November 3, 2016

Ms. Rachel Browder, CHP
Sr. Health Physicist
U.S. Nuclear Regulatory Commission, Region IV
1600 East Lamar Blvd.
Arlington, TX 76011-4511

**SUBJECT: INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY HARMON AVENUE COMPLEX ON THE UNIVERSITY OF NEVADA, LAS VEGAS CAMPUS
LAS VEGAS, NEVADA
[RFTA No. 16-014, Docket No. 03006981]
DCN 5297-SR-01-0**

Dear Ms. Browder:

The Oak Ridge Institute for Science and Education (ORISE), managed by ORAU for DOE, is pleased to provide the enclosed final report detailing the independent confirmatory survey activities of the U.S. Environmental Protection Agency Harmon Avenue Complex on the University of Nevada, Las Vegas. This report provides the summary and results of the ORISE activities performed during the period of September 26-29, 2016. Comments on this draft document will be incorporated into the final report.

You may contact me at 865.574.7008 or David King at 865.574.0685 if you have any questions.

Sincerely,

Kaitlin M. Engel
Health Physicist
ORAU

KME:lw

Enclosure

electronic distribution: T. Carter, NRC HQ; D. King, ORAU; T. Vitkus, ORAU; File/5297; S. Roberts, ORAU; E. Bailey, ORAU; D. Hagemeyer, ORAU

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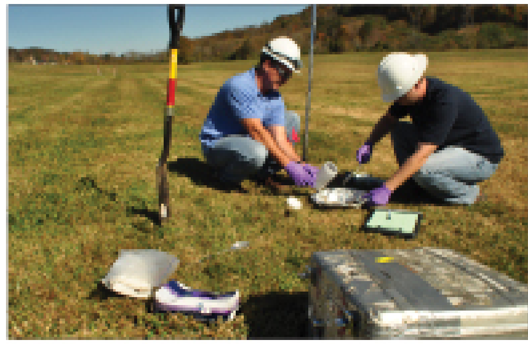

INDENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY HARMON AVENUE COMPLEX ON THE UNIVERSITY OF NEVADA, LAS VEGAS CAMPUS LAS VEGAS, NEVADA

K. M. Engel
ORAU

FINAL REPORT

Prepared for the U.S. Nuclear Regulatory Commission

November 2016

NOTICES

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY HARMON AVENUE COMPLEX ON THE UNIVERSITY OF NEVADA, LAS VEGAS CAMPUS LAS VEGAS, NEVADA

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
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Prepared by
K. M. Engel
ORAU

NOVEMBER 2016

FINAL REPORT

Prepared for the
U.S. Nuclear Regulatory Commission

This document was prepared for U.S. Nuclear Regulatory Commission by the Oak Ridge Institute for Science and Education (ORISE) through an interagency agreement with the U.S. Department of Energy (DOE) (NRC FIN No. F-1244). ORISE is managed by Oak Ridge Associated Universities under DOE contract number DE-SC0014664.

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY HARMON AVENUE COMPLEX ON THE UNIVERSITY OF NEVADA LAS VEGAS CAMPUS LAS VEGAS, NEVADA

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FINAL REPORT

November 2016

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ACRONYMS

CHL	Chemistry Laboratory
CPM	counts per minute
CU	confirmatory unit
DCGL	derived concentration guideline level
DPM	disintegrations per minute
EAX	Exposure Assessment Annex
EPA	U.S. Environmental Protection Agency
EXC	Executive Center
FSS SU	final status survey-survey unit
FSSR	final status survey report
HAC	Harmon Avenue Complex
MDC	minimum detectable concentration
MSL	Monitoring Systems Laboratory
NaI	sodium iodide
NCRFO	National Center for Radiation Field Operations
NIST	National Institute of Standards and Technology
NORM	naturally occurring radioactive material
NRC	U.S. Nuclear Regulatory Commission
OAR	Office of Air and Radiation
ORAU	Oak Ridge Associated Universities
ORD	Office of Research and Development
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram
POS	Program Operations Support
QAL	Quality Assurance Laboratory
REAL	Radiological and Environmental Analytical Laboratory
ROC	radionuclide of concern
UNLV	University of Nevada, Las Vegas

