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August 13, 2019

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Office of Nuclear Material and Safeguards
Division of Decommissioning, Uranium Recovery, and Waste Programs
Reactor Decommissioning Branch
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SUBJECT: DOE Contract No. DE-SC0014664
INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE CALIFORNIA STATE ROUTE 84 FRONTAGE ASSOCIATED WITH THE GE HITACHI VALLECITOS NUCLEAR CENTER; SUNOL, CALIFORNIA
DOCKET NO. 05000018 AND 05000183; RFTA NO. 19-003;
DCN 5334-SR-01-1

Dear Mr. Parrott:

The Oak Ridge Institute for Science and Education (ORISE) is pleased to provide the enclosed revised final report, which describes the procedures and results of the California State Route 84 frontage independent confirmatory survey that ORISE performed during the period of February 5–6, 2019 at the GE Hitachi Vallecitos Nuclear Center in Sunol, California. Additional U.S. Nuclear Regulatory Commission's (NRC's) comments were addressed in this revised version.

You may contact me at 865.576.6659 or Kaitlin Engel at 865.574.7008 if you have any questions or require additional information.

Sincerely,

Erika N. Bailey
Survey and Technical Projects Group Manager
ORISE

KME:jc

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE CALIFORNIA STATE ROUTE 84 FRONTAGE ASSOCIATED WITH THE GE HITACHI VALLECITOS NUCLEAR CENTER SUNOL, CALIFORNIA

K. M. Engel
ORISE

FINAL REPORT
Revision 1

Prepared for the
U.S. Nuclear Regulatory Commission

AUGUST 2019

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE CALIFORNIA STATE ROUTE 84 FRONTAGE ASSOCIATED WITH THE GE HITACHI VALLECITOS NUCLEAR CENTER SUNOL, CALINFORNIA

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ACRONYMS

AA	alternative action
CFR	Code of Federal Regulation
cm	centimeter
cpm	counts per minute
CU	confirmatory unit
DOE	U.S. Department of Energy
DQO	data quality objective
DS	decision statement
GEH	GE Hitachi
GPS	global positioning system
LLNL	Lawrence Livermore National Laboratory
HTD	hard-to-detect
MDC	minimum detectable concentration
NaI	sodium iodide
NIST	National Institute of Standards and Technology
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
PSQ	principal study question
Q-Q	quantile-quantile
TAP	total absorption peak
ROC	radionuclide of concern
UCL	upper confidence level
VNC	Vallecitos Nuclear Center

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE CALIFORNIA STATE ROUTE 84 FRONTAGE ASSOCIATED WITH THE GE HITACHI VALLECITOS NUCLEAR CENTER SUNOL, CALIFORNIA

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that the Oak Ridge Institute for Science and Education (ORISE) perform an independent confirmatory survey of the California State Route 84, also known as Vallecitos Road, frontage of the GE Hitachi (GEH) Vallecitos Nuclear Center (VNC) in Sunol, California. In December 2018, GEH submitted a formal request to the NRC for approval to release for unrestricted use approximately 2.8 hectares of VNC property within a construction easement along California State Route 84. This land will be made available to Alameda County Transportation Commission to support road development and widening (GEH 2018).

ORISE performed independent assessment activities during the period of February 5–6, 2019. Confirmatory survey activities included gamma walkover scanning, gamma direct measurements, and soil sampling in the applicable land area.

Elevated direct gamma radiation levels above background were identified in the landscaped area near the road leading into the site. The elevated counts were attributed to naturally occurring radioactive material (NORM) in the lava rocks used in the landscaping. A total of 20 soil samples were collected throughout the land area: 13 random samples, one judgmental sample, and six additional confirmatory samples, as requested by the NRC.

Radionuclide concentrations in soil samples from the California State Route 84 frontage were evaluated for the presence of gamma-emitting mixed activation and fission products, with particular emphasis on Cs-137, which is a VNC radionuclide of concern (ROC). Samples also were analyzed for gross alpha and beta concentrations.

Cs-137 is ubiquitous in the environment from global atmospheric fallout from weapons testing and the Chernobyl and Fukushima nuclear releases. Therefore, Cs-137 concentrations in the California State Route 84 frontage soil samples were compared with soil samples collected from off-site background and other VNC non-impacted populations. The concentrations observed were compared to the Lawrence Livermore National Laboratory's (LLNL's) environmental surveillance

program results and to C1/C2 non-impacted land area samples collected during a previous confirmatory survey in 2015. In addition to Cs-137, concentrations of naturally occurring radionuclides (K-40, Ra-226, Th-232, and U-238) also were examined between the LLNL, C1/C2, and California State Route 84 frontage land areas.

The concentration of Cs-137 in soil samples collected from the California State Route 84 frontage were within the same range as the 2017 LLNL off-site background environmental monitoring results for Cs-137. Furthermore, the Cs-137 concentrations in the California State Route 84 frontage were statistically demonstrated to be lower than the Cs-137 concentrations found in the C1/C2 area. The lower concentrations were likely due to routine tilling of the road frontage for a fire break. The statistical assessment objectively failed to reject the null hypothesis, thereby concluding that the California State Route 84 frontage land area Cs-137 concentrations are less than or equal to the non-impacted C1/C2 land area concentrations. Comparison of naturally occurring radionuclide concentrations showed that the California State Route 84 frontage soils shared similar natural radiological conditions as the land area outside of LLNL and the C1/C2 land area. Therefore, all results were consistent with the non-impacted determination.

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE CALIFORNIA STATE ROUTE 84 FRONTAGE ASSOCIATED WITH THE GE HITACHI VALLECITOS NUCLEAR CENTER SUNOL, CALIFORNIA

1. INTRODUCTION

The GE Hitachi (GEH) Vallecitos Nuclear Center (VNC) in Sunol, California has been engaged in reactor research, development, testing operations, and post-irradiation examination of reactor fuel since the 1950s (GEH 2018). Much of the reactor-related activities have ceased. One test reactor remains operational while three are in a SAFeSTORage condition. VNC is currently licensed under 10 Code of Federal Regulation (CFR) 50 and 70 as well as a State of California radioactive materials license. In December 2018, GEH submitted a formal request to the U.S. Nuclear Regulatory Commission (NRC) for approval to unconditionally release for unrestricted use a construction easement along California State Route 84, also known as Vallecitos Road. This area is referred to as the California Route 84 frontage in this report. This land will be made available to Alameda County Transportation Commission to support road development and widening (GEH 2018).

The licensee categorized the 2.8 hectare (7 acre) area as non-impacted and, as such, plant-derived radionuclides in concentrations exceeding background should not be present. In support of the release request, GEH conducted an environmental assessment, which included a small-scale sampling campaign and a review of site operating history. The NRC requested that the Oak Ridge Institute for Science and Education (ORISE) perform confirmatory survey activities within the 2.8 hectare area that GEH is requesting for unconditional release. ORISE performed the confirmatory survey on February 5–6, 2019. A previous non-impacted site release request and associated ORISE confirmatory surveys involved Areas “C1” and “C2” (C1/C2) at the VNC site (ORISE 2015). The results from the survey of the C1/C2 area were used for comparison to the current confirmatory survey results. Results from Lawrence Livermore National Laboratory’s (LLNL's) annual environmental surveillance program were used for comparison to the current confirmatory survey results as well.

2. SITE DESCRIPTION

The VNC consists of approximately 650 hectare (1,600 acres) and is located at 6705 Vallecitos Road, Sunol, California. The site is approximately 56 kilometers (35 miles) east-southeast of San Francisco, California, in the Pleasanton quadrangle of Alameda County. The site is situated in a primarily

agricultural setting with a small residential population existing west of the site. The nearest sizable town is Pleasanton, California, located 6.4 kilometers (4.0 miles) north-northwest of the site. The site's boundaries have not changed since the property was purchased in 1956 and are delineated with fencing and "No Trespassing" signs (GEH 2018).

Only approximately 55 hectares of the 650 hectare VNC site were ever used for conducting licensed activities whereas the balance of the site is mostly undeveloped grasslands with hills ranging from 120 to 370 meters (400 to 1,200 feet) above sea level. Developed industrialized areas of the site exist at elevations between 120 and 180 meters (400 to 590 feet) and slope to the southwest. The property is primarily drained by ditches flowing into Vallecitos Creek.

Figure 2.1 presents the VNC land area delineations. The California State Route 84 frontage is located along the southern-most boundary of Areas "A" and "B" as shown in Figure 2.1. The 2.8 hectare VNC property area that is the focus of this survey effort is within an irregular construction easement along California State Route 84 frontage as shown on Figure 2.2.

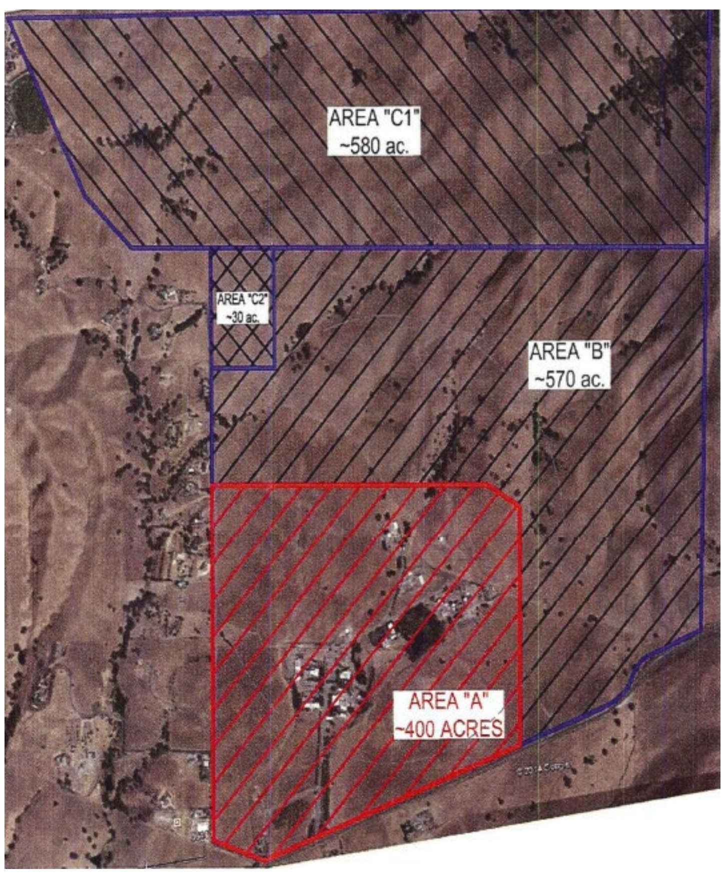

Figure 2.1. VNC Land Area Map

Figure 2.2. California State Route 84 Frontage (Blue Outline)

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 provide a formalized method for planning radiation surveys, improving survey efficiency and effectiveness, and ensuring that the type, quality, and quantity of data collected are adequate for the intended decision applications. The seven steps in the DQO process are 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 defines the problem that necessitates the study, identifies the planning team, and examines the project budget and schedule. The licensee requested approval from the NRC to remove the 2.8 hectare, non-impacted survey area from its 10 CFR Part 50 license. The NRC requested that ORISE perform independent contractor document and field reviews and to conduct confirmatory surveys to generate radiological data to assist the NRC in evaluating the licensee's request for partial site release. The NRC uses these data to assess the site radionuclides of concern (ROCs) and to determine the analytical suite for the samples collected from the non-impacted survey area. Therefore, the problem statement was formulated as follows:

> Confirmatory surveys must be performed to generate independent radiological data to assist the NRC with their assessment of the non-impacted classification of the 2.8 hectare land area included in the licensee's request for partial site release and assess the ratios between identified ROCs in the soil.

3.2 IDENTIFY THE DECISION

The second step in the DQO process identifies the principal study questions (PSQs) and alternative actions (AAs), develops decision statements (DSs), and organizes 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 DSs. PSQs, AAs, and combined DSs are organized based on the survey unit type (i.e., the associated final status survey methodology) and are presented in Table 3.1

Table 3.1. VNC Confirmatory Survey Decision Process	
Principal Study Questions	**Alternative Actions**
PSQ1: Are radionuclide concentrations in the non-impacted land area consistent with available regional background data and ROC statistical parameters of the confirmatory survey for the C1/C2 non-impacted area?	**Yes:** Compile confirmatory data and report results to the NRC for their decision making. Provide independent interpretation that confirmatory field surveys did not identify anomalous areas of residual radioactivity and quantitative laboratory data are consistent with prior background and non-impacted area values, and/or that statistical sample population examination/assessment conditions were met. **No:** Compile confirmatory data and report results to the NRC 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 the NRC's determination of the adequacy of the GEH survey.
PSQ2: Are gamma-emitting ROCs present within collected samples, and/or non-gamma emitting hard-to-detect (HTD)ROCs, if applicable?	**Yes:** Provide analytical results to the NRC that include identified radionuclides and, if applicable, ratios of HTDs to gamma-emitting ROCs. **No:** Provide analytical minimum detectable concentraions (MDCs) and the less-than-MDC results to the NRC.
Decision Statement	
Confirmatory survey results did/did not identify anomalous results or other conditions that refute the non-impacted classification of the subject land area. Independent confirmatory survey results did/did not identify gamma-emitting ROCs in samples and include/do not include additional HTD ROCs for confirmatory samples collected from the non-impacted land area (California State Route 84 Frontage).	

