide-specific $DCGL_W$ represents the concentration above background of a residual radionuclide that would result in a radiological dose of 25 mrem/yr to the average member of the critical group. Because each individual $DCGL_W$ represents 25 mrem/yr, the sum-of-the-fractions (SOF) approach is used to demonstrate compliance with the dose limit for impacted areas of the site. SOF calculations are performed as follows:

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

Where C_j is the concentration of COC "j," and $DCGL_{W,j}$ is the $DCGL_W$ for COC "j." Note that gross concentrations are considered here for conservatism. The analytical results presented in Tables B-2 and B-3 were evaluated and compared to the applicable $DCGL_W$s presented in Table 4.2. SOF calculations are not applicable to samples from the non-impacted areas of the site and due to the extremely low radionuclide concentrations in the samples from impacted areas and only a few values being above the analytical minimum detectable concentrations (MDCs), ORAU did not perform SOF calculations.

5. PROCEDURES

The confirmatory survey activities were conducted during the period of July 6–9, 2015, in accordance with the project-specific confirmatory survey plan, the *ORAU Radiological and Environmental Survey Procedure Manual* and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2015a, 2015b, and 2015c).

5.1 SURFACE SCANS

ORAU performed high-density gamma radiation scans of the accessible lower surfaces inside the Crib House. Five random locations were also selected for high-density beta scans where ZS had performed *in situ* gamma spectroscopy measurements on remaining structural surfaces of the Crib House. Beta scans were performed using Ludlum Model 44-142 plastic scintillation detectors and gamma scans using Ludlum Model 44-10 sodium iodide (NaI) detectors coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. Gamma scans were also performed on accessible exterior portions of the roof of the Crib House where the gamma detector/ratemeter pairs were coupled to global positioning systems (GPS) that enabled real-time gamma count rate and spatial data capture (Figure A-2).

In addition to randomly selected locations for the non-impacted open land areas, gamma radiation surface scans were also planned for low-lying regions, accumulation points, high-traffic pathways, and drainage paths. However, many of these areas were impacted by standing water during the time of the confirmatory survey which prevented ORAU personnel from collecting useful scan data. Therefore, ORAU only performed scans in the vicinity of seven randomly selected locations. Figures A-3 through A-9 present the gamma walkover survey data for the open land areas as well as the surface soil sample locations from each area.

5.2 DIRECT SURFACE ACTIVITY MEASUREMENTS

Qualitative and quantitative surface activity measurements were collected from within the Crib House to assess residual activity levels within each of the five randomly selected ZS *in situ* gamma spectroscopy measurement locations. The ZS *in situ* measurements were made such that the detector field-of-view (FOV) covered an area of 28 m^2. The five randomly selected locations corresponded to the ZS location IDs of RWC-004-1, RWC-009-1, RWC-003-1, RWC-014-1, and RWC-005-1. Since there were no elevated radiation levels of concern detected during scans, ORAU collected five evenly spaced beta direct measurements spanning the FOV for each selected *in situ* location with the exception of two floor measurement locations. In these two locations, the FOVs overlapped with the remaining water pump components and wall locations where ORAU was unable to collect the two measurements above three meters (scaffolding was not available). Figure 5.1 shows the

measurement/numbering format used to collect the direct measurements within the selected *in situ* measurement locations.

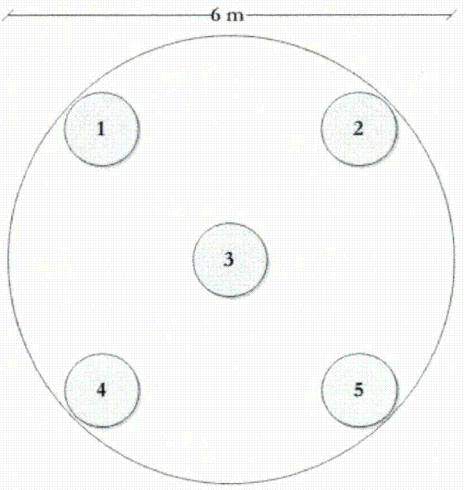

Figure 5.1. Beta Measurement and Concrete Sampling Illustration

5.3 MISCELLANEOUS MATERIAL AND SOIL SAMPLING

Concrete sampling followed the same approach described for direct surface activity measurements within the Crib House. An incremental concrete sample was collected from each of the five direct measurement locations (following the collection of the surface activity measurements) from each of the randomly selected ZS *in situ* measurement areas. The five increments associated with one *in situ* measurement location were packaged separately in the field and then homogenized and combined into one composite sample (using equal weights from each increment) at the Radiological and Environmental Analytical Laboratory (REAL) in Oak Ridge, Tennessee. In total, ORAU collected 25 increments which resulted in five composite samples from the Crib House.

In addition to concrete samples, the NRC requested that two judgmental samples be collected of the residual sediment materials observed inside the remaining pump components. The NRC and ORAU identified two pumps (1B and 2B) containing enough sediment material to be sampled.

Seven surface soil samples were collected from non-impacted open land area survey units, as presented in Figures A-3 through A-9. These locations were randomly generated using Visual Sample Plan (VSP) Version 7.4 software.

6. SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data collected on site were delivered to the ORAU/ORISE facility for analysis and interpretation. Sample custody was transferred to the REAL in Oak Ridge, Tennessee. Sample analyses were performed in accordance with the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2015d). Concrete and soil samples were analyzed by gamma spectroscopy for gamma-emitting ROCs and results were reported in units of picocuries per gram (pCi/g). Analyses for the remaining pure beta-emitting radionuclides (Ni-63 and Sr-90) were not performed at the NRC's request.

7. FINDINGS AND RESULTS

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

7.1 OBSERVATIONS

During survey activities within the Crib House, ORAU technicians noted that the maps for the *in situ* floor measurement locations they were provided did not correspond to the locations where ZS staff indicated they collected some of the *in situ* floor measurements. ORAU conveyed this information to the NRC to request that ZS resolve the discrepancy; however, at the issuance of this report ORAU has not been informed of a resolution. ORAU referenced measurement locations based on the *in situ* floor measurement location map initially provided.

7.2 SURFACE SCANS

The majority of the confirmatory gamma scan results exhibited radiation levels within the detector background range. For the non-impacted areas, elevated gamma radiation count rates were observed when approaching the Independent Spent Fuel Storage Installation (ISFSI) along the eastern edge of SU 10305 (Figure A-5) and near loaded railroad cars over the western berm of SU 10303

(Figure A-7). These increased count rates are expected and are not indicative of contamination. Scans did not identify any areas for further investigation.

7.3 SURFACE ACTIVITY MEASUREMENTS

The majority of the direct beta radiation activity results were consistent with typical background levels. Surface activity for the confirmatory measurement locations ranged from -300 to 2,200 dpm/100 cm^2. Three of the confirmatory measurement locations exhibited residual beta activity above the detector's MDC. The highest direct beta radiation activity for a confirmatory measurement was 2,200 dpm/100 cm^2 on the floor of the Crib House at ZS location ID RWC-004-1. Table B.1 provides a summary of the confirmatory measurement data for each location addressed during the survey.