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY HARMON AVENUE COMPLEX ON THE UNIVERSITY OF NEVADA, LAS VEGAS CAMPUS LAS VEGAS, NEVADA

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that the Oak Ridge Institute for Science and Education (ORISE), managed by ORAU for DOE, perform confirmatory survey activities of the U.S. Environmental Protection Agency (EPA) Harmon Avenue Complex (HAC) on the University of Nevada, Las Vegas (UNLV) campus in Las Vegas, Nevada. Confirmatory activities are intended to ensure, if supported by the results, that the EPA's final status survey data accurately represent final site conditions. The confirmatory survey, performed September 26-29, 2016, included gamma scans, beta scans, alpha and beta direct measurements, and indirect measurements (smears) of the three buildings associated with the HAC. The confirmatory survey did not identify any areas of residual contamination (excluding NORM) in excess of either the decommissioning criteria or the survey unit classification limits. ORISE results confirm that the licensee's results demonstrate compliance with the release criteria for unrestricted use as established in 10 CFR 20.1402.

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY HARMON AVENUE COMPLEX ON THE UNIVERSITY OF NEVADA, LAS VEGAS CAMPUS LAS VEGAS, NEVADA

1. INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) requested that the Oak Ridge Institute for Science and Education (ORISE), managed by ORAU for DOE, perform confirmatory surveys of three buildings located within the U.S. Environmental Protection Agency's Harmon Avenue Complex (HAC) on the campus of the University of Nevada, Las Vegas. The HAC includes the Exposure Assessment Annex (EAX), Quality Assurance Laboratory (QAL), and Monitoring Systems Laboratory (MSL) (sometimes called Program Operations Support [POS]).

The EPA Office of Research and Development (ORD) and Office of Air and Radiation (OAR) operates the HAC under the National Center for Radiation Field Operations' (NCRFO) NRC radioactive materials License #27-05861-02. EPA's current lease of the HAC with UNLV expired on September 30, 2016. The facilities will be cleared of movable contents and once EPA turns over these buildings, it is anticipated that UNLV will reoccupy the space with the exception of the EAX, which will be demolished (EPA 2016a). EPA performed a final status survey using the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* guidance (NRC 2000). At the request of NRC, ORISE performed an independent radiological confirmatory survey to confirm that residual surface activity levels for the radionuclides of concern (ROCs), primarily Pb-210 and Am-241, satisfy derived concentration guideline levels (DCGLs) and to ensure that the EPA's final status survey data accurately represent final site conditions.

2. SITE DESCRIPTION

The HAC is located at 944 East Harmon Avenue, approximately 0.5 kilometers east of its intersection with Swenson Street, on the UNLV campus in Las Vegas, Nevada. The HAC consists of a complex of five separate buildings on a contiguous piece of property and associated parking lots. From west to east (left to right) in Figure 2.1 (EPA 2016a), the buildings include the EAX, the QAL building, the MSL/POS building, the Executive Center (EXC) building, and the Chemistry Laboratory (CHL) building. The facilities house laboratories, offices, common areas, and office

supply, equipment, and hazardous material storage areas. Only EAX, QAL, and about one-third of the MSL/POS were included in the scope of this confirmatory survey effort, as indicated in red in Figure 2.1.

Figure 2.1. HAC – University of Nevada, Las Vegas

Construction of the buildings was completed between 1966 and 1967 with the exception of an addition to the EAX, which was completed in 1976. The EAX building was formerly used as a greenhouse and is mostly constructed of steel framing on a slab-on-grade foundation. Corrugated and flat sheet-metal panels cover the exterior walls and roof of the structure, which replaced glass panels that formerly covered the greenhouse. The northern portion of this structure is constructed of concrete brick walls and a flat built-up roof. QAL and POS are one-story structures constructed on slab-on-grade foundations of concrete brick walls, with some exterior stucco and stone veneer features, and flat built-up roofs. EXC is a similarly constructed two-story building with a concrete basement foundation under a small portion of the structure and a slab-on-grade foundation under the remainder of the structure. CHL is constructed similarly to the QAL and POS (EPA 2016a).