3.3 IDENTIFY INPUTS TO THE DECISION

The third step in the DQO process identifies both the information needed and the sources of this information, determines the basis for action levels, and identifies sampling and analytical methods to meet data requirements. For this effort, information inputs included the following:

- GEH background assessment and soil sample analytical results collected along California State Route 84
- LLNL background datasets
- Area C1/C2 confirmatory survey analytical results
- ORISE gamma walkover surveys
- ORISE volumetric sample analysis results for soil
- Applicable instrumentation and survey and sampling procedures, method procedures, and data management procedures (ORAU 2016a)
- The *Oak Ridge Associated Universities (ORAU) Environmental Services and Radiation Training Quality Program Manual* (ORAU 2018)
- Applicable laboratory equipment and procedures (ORAU 2017)

3.4 DEFINE THE STUDY BOUNDARIES

The fourth step in the DQO process defines target populations and spatial boundaries, determines the timeframe for collecting data and making decisions, addresses practical constraints, and determines the smallest subpopulations, area, volume, and time for which separate decisions must be made. The study boundary is based on the land area identified in the licensee's request for approval of the partial site release and the supplemental information the site provided in response to an NRC request for additional information (GEH 2018 and 2019). This area, the 2.8 hectare California State Route 84 frontage, constituted the confirmatory survey decision boundary as a single confirmatory unit (CU). Temporal boundaries to complete this survey were limited to two 10-hour days on-site on February 5–6, 2019. The majority of the California State Route 84 frontage land area was accessible; inaccessible areas were due to muddy conditions.

3.5 DEVELOP A DECISION RULE

The fifth step in the DQO process specifies appropriate parameters (e.g., mean, median), confirms action levels were above detection limits, and develops an "if…then…" decision rule statement. For this survey effort, the parameter of interest was the Cs-137 concentration in the California State Route 84 frontage. If non-impacted by site operations, Cs-137 concentrations for a representative sample population from the California State Route 84 frontage should be comparable to the concentrations attributable to atmospheric fallout that have been observed for local background or

other non-impacted areas. As such, the California State Route 84 frontage Cs-137 concentrations were directly compared to the LLNL environmental monitoring background concentrations and the previously investigated C1/C2 concentrations. In the event that results were "too close to objectively call," hypothesis testing was planned with the previously collected data for the non-impacted C1/C2. Hypothesis testing adopts a scientific approach where the survey data are used to select between the baseline condition (the null hypothesis, H_0) and an alternative condition.

The null and alternative hypotheses were stated as:

> H_0: California State Route 84 frontage Cs-137 concentration population mean (μ_{CU}) is less than or equal to the C1/C2 mean concentration. Mathematically, the null hypothesis is stated as $\mu_{CU} \leq$ C1/C2.
>
> H_A: California State Route 84 frontage Cs-137 concentration population mean is greater than the C1/C2 mean concentration. Mathematically, the alternative hypothesis is stated as $\mu_{CU} >$ C1/C2.

Identical H_0 and H_A statements also could be made to evaluate the California State Route 84 frontage mean concentration population parameter with the LLNL off-site background environmental monitoring data. However, ORISE did not specifically plan to include this additional two-sample statistical test because the pedigree of the LLNL off-site background data representing independent, random samples from the population—a necessary condition of the statistical test—was not available. Rather these data served the purpose of direct comparison of the relative data dispersion (ranges).

The complete decision rule was stated as follows:

> Compare data with the general distribution, including the maximum observed LLNL background data. Additionally, if the null hypothesis is not rejected and there are no outliers identified indicative of elevated Cs-137 concentrations for individual sample results, then conclude the California State Route 84 frontage Cs-137 concentrations are consistent with previous non-impacted VNC lands that have been released from the site license. Otherwise, perform further evaluation(s). For any noted statistical hypothesis rejections or

concentration anomalies, provide technical comments/recommendations to the NRC for their evaluation and decision making.

3.6 Specify Limits on Decision Errors

The sixth step in the DQO process specifies the decision maker's limits on decision errors, which are then used to establish performance goals for the survey. There were two types of decision errors to consider: Type I (typically designated as alpha or α) and Type II (typically designated as beta or β). A Type I error occurs when the null hypothesis is rejected when it should not be, also known as a false positive, and reflects the confidence level in the decision. A Type II error is incorrectly failing to reject the null hypothesis when the alternative hypothesis is true. It also is known as a false negative. The ability to reject the null hypothesis when it is false is known as the power of the test (power is defined as 1-β).

Two orders of control were implemented to minimize decision errors regarding the DSs introduced in Table 3.1. The first order of control was to select decision error rates that were conservative yet still allowed for the project to be completed within the study boundaries. The Type I error rate was set to 0.05, that is, there is a 5% chance of concluding the CU is greater than the C1/C2 concentrations when it actually is not. The Type II error rate and subsequent power achieved was dependent on the number of samples collected and the concentration variability in the sample set. The number of samples required was based on estimating the CU mean at the 95% confidence level within 0.025 picocuries per gram (pCi/g) above/below the true mean (i.e., a two-sided confidence interval). Based on the assumption that the California State Route 84 frontage was non-impacted, the radiological survey data collected during this survey should be similar to data previously collected in the non-impacted C1/C2 where the mean, upper confidence level (UCL), standard deviation, and maximum Cs-137 levels were 0.134, 0.156, 0.041, and 0.201 pCi/g, respectively (ORISE 2015). The difference between the C1/C2 mean and UCL provided the 0.025 confidence level width planning input discussed above together with the previously determined C1/C2 variability for sample size determination. Both inputs were adjusted for rounding and sample size optimization. For this investigation, 13 random sample locations were planned.

The second order of control was to optimize the confirmatory field measurement and laboratory analytical MDCs. Field scanning MDCs were minimized by following survey procedures for scan

speeds and liberal pausing in response to gamma radiation count rates distinguishable from background.

3.7 Optimize the Design for Obtaining Data

The seventh step in the DQO process reviews the DQO outputs, develops data collection design alternatives, formulates mathematical expressions for each design, selects the sample size to satisfy DQOs, decides on the most resource-effective design of agreed alternatives, and documents requisite details. Survey design and laboratory analyses were optimized by implementing the procedures presented in Sections 5 and 6.

4. APPLICABLE SITE GUIDELINES

The primary ROCs identified for the VNC were beta-gamma emitters—fission and activation products—resulting from reactor operation. Previous review of the facility operating history, historical events, and the results of radiological surveys have been completed. As a result of the review, GEH defined the subject land area as non-impacted, meaning that any of the plant-derived ROCs should not be present in excess of background. The only plant-derived, gamma-emitting, fission product that GEH detected, Cs-137, is also detectable in background. If a land area has not been impacted by site activities, Cs-137 should only be present at concentrations attributable to global fallout (GEH 2018).

5. PROCEDURES

The confirmatory survey activities, conducted during the period of February 5–6, 2019, were 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* (ORISE 2019, ORAU 2016a, 2018). Appendices B and C provide additional information regarding survey instrumentation and related processes discussed within this section.

5.1 Reference System

ORISE referenced confirmatory measurement/sampling locations to global positioning system (GPS) coordinates, specifically NAD 1983 (CORS96) State Plane California. Other

prominent site features also were referenced. Measurement and sampling locations were documented on detailed survey maps.

5.2 SURFACE SCANS

Surface scans of the CU land areas were performed with Ludlum Model 44-10 5 centimeter (cm) by 5 cm sodium iodide (NaI) scintillation detectors coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. Detectors also were coupled to GPS data logging systems that enabled real-time gamma count rate and spatial data capture. Medium-density surface scans were performed within the survey area as time and access permitted. Total scan coverage was dependent on accessibility of the CU. Areas of mud and water limited accessibility to some areas of the CU. Overall scan coverage was 50% to 75%. It was noted during the survey that the California State Route 84 frontage had been routinely tilled to create a fire break.

5.3 GAMMA RADIATION MEASUREMENTS AND SOIL SAMPLING

In total, 20 soil samples were collected from the CU: 13 random locations and seven judgmental locations of which one was based on gamma scan results and six corresponded with licensee sample locations. Site sampling locations were initially approximated using figures and later by using GPS coordinates after conversion to NAD 1983 (CORS96) State Plane California (hence, two samples at site sample location #2).

Samples were collected at a depth of 0 to 15 cm from the surface of the native soil using hand trowels. Sampling equipment was decontaminated in the field after each sample to minimize the potential for cross-contamination. Gamma measurements were performed prior to sample collection. Additional gamma measurements were made at the 15-cm depth after sample collection.

6. 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 in Oak Ridge, Tennessee. Sample analyses were performed in accordance with the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2017). Soil samples were crushed and homogenized and analyzed by gamma spectrometry for gamma-emitting fission and activation products and for gross alpha and beta concentrations using a low-background

proportional counter. The gamma spectra also were reviewed for other identifiable photopeaks. With NRC concurrence, no further analysis for HTD radionuclides was performed based on the radionuclide-specific results of the gamma spectroscopy and gross alpha and beta activity from low background proportional counting. Analytical results are reported as gross concentrations in units of pCi/g. Gamma radiation scan and static measurements are presented as gross counts per minute (cpm).

Scan data sets and radionuclide concentrations were graphed in quantile-quantile (Q-Q) plots, strip charts, and/or box plots for assessment. The Q-Q plot is a graphical tool for assessing the statistical distribution of a data set. For the scan data, the Y-axis represents gross gamma radiation levels in units of cpm. For the soil samples, the Y-axis represents the radionuclide concentration in units of pCi/g. The X-axis represents the data quantiles about the median value. Values less than the median are represented in the negative quantiles; values greater than the median are represented in the positive quantiles. A normal distribution 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. Section 7 provides specific analytical and scan data results and discussions.

7. FINDINGS AND RESULTS

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

Appendices A and B provide the survey data for the CU investigated. Appendices C and D provide additional details regarding field and laboratory instrumentation as well as additional information on calibration, quality assurance, survey and analytical procedures, and detection sensitivities.

7.1 SURFACE SCANS

Table 7.1 provides a summary of the confirmatory gamma radiation scanning survey data.

Table 7.1. Summary of Scanning Results			
Area	**NaI Scan Range (cpm)**		
California State Route 84 frontage	3,600	to	11,000

Figures A.1 through A.9 in Appendix A provide the gamma walkover survey maps for the CU. Elevated direct gamma radiation levels above background were identified in the landscaped area near the road leading into the site (Figure A.2). Figure 7.1 provides the Q-Q plot for the CU's data set and

shows a step function indicating more than one data population. The elevated counts in the plot are attributed to naturally occurring radioactive material (NORM) in the lava rocks used in the landscaping. The NRC staff flagged one area along the fence line for judgmental sampling based on scan results.

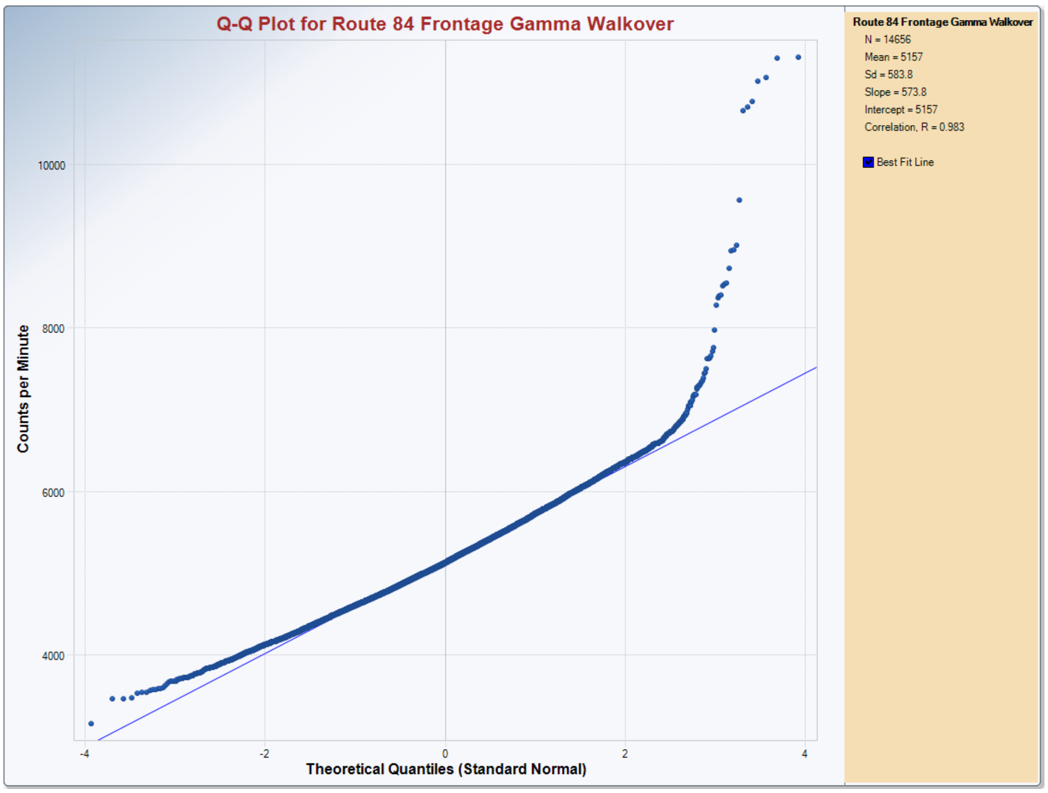

Figure 7.1. Q-Q Plot for Gamma Walkover Survey Data

7.2 Gamma Radiation Measurements and Radionuclide Concentrations in Soil

Figures A.10 through A.14 in Appendix A provide all soil sampling locations where gamma measurements and samples were collected. Table 7.2 provides a summary of the NaI direct measurements collected pre- and post-sampling.