7.4 RADIONUCLIDE CONCENTRATIONS IN MISCELLANEOUS MATERIAL AND SOIL

Analytical results for the Crib House and open land area samples are provided in Tables B-2 and B-3, respectively. All five composite concrete samples from the Crib House exhibited ROC concentrations below the respective analytical MDCs for Co-60, Cs-134, and Cs-137 (Table B-2). A few confirmatory sediment and soil samples exhibited ROC concentrations above the respective analytical MDCs for Co-60 and Cs-137 (Tables B.2 and B.3); however, the Co-60 and Cs-137 concentrations represent a small fraction of the respective $DCGL_W$s. Due to the extremely low radionuclide concentrations in the samples and only a few values being above the analytical MDCs, ORAU did not perform SOF calculations. For the non-impacted land area samples, only Cs-137 was present above the analytical MDC. Cs-137 is expected in low concentrations, therefore confirming the non-impacted designation.

9. SUMMARY

At the NRC's request, ORAU conducted confirmatory survey activities within the remaining portions of the Crib House and the non-impacted open land areas at the ZNPS during the period of July 6–9, 2015. The survey activities included visual inspections, gamma and beta radiation surface scans, gamma and beta radiation measurements, and soil and miscellaneous sampling.

The majority of gamma surface scans and total surface activity measurements were not distinguishable from background. The two sediment samples collected from the pumps within the Crib House contained radionuclide concentrations above analytical MDCs for both Co-60 and Cs-137, but all sample concentrations were well below the respective $DCGL_W$s. Six of the seven surface soil samples collected from the non-impacted land areas contained Cs-137 concentrations above the analytical MDCs but were also well below the Cs-137 $DCGL_W$; low concentrations of Cs-137 is expected in background samples.

The only potential documentation issue identified was the *in situ* floor measurement location discrepancy between the maps provided to ORAU and where ZS staff indicated the measurements were performed. However, based on the results of the confirmatory survey activities, ORAU is of the opinion that the Crib House and non-impacted open land areas satisfy the site criteria for release from radiological controls.

10. REFERENCES

EC 2015. *The Future of Zion.* Webpage: http://www.exeloncorp.com/PowerPlants/zion/Pages/aboutdecommissioning.aspx. Exelon Corporation. Chicago, Illinois. Accessed June 30.

ORAU/ORISE 2014. *Radiation Protection Manual.* Prepared by ORAU under the Oak Ridge Institute for Science and Education contract. Oak Ridge, Tennessee. October.

ORAU 2015a. *Project-Specific Plan for the Confirmatory Survey Activities at the Zion Nuclear Power Station, Crib House and Non-Impacted Open Land Areas, Zion Illinois.* 5271-PL-01-0. Oak Ridge Institute for Science and Education, managed by Oak Ridge Associated Universities. Oak Ridge, Tennessee. July 2.

ORAU 2015b. *ORAU Radiological and Environmental Survey Procedures Manual.* Oak Ridge Institute for Science and Education, managed and operated by ORAU. Oak Ridge, Tennessee. August 6.

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

ORAU 2015d. *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual.* Oak Ridge Institute for Science and Education, managed and operated by ORAU. Oak Ridge, Tennessee. May 7.

ORAU 2015e. *Health and Safety Manual.* ORAU. Oak Ridge, Tennessee. June.

ZS 2014. *Zion Station Restoration Project License Termination Plan: Chapter 2 Site Characterization, Rev. 0.* Zion*Solutions*, LLC. Chicago, Illinois. December 19.

ZS 2015. *STS Package Zion Crib House: STS Sample Plan B3-08101A-F.* Zion*Solutions*, LLC. Chicago, Illinois. June 25.