EPA's work at this facility emphasized radiological monitoring, environmental sampling, radionuclide translocation and uptake studies, analytical chemistry, and characterizing chemical and

physical stressors based on ecological exposure. ORD and OAR Laboratory staff activities typically involved field-based sample collection, monitoring ecological exposures, computer-based modeling, radioactive contamination site assessments, applying monitoring technology, and laboratory work—both chemical and radiological (EPA 2016a).

3. OBJECTIVE

The objective of the confirmatory survey activities was to generate independent radiological data for use by the NRC in evaluating the accuracy and adequacy of the licensee's results.

4. APPLICABLE SITE GUIDELINES

Based on the review of historical records, process knowledge, and the results of characterization and remedial investigation surveys, the residual radioactivity potential for HAC facilities has been reduced to a few credible ROCs. The ROCs were further reduced based upon the results of the characterization survey data. While only a few samples may have indicated the presence of tritium (H-3), these samples were very low in concentration, such that it was less than 1% of the total radioactivity as well as potential dose. Therefore, H-3 was eliminated as an ROC for this effort. Other potential ROCs included one beta emitter: lead-210 (Pb-210) and seven alpha emitters: radium-226 (Ra-226), uranium-234 (U-234), uranium-235 (U-235), uranium-238 (U-238), plutonium (Pu-238), plutonium-239 (Pu-239), and americium-241(Am-241). The licensee selected the most restrictive of the corresponding alpha and beta DCGLs, which are for Am-241 and Pb-210, for survey design and data comparison (EPA 2016a). The licensee's final status survey report (FSSR) presents release criteria for target HAC ROCs, which were taken directly from NUREG-1767 Appendix B (EPA 2016a; NRC 2006). These default criteria/DCGLs are listed in Table 4.1 below.

Table 4.1. DCGL Concentration Limits Equivalent to 25 mrem/year	
ROC	**DCGL (dpm/100 cm^2)[a]**
Pb-210	550
Am-241	27

[a] From NUREG/CR-5512, Vol. 3 (NRC 1999)

5. PROCEDURES

The confirmatory survey activities were conducted during the period of September 26-29, 2016, in accordance with the approved 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 2016d and 2016b).

5.1 Reference System

All data measurement locations were referenced to a Cartesian coordinate system corresponding to either the specific X-Y coordinates from the southwest corner of an individual room floor or the lower left corner of walls. Direct measurement locations were referenced to the site's direct measurement locations. Indirect measurements (smears) were numbered/labeled according to ORAU 2015b and referenced to the direct measurement location.

5.2 Surface Scans

Beta radiation surface scans were performed at judgmentally selected locations with a Ludlum model 44-142 plastic scintillator coupled to a Ludlum Model 2221 ratemeter-scaler. Focus was given to areas that appeared to have a high potential for contamination (near floor drains, under sinks, discolored areas, etc.). Low to medium density gamma radiation scans of the floor and walls (up to 6 feet) were performed using a Ludlum model 44-10 sodium iodide (NaI) detector, coupled to a Ludlum Model 2221 ratemeter-scaler. Areas of elevated radiation, as indicated by an audible increase in output from the ratemeter-scaler, were marked for further investigation.

5.3 SURFACE ACTIVITY MEASUREMENTS

Total alpha and beta surface activity measurements were collected from both judgmental locations and, where identifiable, at licensee FSS random locations. Eighty-nine direct measurements were collected from the Class 1 and 2 survey units and were approximately in the same location as the licensee's direct measurement locations for paired data comparison. Five judgmental direct measurement locations were selected based upon the surface scans.

Material-specific background measurements were collected from non-impacted structures and surfaces, to the extent possible, of similar construction materials.

Direct measurements were made using a Ludlum model 43-92 zinc sulfide scintillation detector for alpha radiation and a Ludlum model 44-142 plastic scintillator for beta radiation. Detectors were coupled to Ludlum Model 2221 ratemeter-scalers. The count time for both confirmatory and background measurements was 5 minutes.

5.4 REMOVABLE ACTIVITY MEASUREMENTS

Smear samples, to quantify removable alpha and beta surface activity, were collected from seventy-one direct measurement locations: 100% direct measurement locations within the class 1 areas unless lab equipment was present in the location (i.e., cabinets) or the location had been recently repainted and 50% of the locations in the class 2 areas. Five smears were collected from judgmental locations. Smear samples were not collected from material-specific background locations.