Table 7.2. Summary of Soil Sampling Direct Measurements

Measurement Type	No. of Samples	NaI Measurement (cpm)	
		Pre-Sample	Post-Sample
Random	13	4,700 to 6,200	4,800 to 7,500
Judgmental	7	4,400 to 5,300	4,800 to 5,700

The gamma direct measurements corresponded to the levels observed during surface scans, with no elevated count rates noted at sampling locations. Additionally, the post-sample measurements did not identify any subsurface anomalies.

Table 7.3 provides a summary of the Cs-137, gross alpha and gross beta concentrations. Review of the gamma spectra did not identify any additional fission/activation products or gamma-emitting transuranics. The only other radionuclides identified were NORM. Summary data for the primary NORM radionuclides also are provided in Table 7.3. Appendix B provides the individual sample data.

Table 7.3. Summary of Radionuclide Concentrations (pCi/g)

Measurement Type		Cs-137	Gross Alpha	Gross Beta	K-40	Ra-226 (by Pb-214)	U-238 (by Th-234)	Th-232 (by Ac-228)
Random Samples	Min	0.006	3.2	6.8	4.33	0.322	0.39	0.435
	Max	0.103	8.5	13.9	10.35	0.520	1.18	0.699
Judgmental	Min	0.010	3.2	9.8	6.57	0.361	0.32	0.411
	Max	0.071	10.2	13.6	10.19	0.510	0.80	0.687

Figure 7.2 provides strip charts comparing the Cs-137, potassium-40 (K-40), thorium-232 (Th-232), and uranium-238 (U-238) concentrations for the California State Route 84 frontage, the last 9 years of LLNL data, and the C1/C2. Ra-226 was not provided in the LLNL dataset; therefore, results were not depicted in Figure 7.2. The LLNL data used in the comparison represent the 2009 to 2017 environmental surveillance program results for soil samples collected from off-site areas that are known to be non-impacted by LLNL. (Gallegos 2010, Jones 2011-2015, Rosene 2016-2018).

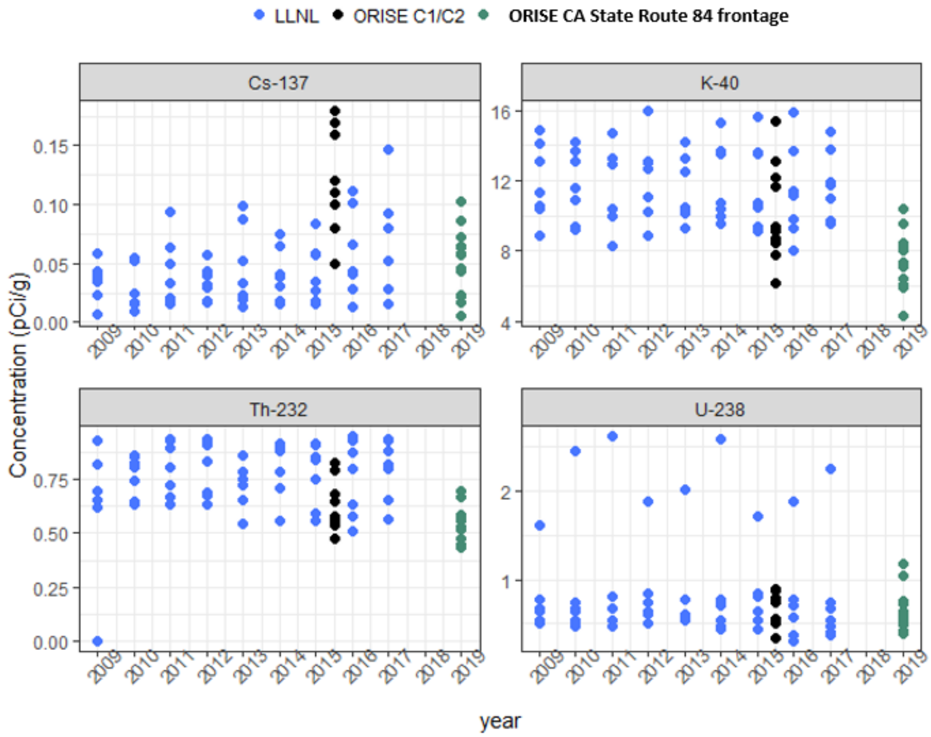

Figure 7.2. Comparison of Cs-137, K-40, Th-232, and U-238 Concentrations

Cs-137 is present in soil as the result of atmospheric fallout deposition and is typically present within the first few centimeters of soil. Therefore, comparison of the three populations is necessary to evaluate whether the Cs-137 identified in the California State Route 84 frontage samples is due to site operations. The California State Route 84 frontage results were compared with the LLNL population. Figure 7.2 also shows that the 2019 California State Route 84 frontage Cs-137 data are within range of the LLNL data from the previous years. It is noted that that the C1/C2 Cs-137 concentration upper bound is slightly higher than both the LLNL and California State Route 84 frontage Cs-137 data ranges. The reason for this can be attributed to differences between disturbed and undisturbed soils. Routine tilling that was performed along California State Route 84 frontage will result in blending surface soil with deeper strata (i.e., below 15 cm), thereby reducing the Cs-137 concentration within the 15-cm depth increment that the samples represent. Similarly, a number of LLNL off-site sample locations appear to be in developed areas where the soil is likely to have been disturbed, based on aerial photographs. In contrast, undisturbed surface soils are expected to exhibit higher concentrations of surface deposited Cs-137, such as in the C1/C2.

The second population comparison was between the California State Route 84 frontage and the C1/C2. Evaluation of Figure 7.2 illustrates that the California State Route 84 frontage random

sample Cs-137 concentration sample distribution shifted downward relative to the C1/C2 distribution. Overall, the California State Route 84 frontage population mean concentration is 2.5 times less than the C1/C2 population, with means of 0.05 pCi/g and 0.13 pCi/g, respectively. Although unnecessary based on the above evidence, a hypothesis test was performed on the data. The Student (pooled) t-test was used to compare the difference between the means of the two sample populations. This test is appropriate for small sets of data collected independently from one another, assumes equal variances between the data sets, and when both populations represent normal distributions. The null and alternative hypotheses, H_0 and H_A, respectively, are stated in Section 3.5. The test was performed using ProUCL 5.1.002 and is presented in Appendix A. Because the test statistic (t-test value) is less than the critical value (-5.774 and 1.717, respectively) and the p-value (1) is greater than 0.05, there is not enough evidence to reject H_0 (null hypothesis); therefore, conclude that the CU1 mean concentration is less than or equal to the C1/C2 area mean.

Additional analysis of the California State Route 84 frontage data included comparisons of Cs-137 concentrations in random and judgmental samples for evidence of outliers. The Figure 7.3 box plot shows that judgmental samples were within the random sample population parameters.

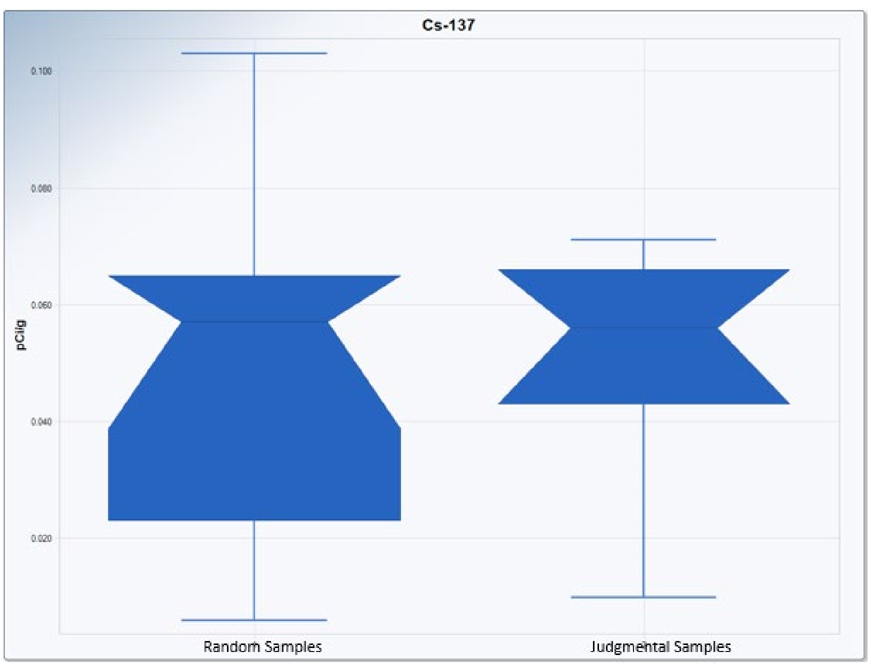

Figure 7.3. Comparison of Random and Judgmental Sample Populations

In addition to Cs-137, the NORM concentrations were compared between the California State Route 84 frontage, the LLNL, and the C1/C2 sample populations. Figure 7.2 also provides the strip charts for the three populations for K-40, Th-232, and U-238. With the exception of K-40 and Th-232, the comparisons show the California State Route 84 frontage, LLNL, and C1/C2 have similar naturally occurring radiological conditions. For K-40 and Th-232, the California State Route 84 frontage concentrations are slightly lower than the C1/C2 concentrations, which is commonly observed for different soil types and/or due to spatial variability in natural background concentrations. Changes in NORM concentrations from tilling are expected to be minimal, as NORM is distributed throughout the soil column rather than only as a result of surface deposition.

The LLNL dataset did not provide gross alpha and beta results for the samples collected outside of LLNL boundaries. Therefore, only the gross alpha and beta results from GEH's investigation were compared to the ORISE California State Route 84 frontage results (GEH 2018).

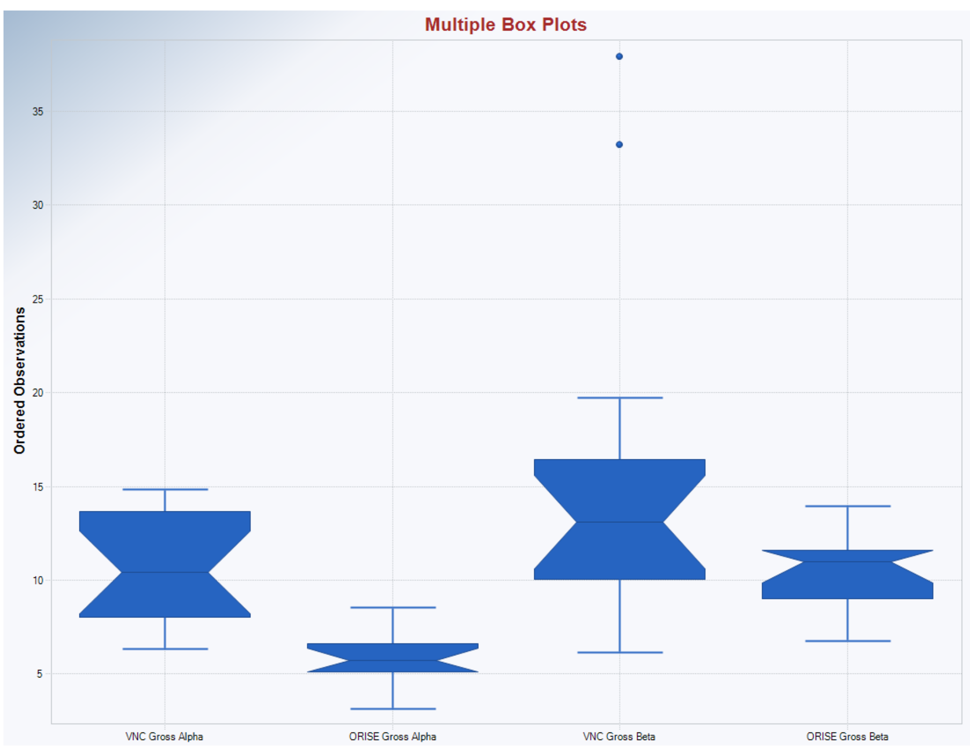

Figure 7.4. Comparison of Gross Alpha and Beta Results for California State Route 84 Frontage

Figure 7.4 provides box plots of the gross alpha and beta results for both the licensee's and ORISE's samples. Appendix B provides the datasets used for comparison. The ORISE gross alpha and beta results were generally lower than the licensee's results. The observed differences are unremarkable. Moreover, the gross activity data only serve as a qualitative screening tool that the site used to select a sample for more rigorous analyses. The licensee's systematic higher results would result in a greater probability that the gross activity would exceed the investigation level that the site uses to require gamma spectroscopy. The differences are possibly a result of systematic bias between the analytical processes of the two laboratories.