APPENDIX A
FIGURES

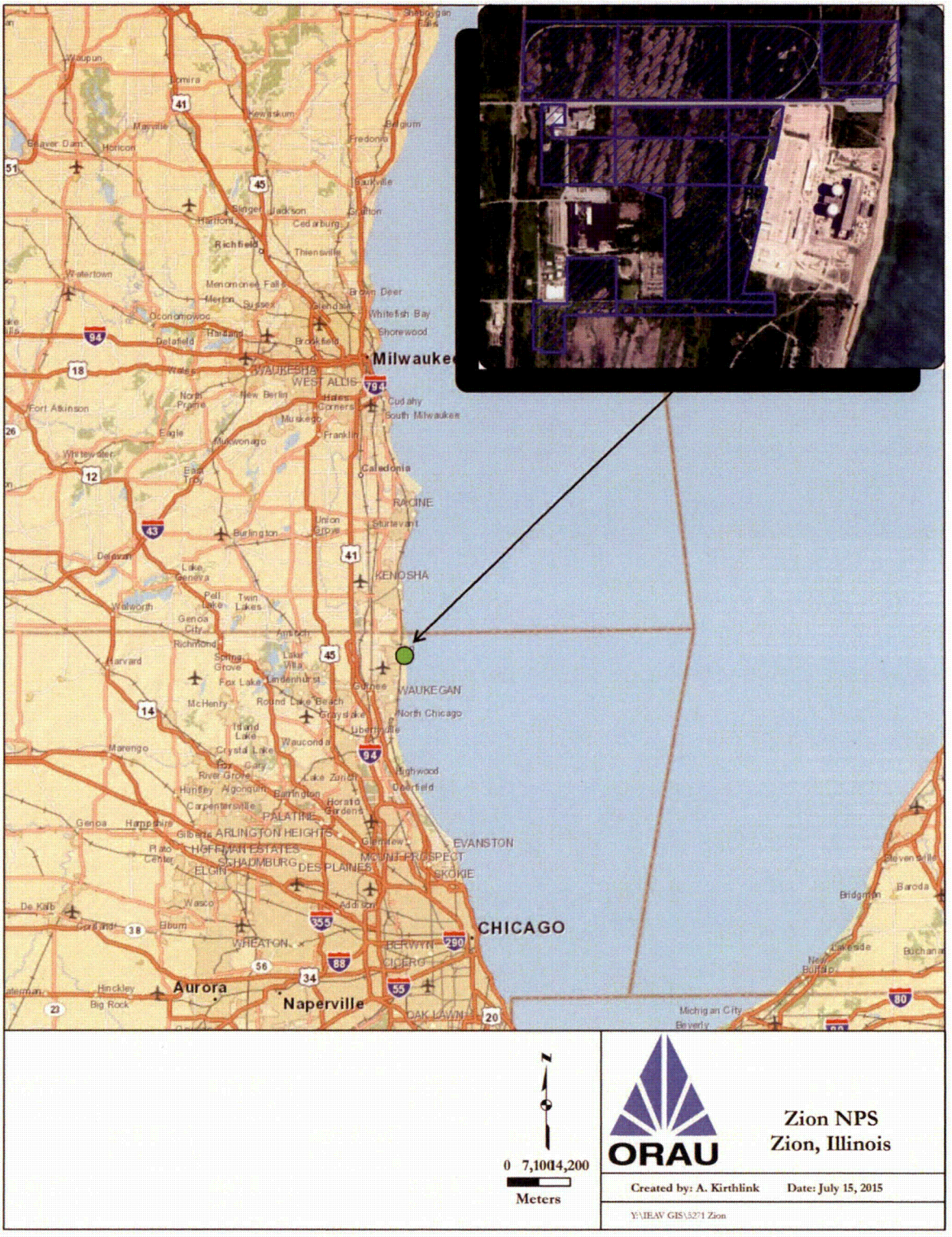

Figure A-1. Location of the Zion Nuclear Power Station, Zion, Illinois

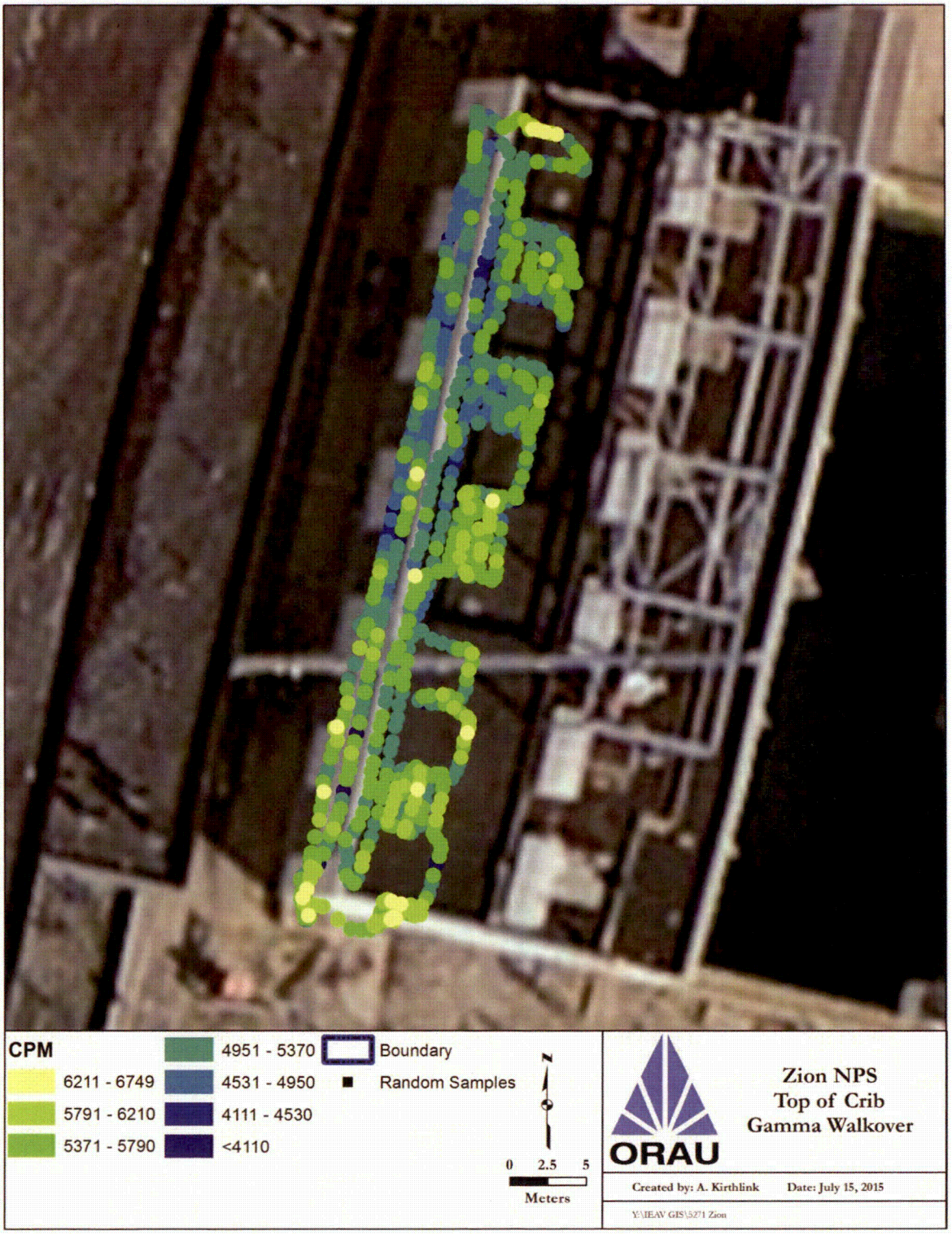

Figure A-2. Top of Crib House—Gamma Walkover Scan

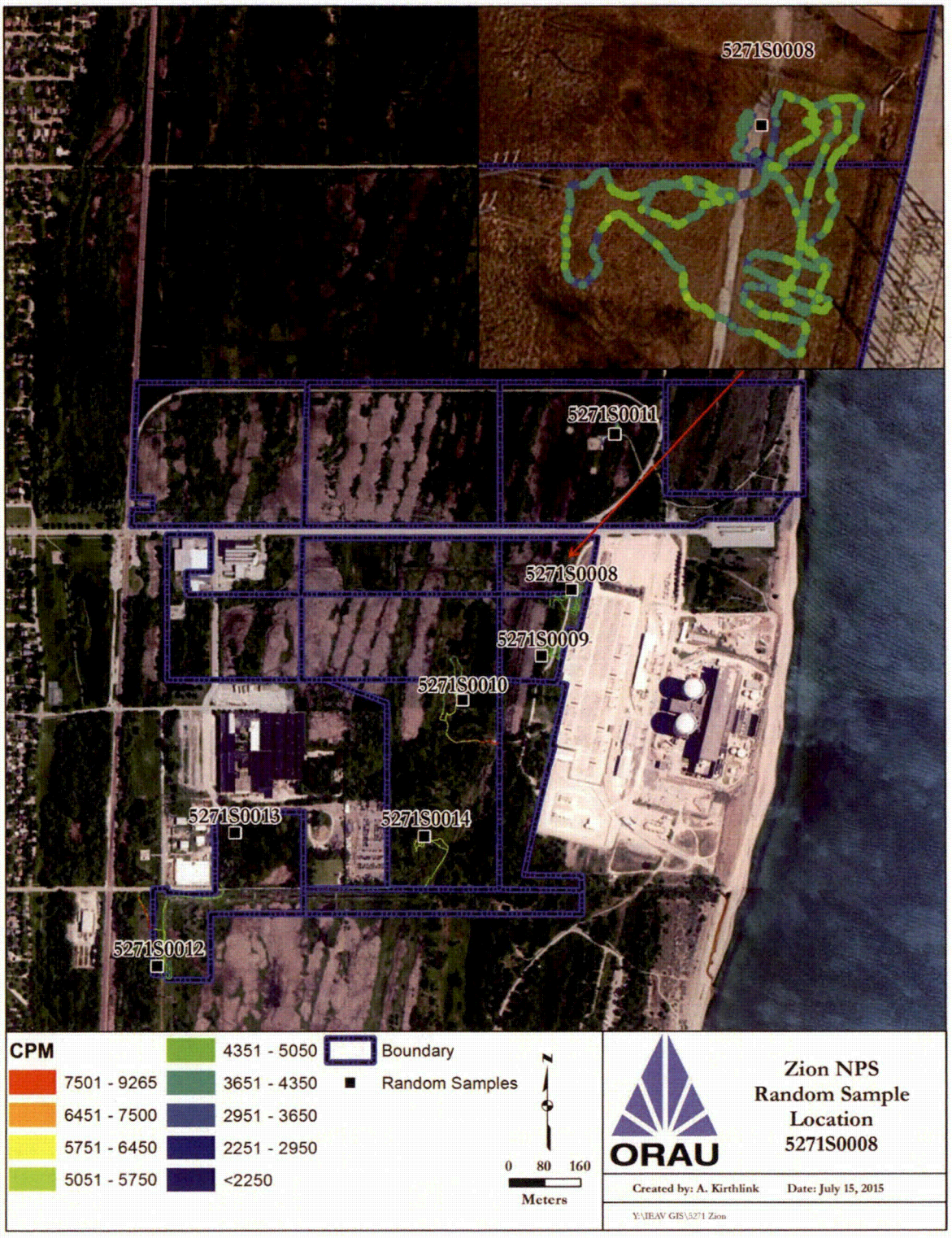

Figure A-3. Non-Impacted Land Area, SU10215—Gamma Walkover Scan and Sample Location 5271S0008