8. SUMMARY

At the NRC's request, ORISE conducted confirmatory survey activities of the California State Route 84 frontage at the GEH Vallecitos Nuclear Center in Sunol, California during the period of February 5–6, 2019. The survey activities included gamma scans, gamma direct measurements, and soil sampling.

Elevated direct gamma radiation levels above background were identified in the landscaped area near the road leading into the site. The elevated counts are attributed to NORM in the lava rocks used in the landscaping. Overall gamma scans ranged from 3,600 cpm up to 11,000 cpm. Twenty soil samples were collected throughout the CU: 13 random and seven judgmental sampling locations.

The radionuclide concentrations in the soil samples from the California State Route 84 frontage were compared to the radionuclide concentrations in soil samples collected as part of LLNL's environmental surveillance programs and from the C1/C2 area collected during a previous confirmatory survey. In addition to Cs-137, other background radionuclide concentrations were examined: K-40, Ra-226, Th-232, and U-238. The California State Route 84 frontage Cs-137 concentrations were within the range of the LLNL off-site environmental monitoring Cs-137 concentrations. The Cs-137 concentrations in the California State Route 84 frontage were lower than the Cs-137 concentrations found in the C1/C2. Thus, the null hypothesis was not rejected, concluding that the California State Route 84 frontage sample population was less than or equal to the C1/C2 sample population. Comparison of the NORM concentrations showed that the California State Route 84 frontage had similar radiological conditions as the LLNL off-site locations and the C1/C2. Therefore, all results were consistent with the non-impacted determination.

9. REFERENCES

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APPENDIX A: FIGURES

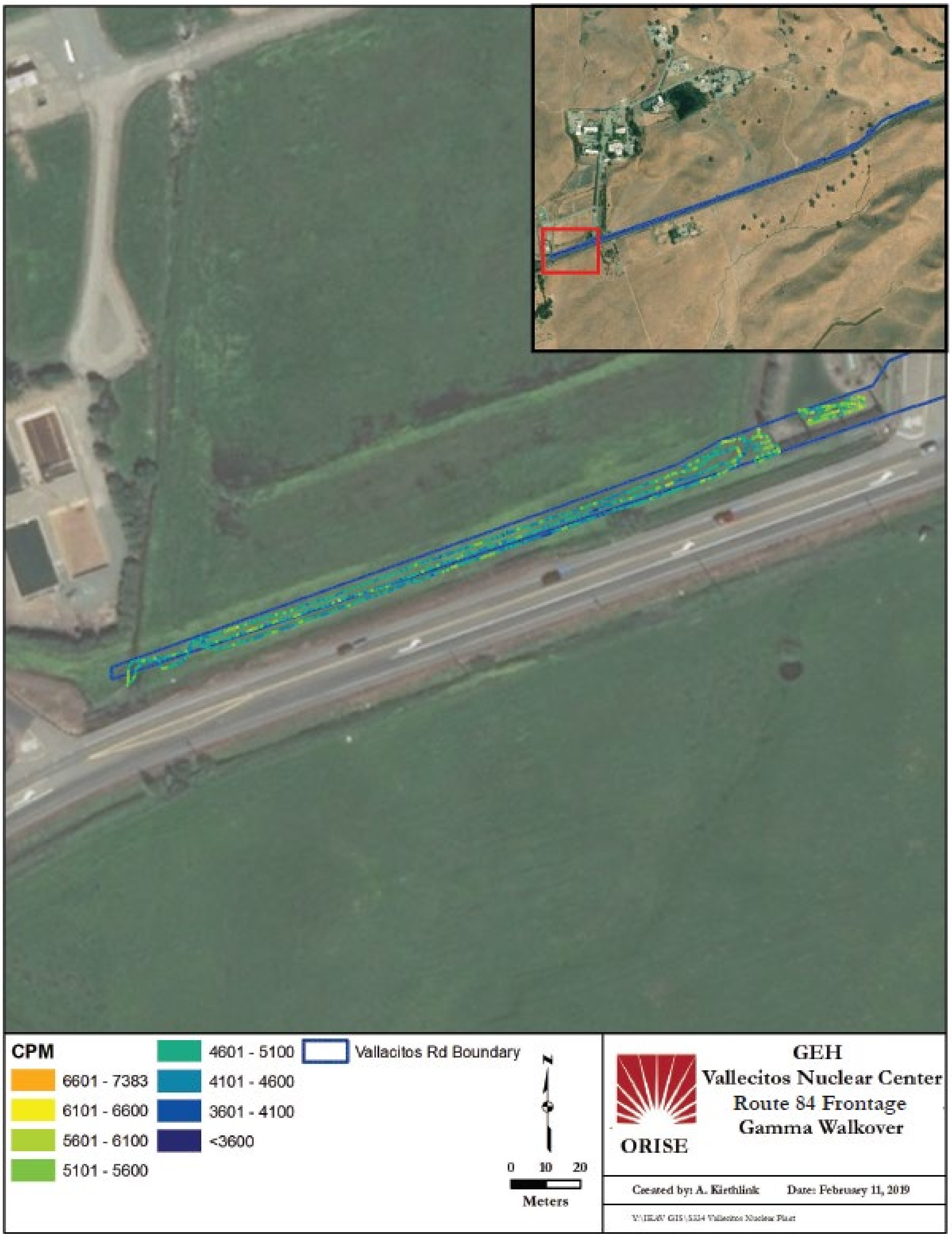

Figure A.1. Gamma Walkover Data (1 of 9)

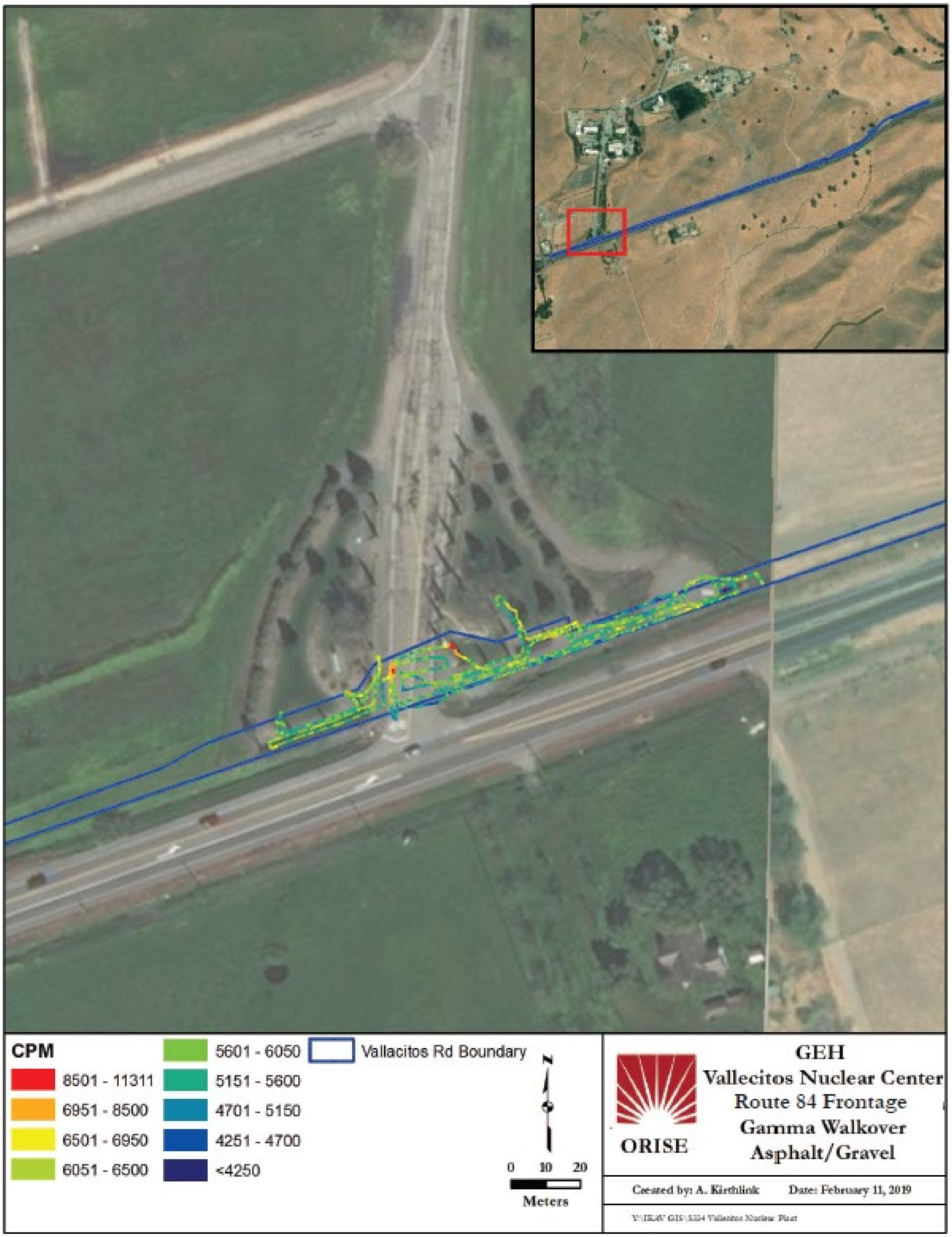

Figure A.2. Gamma Walkover Data (2 of 9) with Elevated Radiation Levels in the Landscaping

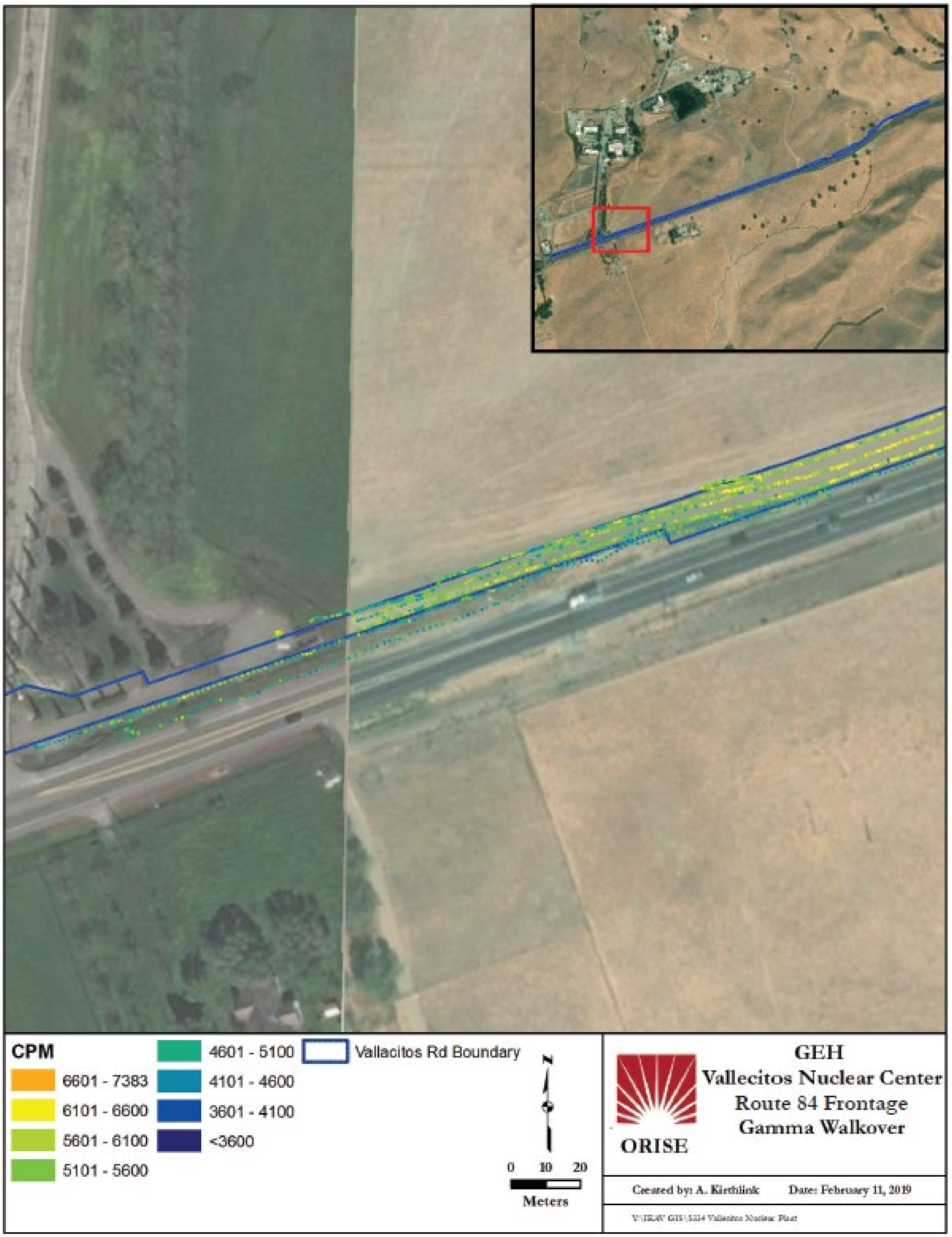

Figure A.3. Gamma Walkover Data (3 of 9)

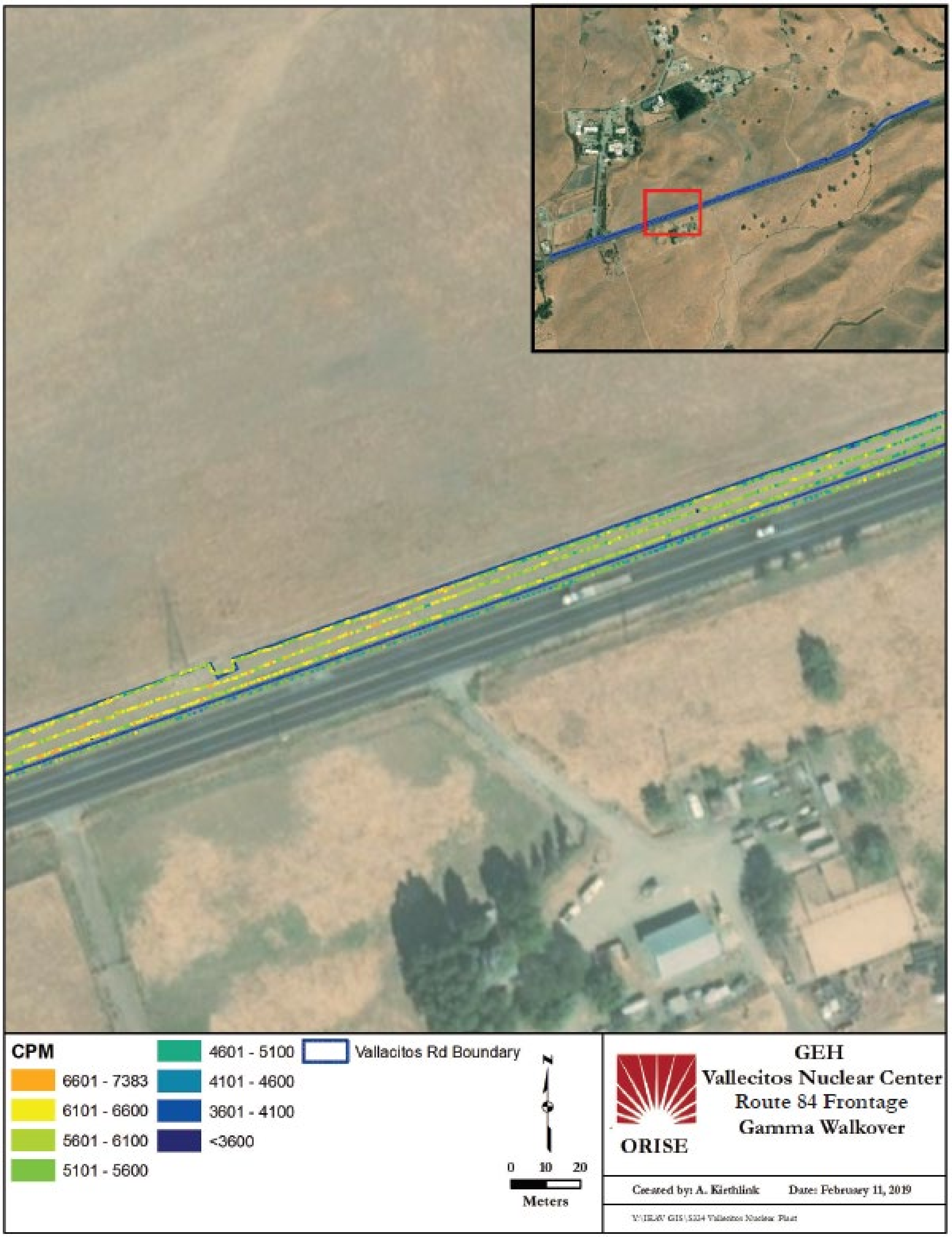

Figure A.4. Gamma Walkover Data (4 of 9)

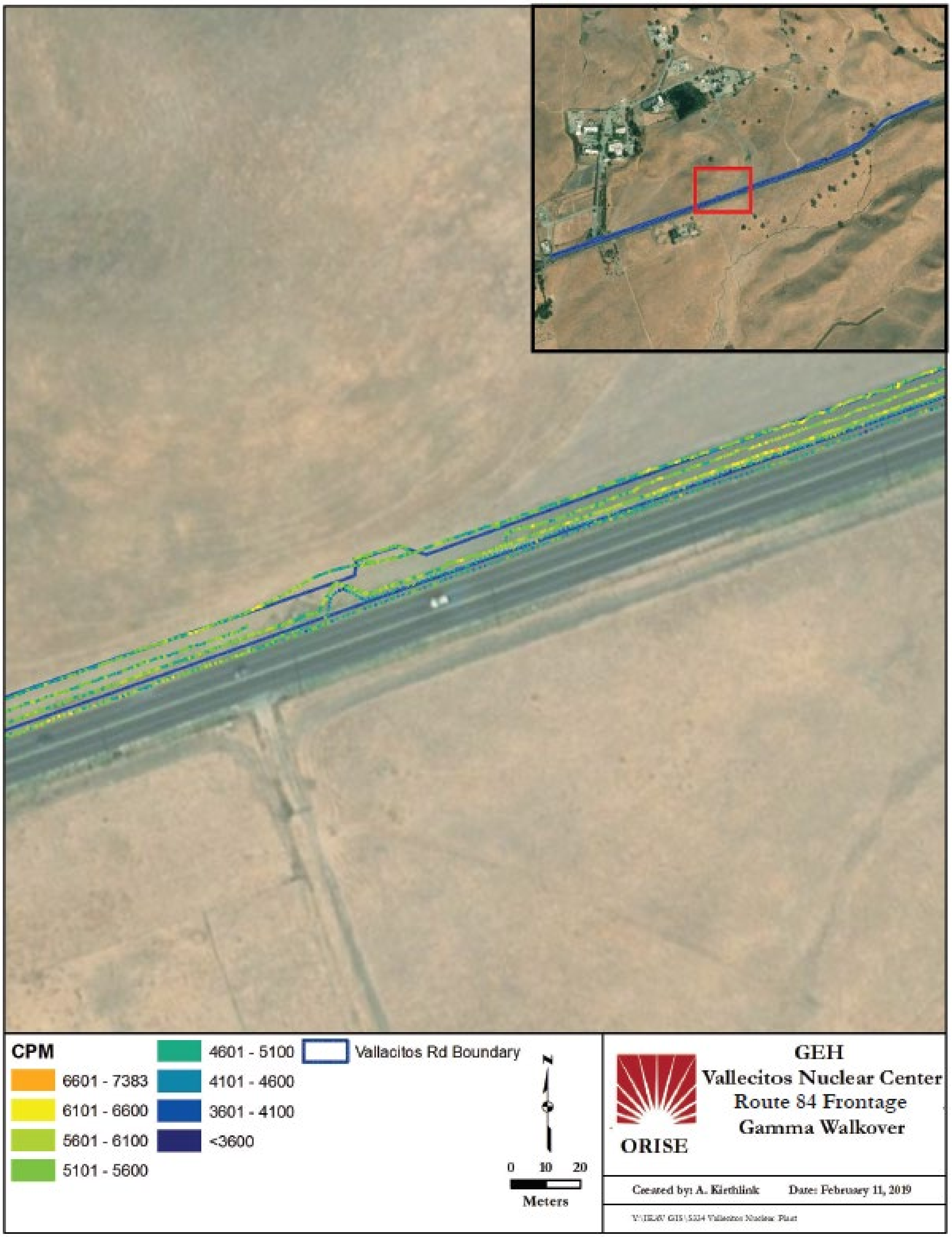

Figure A.5. Gamma Walkover Data (5 of 9)

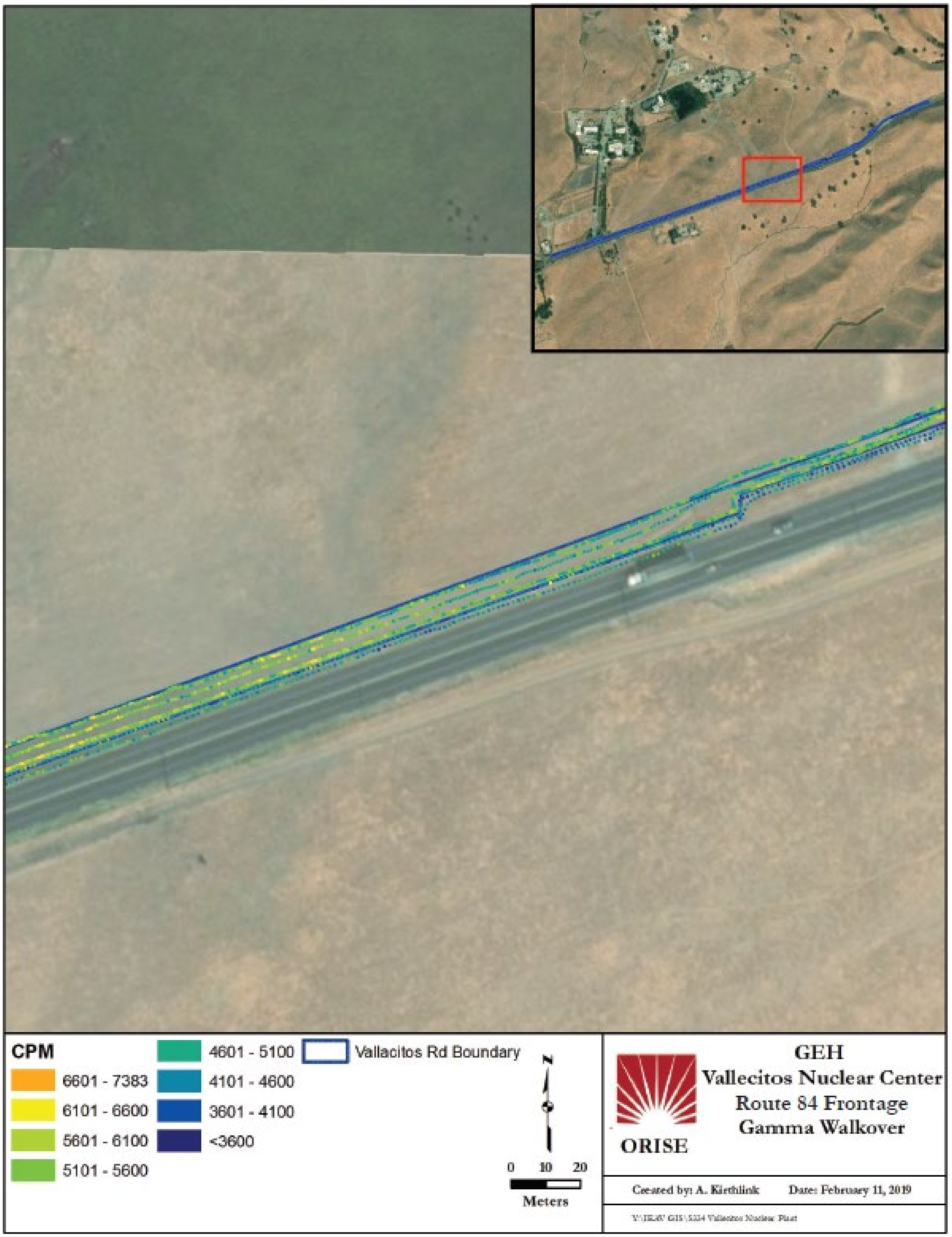

Figure A.6. Gamma Walkover Data (6 of 9)