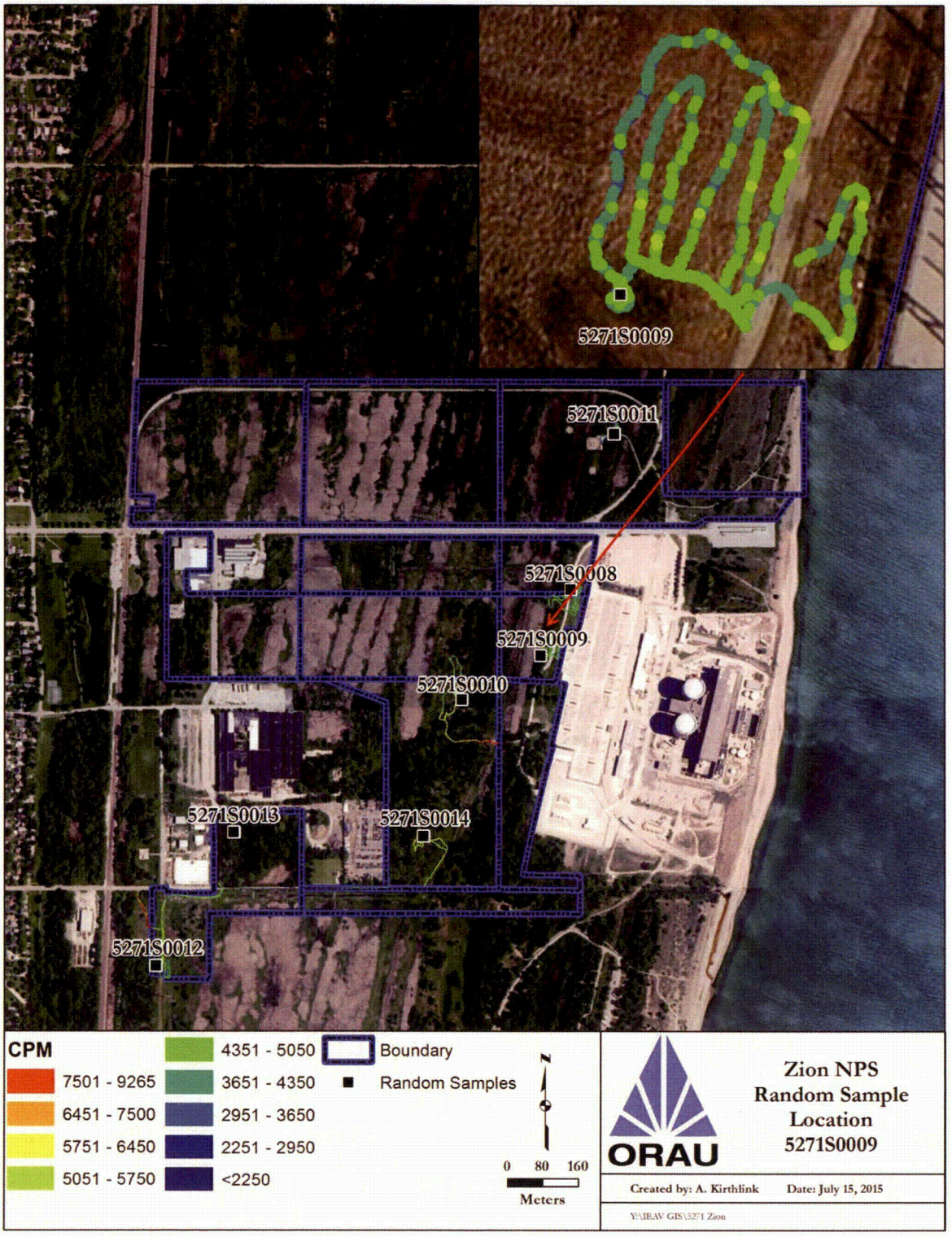

Figure A-4. Non-Impacted Land Area, SU10216—Gamma Walkover Scan and Sample Location 5271S0009