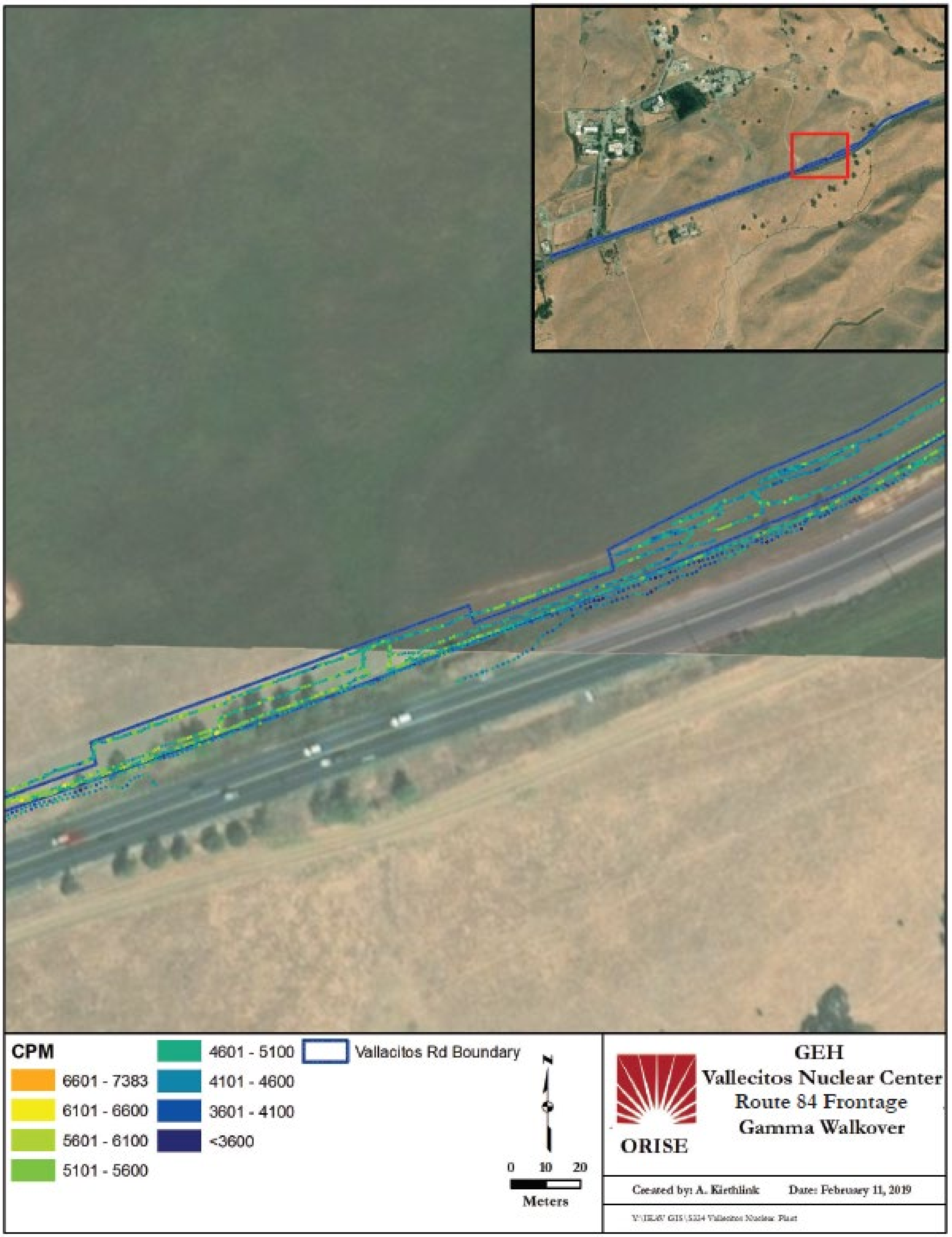

Figure A.7. Gamma Walkover Data (7 of 9)

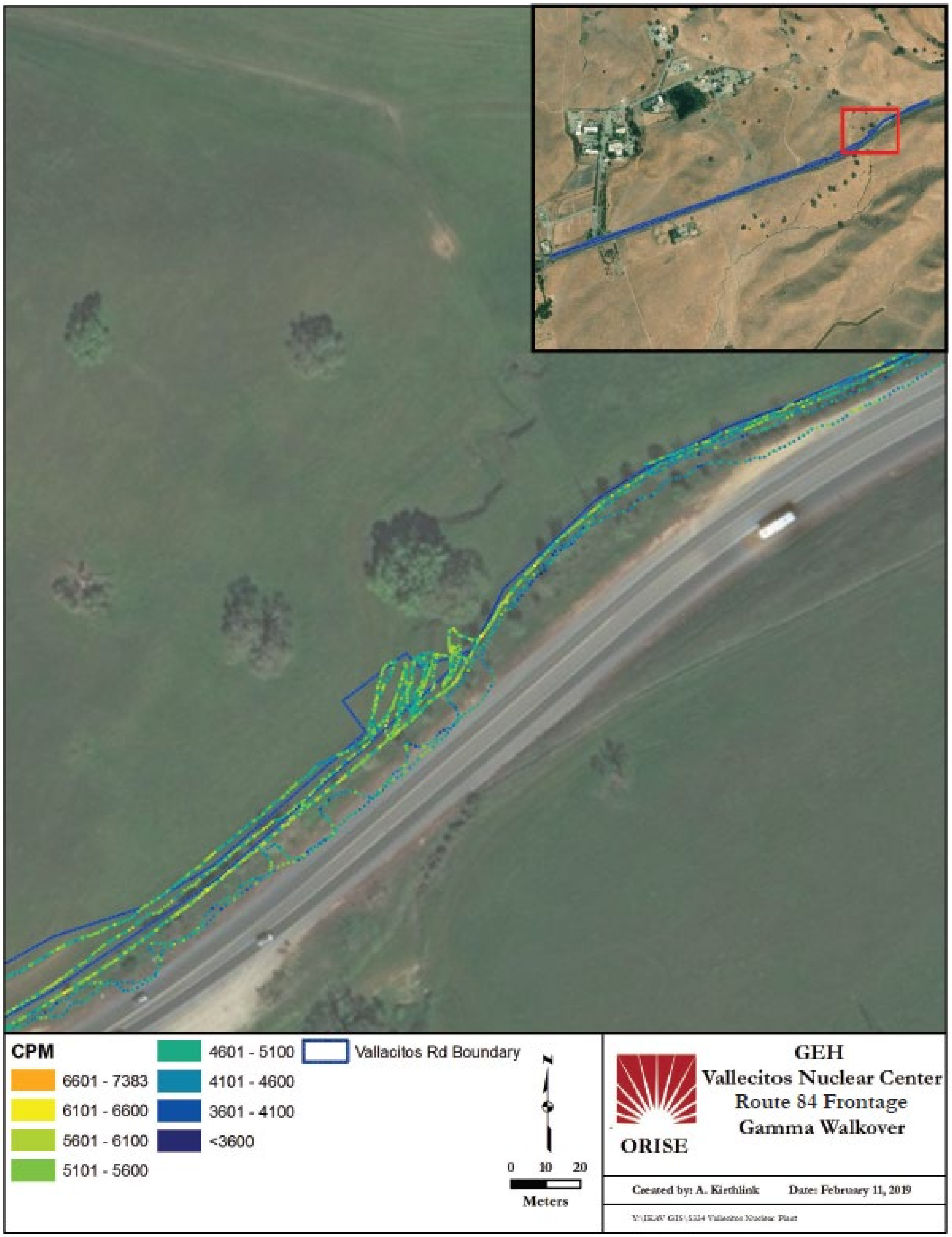

Figure A.8. Gamma Walkover Data (8 of 9)

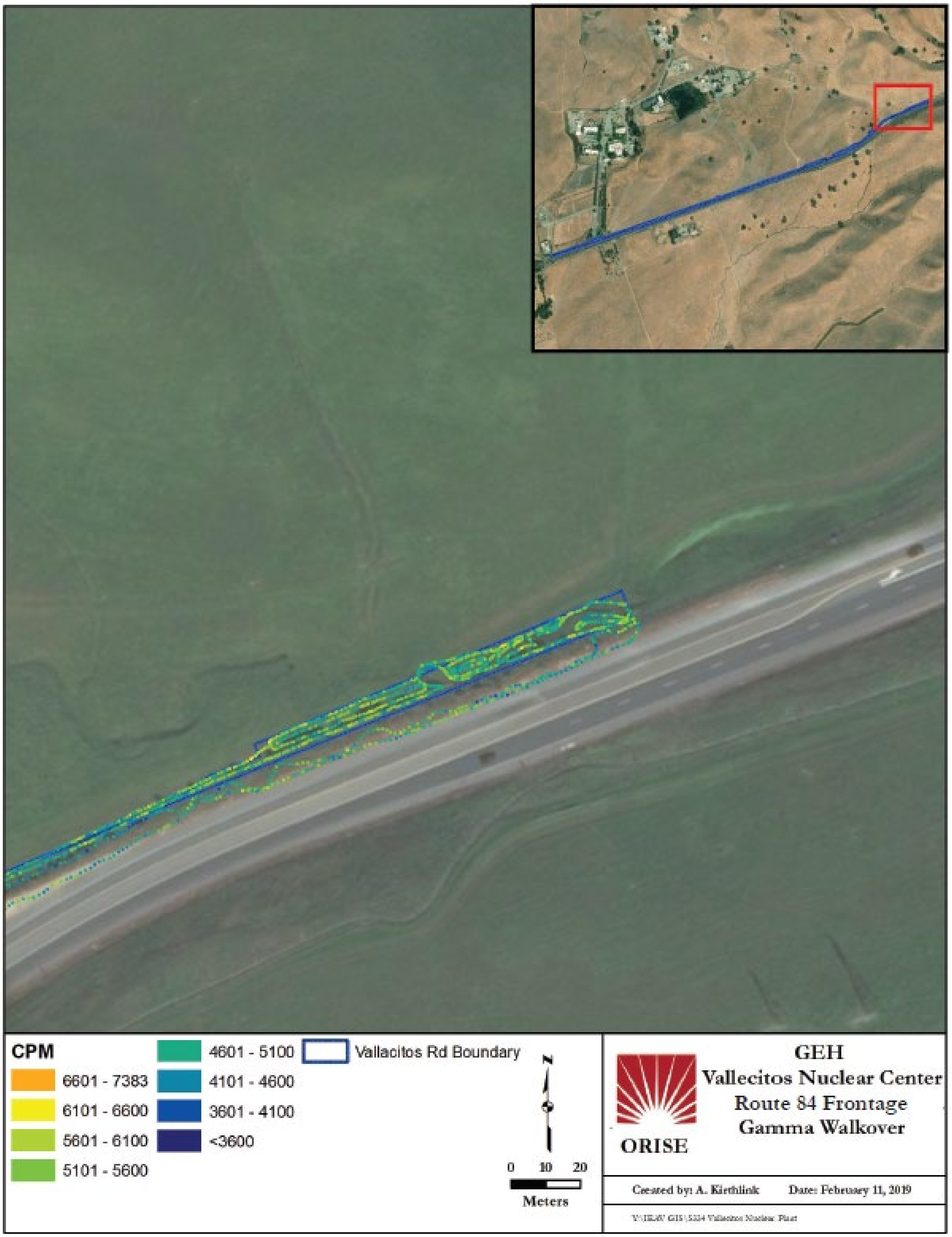

Figure A.9. Gamma Walkover Data (9 of 9)

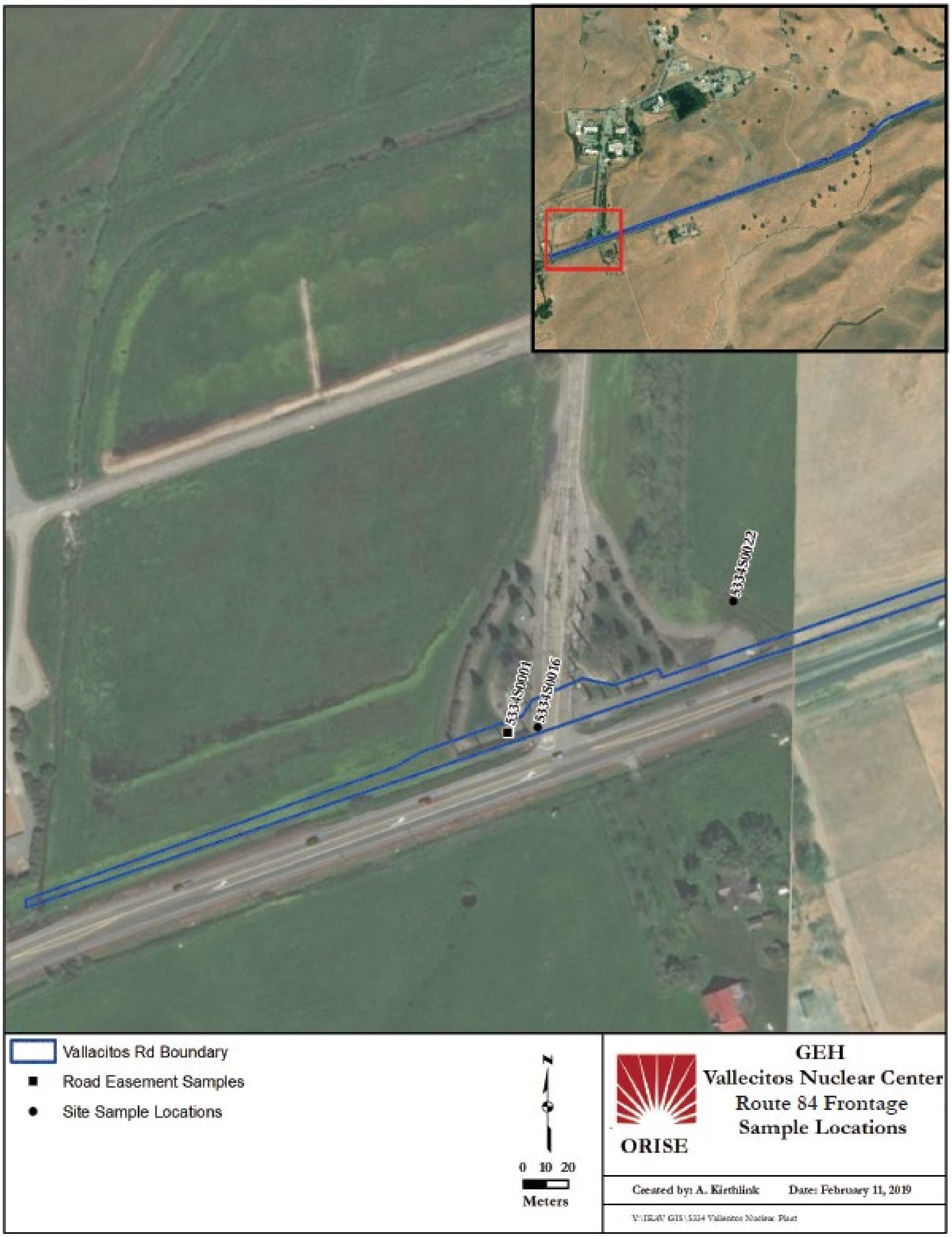

Figure A.10. Soil Sampling Locations (1 of 5)