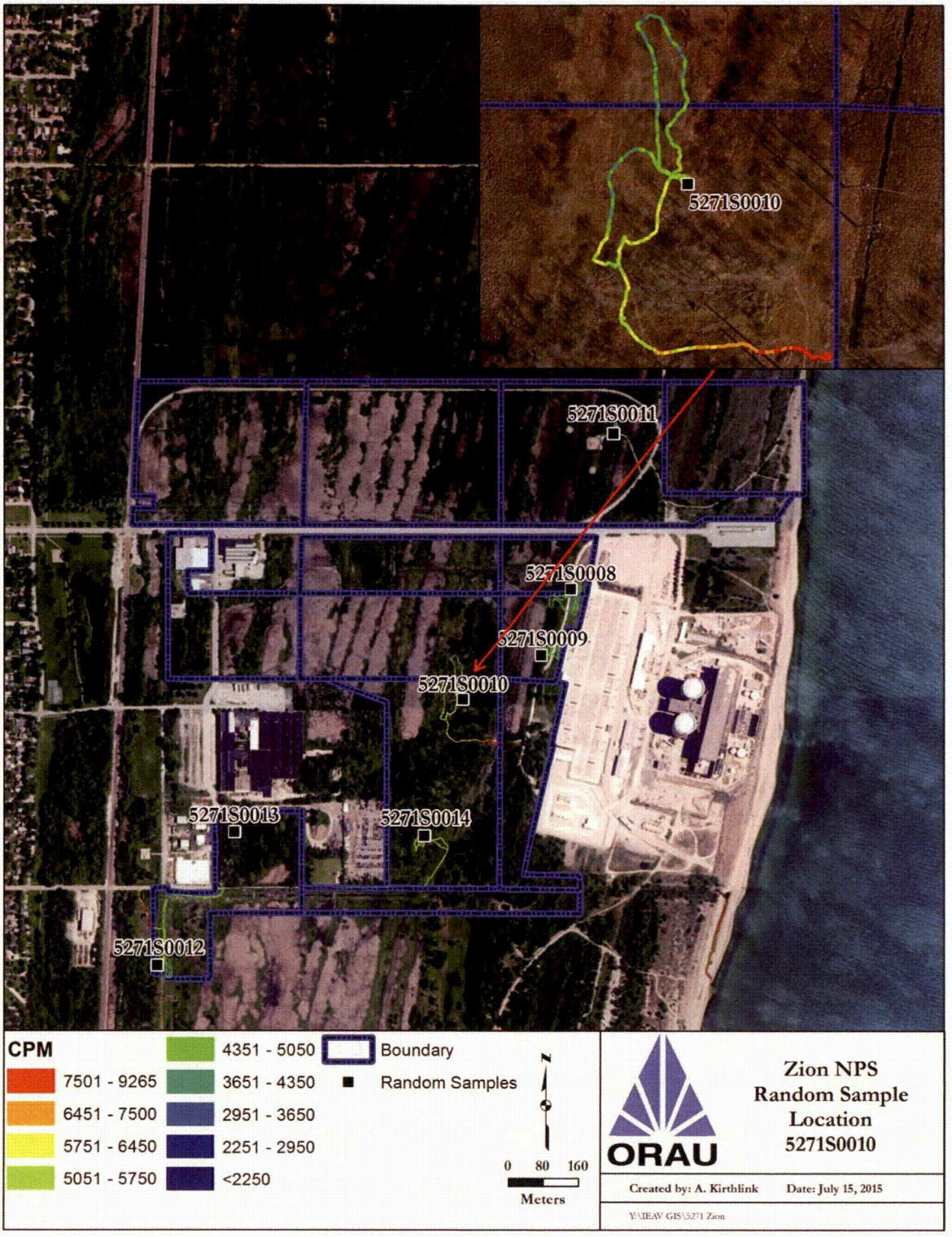

Figure A-5. Non-Impacted Land Area, SU10305—Gamma Walkover Scan and Sample Location 5271S0010

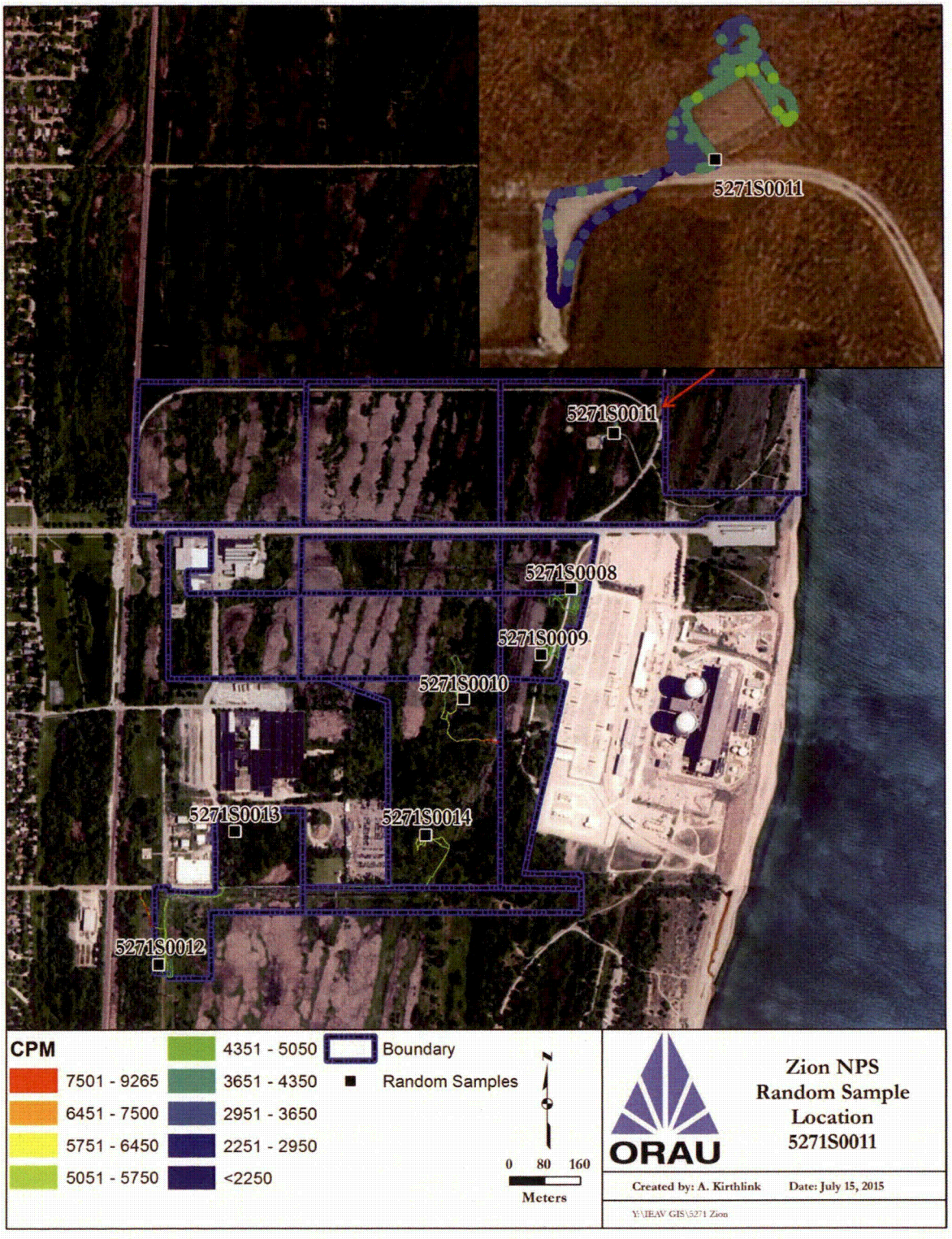

Figure A-6.Non-Impacted Land Area, SU10402—Gamma Walkover Scan and Sample Location 5271S0011