Figure A.11. Soil Sampling Locations (2 of 5)

Figure A.12. Soil Sampling Locations (3 of 5)

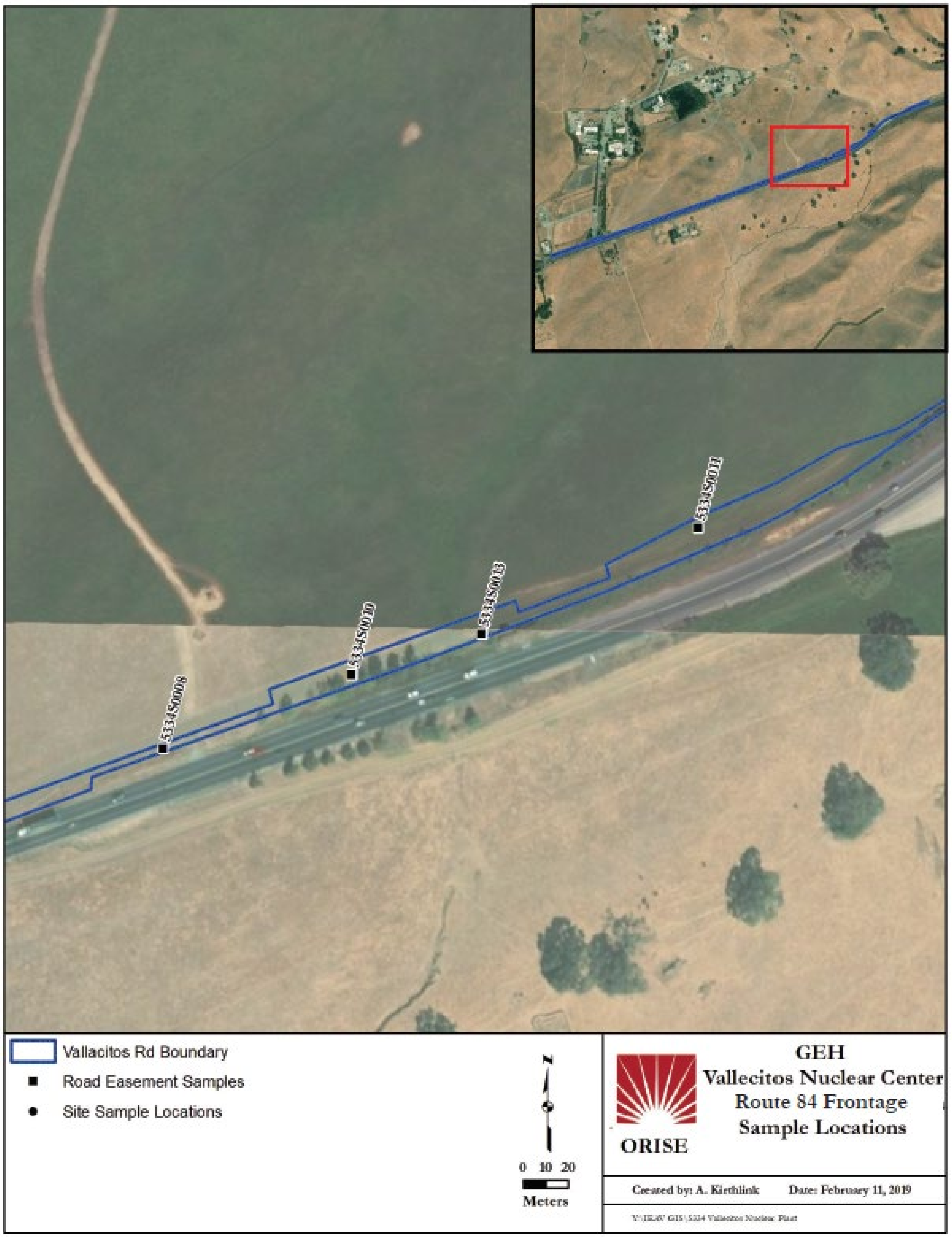

Figure A.13. Soil Sampling Locations (4 of 5)

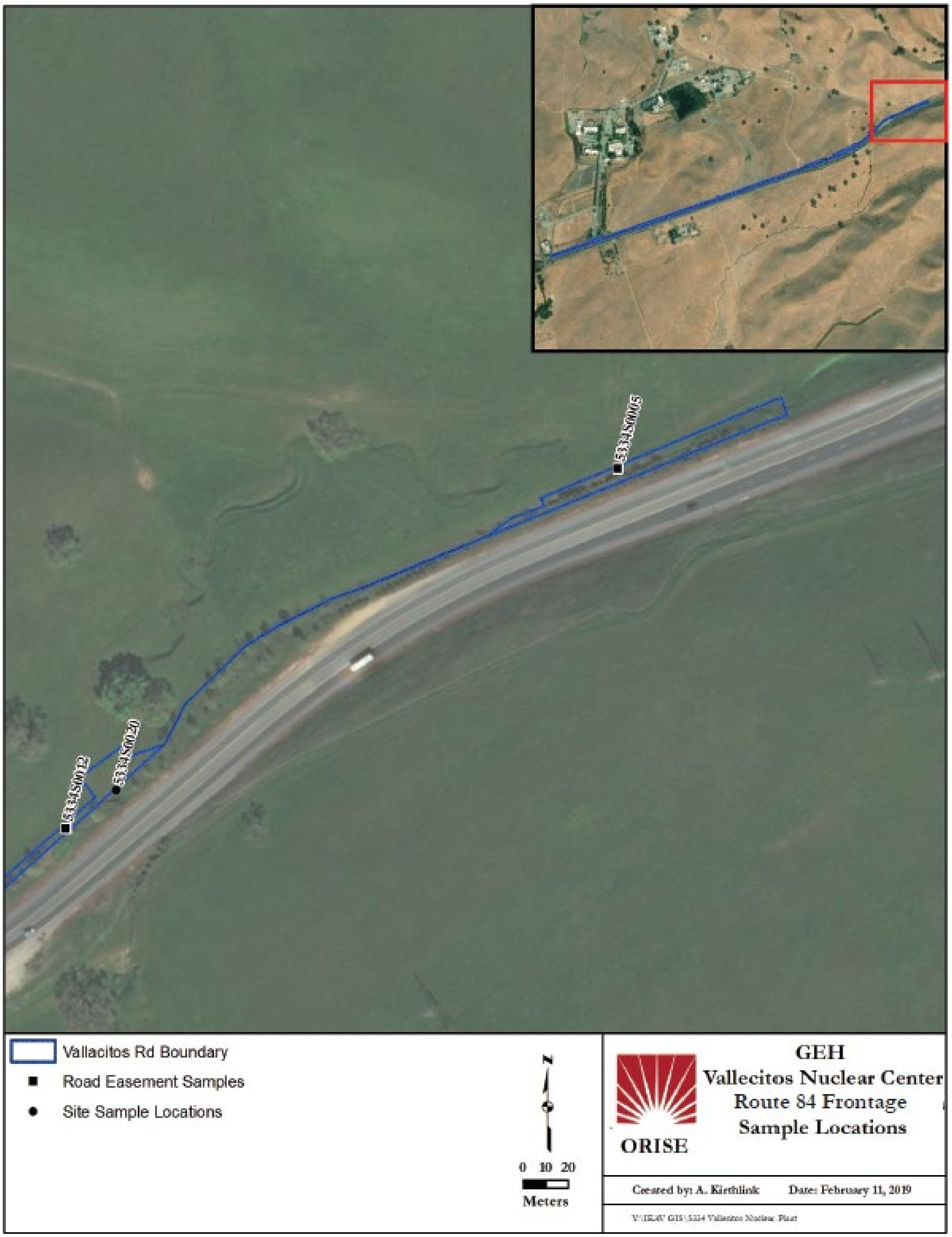

Figure A.14. Soil Sampling Locations (5 of 5)

APPENDIX B: DATA TABLE

Table B.1. Soil Sampling Measurement Locations						
Coordinates (ft)		Measurement Type	Gamma Count (cpm)		Soil Sample Number	Notes
X (Easting)	Y (Northing)		Pre-Sample	Post-Sample		
2044959	6172291	Random	5,500	6,100	5334S0001	
2045913	6175097	Random	5,400	5,900	5334S0002	
2045792	6174717	Random	5,400	6,200	5334S0003	
2045453	6173792	Random	5,700	6,300	5334S0004	
2047297	6177847	Random	5,200	5,600	5334S0005	
2045472	6173831	Random	5,500	6,300	5334S0006	
2045295	6173299	Random	6,200	7,500	5334S0007	
2046184	6175801	Random	4,900	5,700	5334S0008	
2045249	6173128	Random	5,800	6,600	5334S0009	
2046292	6176076	Random	5,200	5,900	5334S0010	
2046506	6176583	Random	4,700	4,800	5334S0011	
2046771	6177039	Random	5,000	5,500	5334S0012	
2046351	6176266	Random	4,800	5,300	5334S0013	
Mean			5,300	6,000	--	
Minimum			4,700	4,800	--	
Maximum			6,200	7,500	--	
6173364	2045927	Judgmental	5,300	5,700	5334S0014	Flagged by NRC
6173141	2043220	Judgmental	4,900	5,400	5334S0015	Site Loc. 2, Approx. Location
6172340	2044969	Judgmental	4,800	5,500	5334S0016	Site Loc. 10, using GPS coords.
6174783	2045803	Judgmental	5,000	5,400	5334S0019	Site Loc. 8, using GPS coords.
6177110	2046829	Judgmental	4,500	4,800	5334S0020	Site Loc. 9, using GPS coords.
6173133	2045219	Judgmental	4,900	5,400	5334S0021	Site Loc. 2, using GPS coords.
6172618	2045149	Judgmental	4,400	5,000	5334S0022	Site Loc. 7, using GPS coords.
Mean			4,800	5,300	--	
Minimum			4,400	4,800	--	
Maximum			5,300	5,700	--	

Table B.2. Radionuclide Concentrations in Soil Samples														
Sample	Measurement Type	Cs-137 (pCi/g)				Gross Alpha (pCi/g)				Gross Beta (pCi/g)				
		Conc.		TPU[a]	MDC[b]	Conc.		TPU	MDC	Conc.		TPU	MDC	
5334S0001	Random	0.023	±	0.014	0.029	**5.4** [c]	±	2.7	3.5	**11.6**	±	2.8	3.5	
5334S0002	Random	**0.063**	±	0.019	0.034	**6.7**	±	2.8	3.4	**11.5**	±	2.8	3.4	
5334S0003	Random	**0.046**	±	0.013	0.031	**4.0**	±	2.4	3.4	**12.9**	±	2.9	3.3	
5334S0004	Random	0.006	±	0.028	0.062	3.2	±	2.4	3.5	**6.8**	±	2.4	3.4	
5334S0005	Random	**0.073**	±	0.020	0.034	**6.8**	±	2.9	3.4	**9.4**	±	2.6	3.5	
5334S0006	Random	0.023	±	0.009	0.025	**8.5**	±	3.1	3.4	**11.1**	±	2.7	3.2	
5334S0007	Random	**0.043**	±	0.016	0.031	**6.3**	±	2.8	3.4	**13.9**	±	3.0	3.5	
5334S0008	Random	**0.103**	±	0.021	0.031	**5.4**	±	2.7	3.4	**7.2**	±	2.4	3.3	
5334S0009	Random	**0.065**	±	0.016	0.026	**4.8**	±	2.8	3.9	**13.9**	±	3.0	3.2	
5334S0010	Random	**0.059**	±	0.014	0.029	**5.7**	±	2.8	3.7	**11.0**	±	2.7	3.3	
5334S0011	Random	**0.086**	±	0.018	0.025	**6.6**	±	2.9	3.6	**7.6**	±	2.3	3.1	
5334S0012	Random	**0.057**	±	0.019	0.034	**6.6**	±	2.9	3.6	**9.0**	±	2.5	3.1	
5334S0013	Random	0.017	±	0.010	0.021	**5.1**	±	2.7	3.6	**9.9**	±	2.6	3.3	
Mean		0.051			--	5.8			--	10.4			--	
Minimum		0.006			--	3.2			--	6.8			--	
Maximum		0.103			--	8.5			--	13.9			--	
5334S0014	Judgmental	**0.066**	±	0.016	0.032	**10.0**	±	3.4	3.7	**13.6**	±	3.0	3.4	
5334S0015	Requested by NRC	**0.049**	±	0.016	0.035	**7.1**	±	3.0	3.6	**11.9**	±	2.7	3.1	
5334S0016	Requested by NRC	**0.056**	±	0.015	0.025	3.2	±	2.4	3.6	**10.2**	±	2.6	3.2	
5334S0019	Requested by NRC	**0.065**	±	0.017	0.030	**10.2**	±	3.5	3.8	**13.1**	±	2.9	3.3	
5334S0020	Requested by NRC	0.010	±	0.012	0.029	**4.5**	±	2.7	3.8	**11.4**	±	2.7	3.3	
5334S0021	Requested by NRC	**0.043**	±	0.014	0.027	**8.1**	±	3.2	3.9	**10.0**	±	2.6	3.3	
5334S0022	Requested by NRC	**0.071**	±	0.016	0.024	**4.3**	±	2.6	3.8	**9.8**	±	2.5	3.2	
Minimum		0.010			--	3.2			--	9.8			--	
Maximum		0.071			--	10.2			--	13.6			--	