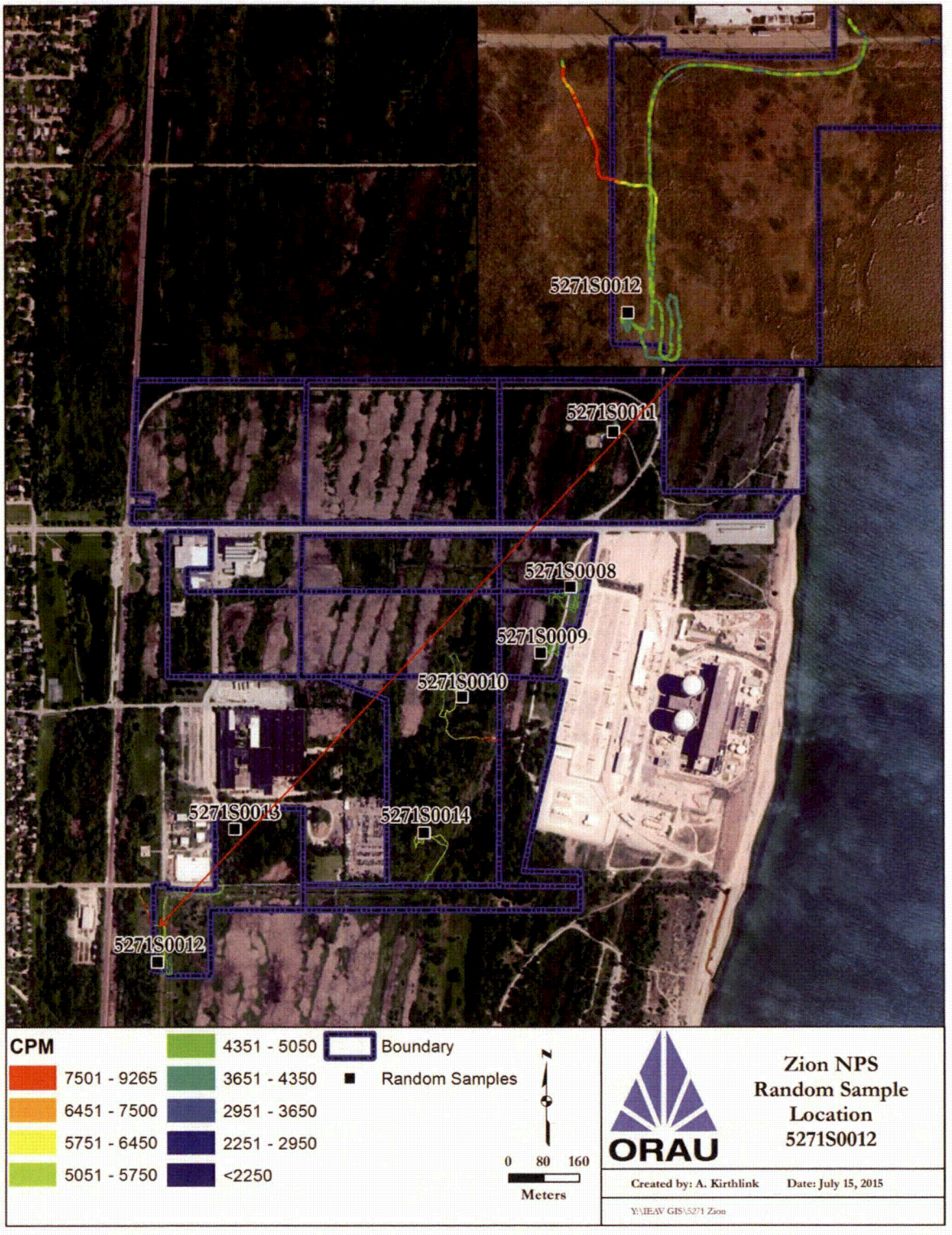

Figure A-7. Non-Impacted Land Area, SU10303—Gamma Walkover Scan and Sample Location 5271S0012

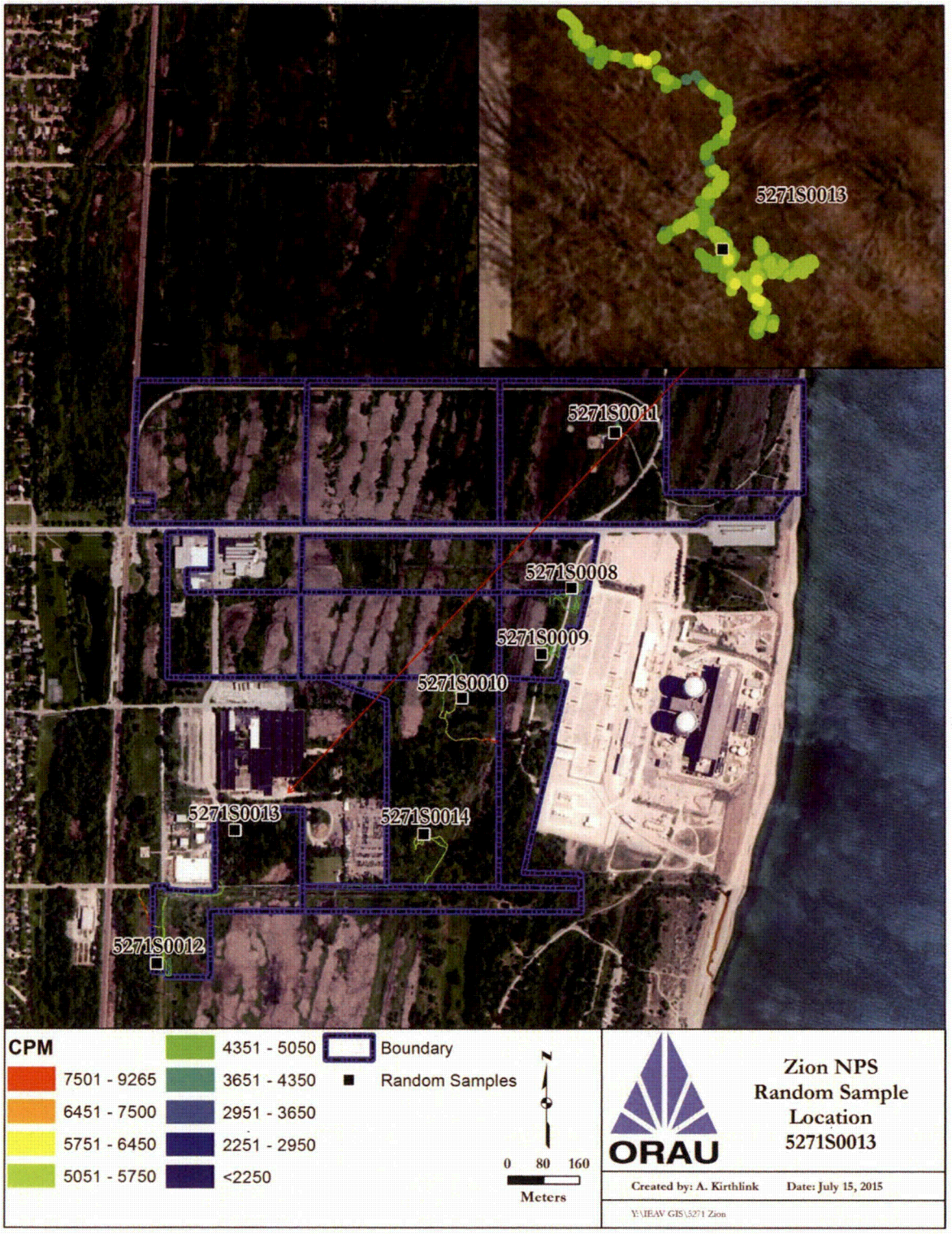

Figure A-8. Non-Impacted Land Area, SU10303—Gamma Walkover Scan and Sample Location 5271S0013

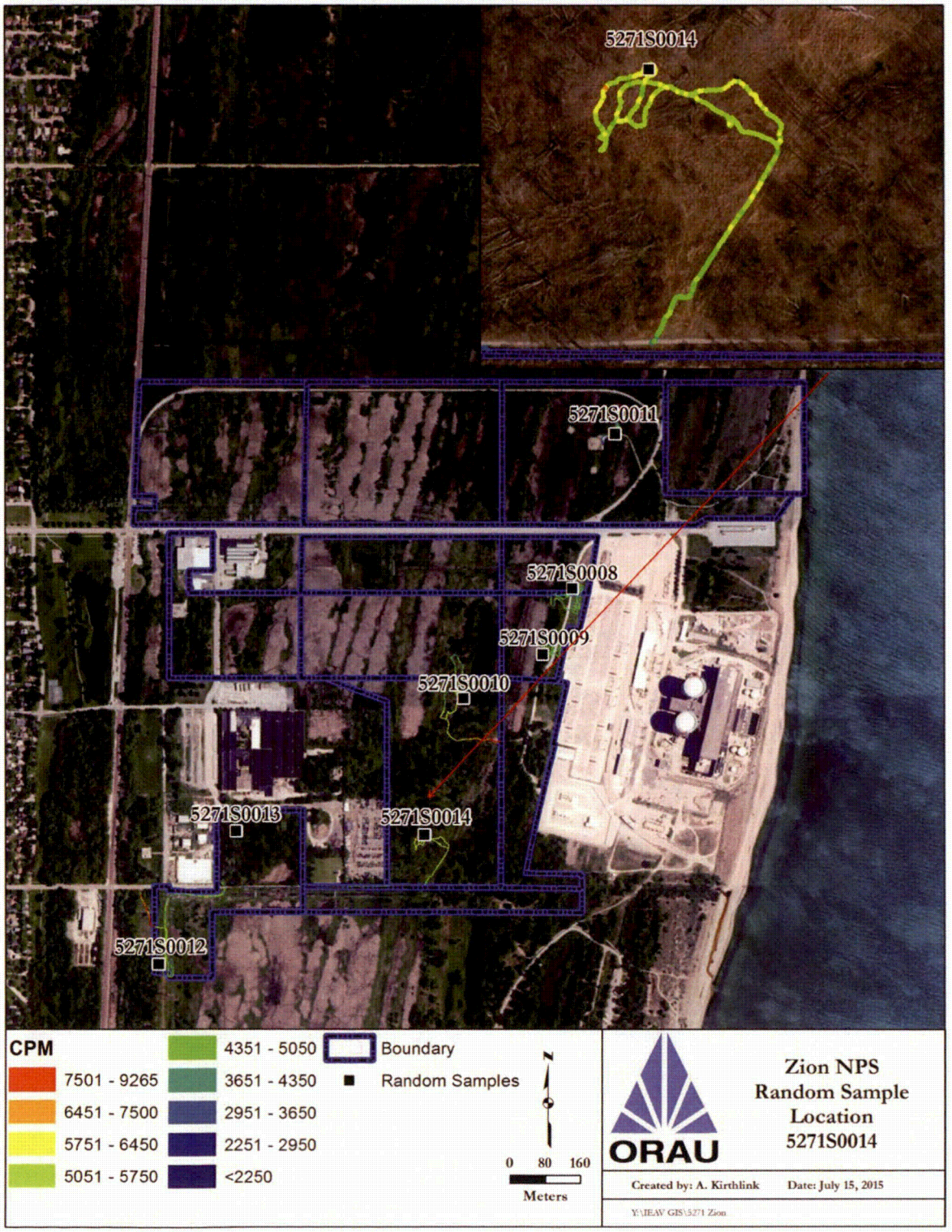

Figure A-9. Non-Impacted Land Area, SU10305—Gamma Walkover Scan and Sample Location 5271S0014

APPENDIX B
DATA TABLES

Table B.1. Surface Activity Levels for Structural Surfaces of the Crib House							
ZS Location ID	ORAU Location ID	Surface	Order of Measurements	Gross Gamma Count Rate (cpm)	Gross Beta Count Rate (cpm)	Net Beta Surface Activity (dpm/100 cm^2)[a]	Net Beta Surface Activity (pCi/m^2)[a]
RWC-004-1	5271M0001	Floor	1	5,624	613	1046	4.71E+04
		Floor	2	5,801	582	728	3.28E+04
		Floor	3	5,768	544	338	1.52E+04
		Floor	4	5,801	726	2205	9.93E+04
		Floor	5	5,869	616	1077	4.85E+04
RWC-009-1	5271M0002	Floor	1	5,721	534	236	1.06E+04
		Floor	2	5,416	543	328	1.48E+04
		Floor	3	5,689	506	-51	-2.31E+03
		Floor	4	5,939	517	62	2.77E+03
		Floor	5	5,732	496	-154	-6.93E+03
RWC-003-1	5271M0003	East Wall	1	5,233	206	-297	-1.34E+04
		East Wall	2	4,956	254	195	8.78E+03
		East Wall	3	5,150	225	-103	-4.62E+03
		East Wall	4	5,231	249	144	6.47E+03
		East Wall	5	5,502	237	21	9.24E+02
RWC-014-1	5271M0004	North Wall	1	5,449	256	215	9.70E+03
		North Wall	2	5,463	247	123	5.54E+03
		North Wall	3	5,398	227	-82	-3.70E+03
		North Wall	4	5,733	231	-41	-1.85E+03
		North Wall	5	5,664	257	226	1.02E+04
RWC-005-1	5271M0005	West Wall	1	4,824	223	-123	-5.54E+03
		West Wall	2	4,688	215	-205	-9.24E+03
		West Wall	3	4,673	221	-144	-6.47E+03
		West Wall	4	4,629	235	0	0.00E+00
		West Wall	5	4,736	256	215	9.70E+03

[a]Detectors calibrated to Tc-99.

Table B.2. Radionuclide Concentrations in the Crib House[a, b, c]					
Sample Data or Type	ORAU Sample ID	ZS *in situ* Location ID	Co-60 (pCi/g)	Cs-134 (pCi/g)	Cs-137 (pCi/g)
Concrete Samples from the Crib House					
Random	5271M0001	RWC-004-1	0.002 ± 0.041, 0.088	0.021 ± 0.038, 0.088	0.016 ± 0.037, 0.084
	5271M0002	RWC-009-1	0.010 ± 0.027, 0.064	0.031 ± 0.027, 0.071	-0.001 ± 0.031, 0.068
	5271M0003	RWC-003-1	-0.005 ± 0.016, 0.032	0.009 ± 0.015, 0.035	0.006 ± 0.0088, 0.0207
	5271M0004	RWC-014-1	0.002 ± 0.014, 0.032	0.003 ± 0.015, 0.033	0.000 ± 0.014, 0.032
	5271M0005	RWC-005-1	0.020 ± 0.019, 0.047	0.008 ± 0.021, 0.047	0.005 ± 0.016, 0.036
Sediment Samples collected from select pumps within the Crib House					
Judgmental	5271S0006	Pump 1B	0.052 ± 0.022, 0.041	0.021 ± 0.020, 0.048	0.044 ± 0.016, 0.029
	5271S0007	Pump 2B	0.363 ± 0.047, 0.053	0.030 ± 0.029, 0.067	0.151 ± 0.028, 0.042

[a]Uncertainties represent the 95% confidence level, based on total propagated uncertainties.