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

Table B.3. NORM Radionuclide Concentrations in Soil Samples																	
Sample	Measurement Type	K-40 (pCi/g)				Ra-226 (pCi/g)				U-238 (pCi/g)				Th-232 (pCi/g)			
		Conc.		TPU[a]	MDC[b]	Conc.		TPU	MDC	Conc.		TPU	MDC	Conc.		TPU	MDC
5334S0001	Random	**8.41** [c]	±	0.86	0.44	**0.506**	±	0.054	0.049	0.49	±	0.31	0.67	**0.56**	±	0.10	0.14
5334S0002	Random	**8.28**	±	0.80	0.49	**0.460**	±	0.049	0.049	**0.76**	±	0.29	0.48	**0.67**	±	0.10	0.12
5334S0003	Random	**7.18**	±	0.74	0.61	**0.439**	±	0.050	0.060	0.72	±	0.55	1.21	**0.584**	±	0.097	0.119
5334S0004	Random	**6.43**	±	0.83	0.83	**0.322**	±	0.048	0.060	0.42	±	0.27	0.59	**0.45**	±	0.11	0.17
5334S0005	Random	**7.12**	±	0.76	0.49	**0.432**	±	0.050	0.046	0.59	±	0.30	0.61	**0.442**	±	0.094	0.125
5334S0006	Random	**8.06**	±	0.73	0.44	**0.449**	±	0.047	0.057	**0.64**	±	0.24	0.40	**0.567**	±	0.085	0.088
5334S0007	Random	**10.35**	±	0.98	0.66	**0.520**	±	0.057	0.067	1.04	±	0.63	1.33	**0.67**	±	0.11	0.12
5334S0008	Random	**5.94**	±	0.68	0.44	**0.382**	±	0.049	0.052	**0.58**	±	0.28	0.54	**0.514**	±	0.098	0.110
5334S0009	Random	**9.57**	±	0.84	0.45	**0.495**	±	0.047	0.044	**0.73**	±	0.26	0.43	**0.699**	±	0.099	0.107
5334S0010	Random	**7.34**	±	0.74	0.59	**0.512**	±	0.052	0.055	**1.18**	±	0.59	1.16	**0.517**	±	0.090	0.115
5334S0011	Random	**4.33**	±	0.53	0.57	**0.385**	±	0.046	0.056	0.54	±	0.49	1.09	**0.475**	±	0.083	0.099
5334S0012	Random	**7.30**	±	0.77	0.43	**0.444**	±	0.051	0.049	0.39	±	0.26	0.57	**0.53**	±	0.10	0.13
5334S0013	Random	**6.12**	±	0.59	0.37	**0.357**	±	0.037	0.040	**0.60**	±	0.22	0.36	**0.435**	±	0.071	0.077
Mean		7.42			--	0.439			--	0.67			--	0.547			--
Minimum		4.33			--	0.322			--	0.39			--	0.435			--
Maximum		10.35			--	0.520			--	1.18			--	0.699			--
5334S0014	Judgmental	**10.19**	±	0.96	0.66	**0.510**	±	0.056	0.062	0.46	±	0.58	1.34	**0.66**	±	0.11	0.13
5334S0015	Requested by NRC	**7.49**	±	0.80	0.46	**0.482**	±	0.056	0.057	**0.77**	±	0.32	0.58	**0.59**	±	0.11	0.14
5334S0016	Requested by NRC	**6.61**	±	0.68	0.37	**0.418**	±	0.045	0.045	**0.77**	±	0.29	0.50	**0.518**	±	0.091	0.113
5334S0019	Requested by NRC	**7.42**	±	0.71	0.68	**0.450**	±	0.050	0.068	0.36	±	0.45	1.04	**0.625**	±	0.093	0.115
5334S0020	Requested by NRC	**6.57**	±	0.64	0.61	**0.361**	±	0.042	0.058	0.32	±	0.42	0.98	**0.411**	±	0.075	0.110
5334S0021	Requested by NRC	**8.64**	±	0.76	0.41	**0.469**	±	0.044	0.039	**0.73**	±	0.25	0.41	**0.625**	±	0.089	0.092
5334S0022	Requested by NRC	**7.28**	±	0.69	0.46	**0.393**	±	0.048	0.071	**0.80**	±	0.30	0.51	**0.687**	±	0.097	0.093
Minimum		6.57			--	0.361			--	0.32			--	0.411			--
Maximum		10.19			--	0.510			--	0.80			--	0.687			--

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

Table B.4. C1/C2 Cs-137 and NORM Concentrations (pCi/g)						
C1/C2 Sample ID	Year	Cs-137	K-40	Ra-226	U-238	Th-232
5273S0001	2015	0.058	12.2	0.5	0.51	0.65
5273S0002	2015	0.186	9.4	0.452	0.54	0.65
5273S0003	2015	0.128	6.15	0.421	0.53	0.536
5273S0004	2015	0.093	13.1	0.424	0.56	0.79
5273S0005	2015	0.179	8.74	0.503	0.74	0.554
5273S0006	2015	0.129	11.7	0.508	0.8	0.68
5273S0007	2015	0.130	9.13	0.331	0.53	0.549
5273S0008	2015	0.129	15.4	0.554	0.87	0.83
5273S0009	2015	0.201	8.62	0.428	0.9	0.58
5273S0010	2015	0.123	8.43	0.366	0.34	0.479
5273S0011	2015	0.116	7.74	0.391	0.5	0.566

Table B.5. VNC Gross Alpha and Gross Beta Concentrations (pCi/g)			
VNC Sample ID	Year	Gross Alpha	Gross Beta
S01	2018	10.5	16.2
S02	2018	14.8	12.5
S03	2018	10.3	8.60
S04	2018	8.00	8.13
S05	2018	8.95	13.3
S06	2018	7.34	10.8
S07	2018	14.3	13.7
S08	2018	14.4	16.7
S09	2018	8.06	33.2
S10	2018	11.9	37.9
S11	2018	7.12	6.19
S12	2018	6.38	9.33
S13	2018	9.5	19.7
S14	2018	14	12.3
S15	2018	12.2	12.9
S16	2018	13.3	15.3

Table B.6. 2009-2013 LLNL Concentrations (pCi/g)[a]									
LLNL Sample ID	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cs-137 Concentrations Decay-Corrected to 2019									
L-AMON-SO	0.0365	0.017	0.0630	0.018	0.087	0.0747	0.0567	0.101	0.0929
L-CHUR-SO	0.0580	0.0527	0.094	0.0575	0.099	0.0651	0.0838	0.0656	0.0800
L-FCC-SO	0.0408	0.017	0.016	0.02992	0.0235	0.0386	0.0271	0.0277	0.0284
L-HOSP-SO	0.0344	0.0242	0.0337	0.0391	0.0330	0.0313	0.0345	0.111	0.147
L-PATT-SO	0.0236	0.015	0.021	0.0322	0.020	0.018	0.018	0.0404	0.0284
L-TANK-SO	0.0430	0.0549	0.0495	0.0437	0.0518	0.0410	0.0592	0.0429	0.0516
L-ZON7-SO	0.0073	0.009	0.017	0.016	0.014	0.016	0.015	0.013	0.015
K-40 Concentrations									
L-AMON-SO	14.11	13.70	14.70	13.11	14.19	15.30	15.59	15.89	14.81
L-CHUR-SO	13.11	13.11	13.30	13.00	13.30	13.51	13.51	13.70	13.81
L-FCC-SO	11.30	9.378	10.00	10.19	10.41	10.70	9.351	9.2703	9.703
L-HOSP-SO	10.41	11.59	9.9459	12.70	10.486	10.405	10.486	11.189	11.89
L-PATT-SO	14.89	14.19	12.89	16.00	12.49	13.70	13.59	11.41	11.70
L-TANK-SO	8.8378	9.2432	8.270	8.8378	9.297	9.5135	9.081	8.0000	9.568
L-ZON7-SO	10.59	10.89	10.41	11.11	10.108	10.00	10.70	9.784	11.00
U-238 Concentrations									
L-AMON-SO	0.673	0.74	0.67	0.74	0.57	0.74	0.84	0.71	0.67
L-CHUR-SO	0.77	0.50	0.81	0.84	0.61	0.77	0.54	0.77	0.74
L-FCC-SO	0.77	0.47	0.54	0.50	0.57	0.437	0.44	0.30	0.370
L-HOSP-SO	0.64	0.639	0.47	0.606	0.606	0.471	0.81	0.370	0.47
L-PATT-SO	0.50	0.67	0.54	0.639	0.77	0.71	0.54	0.57	0.404
L-TANK-SO	0.54	0.538	0.538	0.505	0.54	0.538	0.64	0.370	0.54
L-ZON7-SO	1.6	2.5	2.6	1.9	2.0	2.6	1.7	1.9	2.3
Th-232 Concentrations									
L-AMON-SO	0.929	0.831	0.929	0.831	0.754	0.918	0.918	0.951	0.885
L-CHUR-SO	0.820	0.809	0.940	0.907	0.863	0.907	0.853	0.929	0.929
L-FCC-SO	0.656	0.634	0.721	0.689	0.656	0.710	0.590	0.579	0.656
L-HOSP-SO	0.623	0.645	0.634	0.678	0.546	0.557	0.557	0.514	0.568
L-PATT-SO	0.820	0.853	0.809	0.940	0.721	0.885	0.842	0.874	0.798
L-TANK-SO	0.700	0.743	0.667	0.634	0.754	0.787	0.754	0.634	0.820
L-ZON7-SO	0.831	0.863	0.896	0.929	0.787	0.896	0.907	0.798	0.940

[a] Ra-226 concentrations not available.

Table B.7. Results of the Student (Pooled) t-Test					
Date/Time of Computation		ProUCL 5.1 7/2/2019 12:47:43 PM			
From File		WorkSheet.xls			
Full Precision		OFF			
Confidence Coefficient		95%			
Substantial Difference (S)		0			
Selected Null Hypothesis		Sample 1 Mean <= Sample 2 Mean (Form 1)			
Alternative Hypothesis		Sample 1 Mean > the Sample 2 Mean			
Sample 1 Data: ORISE					
Sample 2 Data: C1/C2					
Sample 1 vs Sample 2 Two-Sample t-Test					
H_0: Mean of Sample 1 - Mean of Sample 2 <= 0					
Method		DF	t-Test Value	Critical t (0.05)	P-Value
Pooled (Equal Variance)		22	-5.774	1.717	1
Pooled SD 0.035					
Conclusion with Alpha = 0.050					
Student t (Pooled) Test: Do Not Reject H_0 Conclude Sample 1 <= Sample 2					
Test of Equality of Variances					
Variance of Sample 1			8.09E-04		
Variance of Sample 2			0.00172		
Numerator DF	Denominator DF	F-Test Value	P-Value		
10	12	2.128	0.216		
Conclusion with Alpha = 0.05					
Two variances appear to be equal					

APPENDIX C: SURVEY AND ANALYTICAL PROCEDURES

C.1. PROJECT HEALTH AND SAFETY

ORISE performed all survey activities in accordance with the *ORAU Radiation Protection Manual*, the *ORAU Health and Safety Manual*, and the *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2014, ORAU 2016b, and ORAU 2016a). 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 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.

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 documents:

- *ORAU Radiological and Environmental Survey Procedures Manual* (ORAU 2016a)
- *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2017)
- *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2018)

The procedures contained in these manuals were developed to meet the requirements of U.S. Department of Energy (DOE) Order 414.1D and the 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 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 concentrations (MDCs) for the sodium iodide (NaI) scintillation detectors were not determined because 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.

C.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.

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 into an appropriate volume Marinelli beaker or container. 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 computer capabilities inherent in the analyzer system. All total absorption peaks (TAPs) associated with the ROCs 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 MDCs for a 1-hour count time for ROCs are presented in Table C.1.

Table C.1. Typical MDCs Total Absorption Peak for Gamma Emitters

Radionuclide	TAP (keV)[a]	MDC (pCi/g)
Cs-137	661.66	0.05
U-238 by Th-234	63.29	0.75
Ra-226 by Pb-214	351.93	0.08
K-40	1,460.82	0.5
Th-232 by Ac-228	911.20	0.14

[a]kilo electron volt

C.4.2 Low Background Proportional Counter

Samples were dried and processed to provide homogeneity, and a known quantity was transferred to a planchet and counted in a low-background proportional counter. The activity determined by this method is not indicative of any specific nuclide, but, instead, gross alpha and gross beta. Samples were counted for 200 minutes. Typical MDCs are 3.8 pCi/g for alpha and 3.3 pCi/g for beta.

C.4.3 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.

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 Geo 7X
(Trimble Navigation Limited, Sunnyvale, CA)

D.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)