[b]MDC = minimum detectable concentration; these are the values after the comma

[c] = zero value due to rounding

Table B.3. Radionuclide Concentrations in the Non-Impacted Open Land Areas[a, b]					
Sample Data or Type	Sample ID	ZS Survey Unit	Co-60 (pCi/g)	Cs-134 (pCi/g)	Cs-137 (pCi/g)
Soil Samples from the Non-Impacted Open Land Areas					
Random	5271S0008	10215	0.005 ± 0.020, 0.045	0.002 ± 0.019, 0.042	0.136 ± 0.022, 0.027
	5271S0009	10216	-0.009 ± 0.010, 0.041	-0.007 ± 0.013, 0.046	0.255 ± 0.031, 0.025
	5271S0010	10305	-0.003 ± 0.017, 0.040	0.021 ± 0.016, 0.040	0.253 ± 0.030, 0.025
	5271S0011	10402	0.002 ± 0.017, 0.037	-0.0039 ± 0.0088, 0.0340	0.040 ± 0.012, 0.022
	5271S0012	10303	-0.023 ± 0.030, 0.055	0.025 ± 0.021, 0.053	0.264 ± 0.036, 0.034
	5271S0013	10303	0.014 ± 0.027, 0.060	0.019 ± 0.023, 0.054	0.063 ± 0.020, 0.036
	5271S0014	10305	-0.006 ± 0.021, 0.044	-0.0059 ± 0.0062, 0.0462	0.013 ± 0.011, 0.026

[a]Uncertainties represent the 95% confidence level, based on total propagated uncertainties.

[b]MDC = minimum detectable concentration; these are the values after the comma

APPENDIX C
SURVEY AND ANALYTICAL PROCEDURES

C.1 PROJECT HEALTH AND SAFETY

ORAU performed all survey activities in accordance with the *ORAU/ORISE Radiation Protection Manual*, the *ORAU Health and Safety Manual*, and the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU/ORISE 2014, ORAU 2015e, and ORAU 2015b). Prior to on-site activities, a work-specific hazard checklist was completed for the project and discussed with field personnel. The planned activities were thoroughly discussed with site personnel prior to implementation to identify hazards present. Additionally, prior to performing work, a pre-job briefing and walk down of the Crib House were completed with field personnel to identify hazards present and discuss safety concerns. Should ORAU have identified a hazard not covered in the *ORAU Radiological and Environmental Survey Procedures Manual* or the project's work-specific hazard checklist for the planned survey and sampling procedures, work would not have been initiated or continued until it was addressed by an appropriate job hazard analysis and hazard controls.

C.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 ORAU documents:

- *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2015b)
- *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2015c)
- *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2015d)

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

C.3 SURVEY PROCEDURES

C.3.1 SURFACE SCANS

Scans for elevated gamma radiation were performed by passing the detector slowly over the surface. The distance between the detector and surface was maintained at a minimum. Specific scan minimum detectable concentration (MDCs) for the sodium iodide scintillation detectors (NaI) were not determined as the instruments were used solely as a qualitative means to identify elevated gamma radiation levels in excess of background. Identifications of elevated radiation levels that could exceed the site criteria were determined based on an increase in the audible signal from the indicating instrument.

Beta scans were performed using small, hand-held scintillation detectors with a 1.2 mg cm^2 window. Identification of elevated radiation levels was based on increases in the audible signal from the indicating instrument. Beta surface scan MDCs were estimated using the approach described in NUREG-1507. The scan MDC is a function of many variables, including the background level. Additional parameters selected for the calculation of scan MDCs included a two-second observation interval, a specified level of performance at the first scanning stage of 95% true positive and 25% false positive rate, which yields a d' value of 2.32 (NUREG-1507, Table 6.1), and a surveyor efficiency of 0.5. The beta total efficiency was 0.10 for Co-60 (calibrated with Tc-99). The detector used had a general background of 300 cpm. The minimum detectable count rate (MDCR) and scan MDC was calculated as:

$$B_i = (300)(2\text{ s})(1\text{ min}/60\text{ s}) = 10\text{ counts}$$

$MDCR = (2.32)(10 \text{ counts})^{1/2}[(60 \text{ s/min})/2s] = 220 \text{ cpm}$

$MDCR_{surveyor} = 220/(0.5)^{1/2} = 311 \text{ cpm}$

Scan MDC = (311)/(.10) = 3,110 dpm/100 cm^2

C.3.2 SURFACE ACTIVITY MEASUREMENTS

Measurements of total beta surface activity levels were performed using hand-held scintillation detectors coupled to portable ratemeter-scalers. Count rates (cpm), which were integrated over one minute with the detector held in a static position, were converted to activity levels (dpm/100 cm^2) by dividing the count rate by the total static efficiency ($\varepsilon_i \times \varepsilon_s$) and correcting for the physical area of the detector (not required for these detectors). ORAU did not determine construction material-specific background for each surface type encountered for determining net count rates. Instead, ORAU took the conservative approach followed by the licensee and subtracted instrument's ambient background for the area (varied, 235 cpm used in the example below) when determining surface activity. An example *a priori* MDC for beta activity is given by:

$$MDC = \frac{3 + \left(4.65\sqrt{B}\right)}{G\,\varepsilon_{tot}}$$

Where:

B	=	background
ε_{tot}	=	total efficiency
G	=	geometry correction factor (1.0)

The *a priori* beta static MDC was approximately 743 dpm/100 cm^2 for Co-60.

C.3.3 MISCELLANEOUS MATERIAL AND SOIL SAMPLING

Soil and sediment samples (approximately 0.5 kilogram each) were collected using a clean garden trowel, then transferred into a new sample container by ORAU personnel. The five concrete increments associated with one *in situ* measurement location from within the Crib House were packaged separately in the field and then homogenized and combined into one composite sample (using equal weights from each increment) at the REAL in Oak Ridge, Tennessee. In total, ORAU collected 25 concrete increments which resulted in five composite samples from within the Crib House. ORAU personnel labeled each sample in accordance with ORAU survey procedures and completed the required custody documentation.

C.4 RADIOLOGICAL ANALYSIS

C.4.1 GAMMA SPECTROSCOPY

Samples were analyzed as received, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples 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 the computer capabilities inherent in the analyzer system. All total absorption peaks (TAPs) associated with the ROCs were reviewed for consistency of activity. Spectra were also reviewed for other identifiable TAPs. TAPs used for determining the activities of ROCs and the typical associated MDCs for a one-hour count time were:

Radionuclide[a]	TAP (MeV)	MDC (pCi/g)
Co-60	1.173	0.05
Cs-134	0.796	0.05
Cs-137	0.662	0.04

[a]Spectra were also reviewed for other identifiable TAPs.

C.5 DETECTION LIMITS

Detection limits, referred to as MDCs, were based on 95% confidence level via the NUREG-1507 method. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.

APPENDIX D
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.

D.1 SCANNING AND MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

D.1.1 GAMMA

Ludlum NaI 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 Data Logger (Trimble Navigation Limited, Sunnyvale, California)

D.1.2 BETA

Ludlum Plastic Scintillation Detector Model 44-142, 100 cm^2 physical area
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to:
Trimble Data Logger (Trimble Navigation Limited, Sunnyvale, California)

D.2 LABORATORY ANALYTICAL INSTRUMENTATION

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

High-Purity, Intrinsic Detector
Model No. GMX-45200-5
CANBERRA Model No: GC4020
(Canberra, Meriden, Connecticut)

Used in conjunction with:
Lead Shield Model G-11
Lead Shield Model SPG-16-K8
(Nuclear Data)
Multichannel Analyzer
Canberra's Gamma Software
Dell Workstation
(Canberra, Meriden, Connecticut)