6. SAMPLE ANALYSIS AND DATA INTERPRETATION

Smear samples and data collected on site were delivered to the ORISE facility for analysis and interpretation. Sample custody was transferred to the Radiological and Environmental Analytical Laboratory (REAL) in Oak Ridge, Tennessee. Sample analyses were performed in accordance with the *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual* (ORAU 2016c). Smear samples were analyzed for gross alpha and gross beta activity using a low-background proportional counter. The analytical results and surface activity measurement data were reported in units of disintegrations per minute per 100 square centimeters (dpm/100 cm^2). The data generated are discussed in the subsequent sections.

The two-sided sign test was performed on paired radiological measurement data for each final status survey-survey unit (FSS SU) to determine if there were noticeable biases in the licensee's data that would require additional study. The null hypothesis (H_0), or assumed base condition, is that the difference in median surface activity concentrations between ORISE and the licensee's data is zero (i.e., the two populations are similar). The alternative hypothesis (H_A) is the median difference between ORISE and the licensee's surface activity measurements does not equal zero (i.e., the two populations are different). The sign test statistic, B, is the number of pairs for which the ORISE measurement is greater than the licensee's measurement. H_0 is rejected in favor of H_A at a specific significance level (α) when:

$$B \leq l - 1 \; or \; B \geq u$$

Using a significance level of α = 0.05 (95% confidence level), the values for *l* and *u* were determined from Gilbert 1987, Table A14.

Appendix D provides the representative minimum detectable concentrations (MDCs) achieved, as well as additional information on survey and analytical procedures

7. FINDINGS AND RESULTS

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

7.1 CONFIRMATORY UNITS

Due to time constraints, confirmatory activities were focused on Class 1 and 2 survey units. Table 7.1 provides a summary of survey units investigated and activities performed in each one.

Table 7.1. UNLV HAC Survey Units

FSS Unit Number	MARSSIM Class	Rooms Included in FSS Unit	Scans Performed	Direct Measurements Performed	Indirect Measurements Performed
FSS-QAL-1-1	1	QAL **35**	Yes	Yes	Yes
FSS-QAL-1-2	1	QAL **46**	Yes	Yes	Yes
FSS-QAL-2-1	2	QAL **2, 3, 4, 18, 19, 20, 21, 22, 25, 34, 47**	Yes	Yes	Yes

Table 7.1. UNLV HAC Survey Units					
FSS Unit Number	**MARSSIM Class**	**Rooms Included in FSS Unit**	**Scans Performed**	**Direct Measurements Performed**	**Indirect Measurements Performed**
FSS-EAX-2-1	2	EAX **1, 3, 4, 9, 11/12**	Yes	Yes	Yes
FSS-POS-3-1	3	POS 2, 9, 10, 11, 12.1, 12.3, 13, 14, **15**, 26, 27, 28, 29, 30	Yes	No	No
FSS-QAL-3-1	3	QAL 1, 5, 6, 11, 12, 13, 14, 16.1, 17, 26/27, 28, 29/30, 31, 32, 33, 36, 39, 42.1, 45.1, **45.2**	Yes	No	No

[a] Rooms in bold were included in confirmatory activities

7.2 Surface Activity Measurements

The beta radiation scans of judgmentally selected locations did not identify any areas of elevated direct beta radiation.

The gamma radiation scans of floors and walls encountered several different material types that resulted in different detector responses; however, in general the detector response was uniform over the material type. Several drywalls exhibited uniform, widespread elevated counts. Upon investigation, it was discovered that on the other side of these walls were white wall tiles, which overall exhibited a higher response due to naturally occurring radioactive material (NORM) commonly found in these material types.

Five areas of elevated gamma radiation were marked for further investigation based on scan data: 3 locations in FSS-QAL-1-1 and 2 locations in FSS-EAX-2-1. The gamma surface scans did not identify any areas of elevated direct radiation in the Class 3 survey units.

A summary of ORISE's total and removable direct measurement data is provided below in Table 7.2. The complete data set is provided in Table B-1.

Table 7.2. Summary of Confirmatory Measurements						
	Total Surface Activity (dpm/100 cm²)			Removable Surface Activity (dpm/100 cm²)		
Alpha	-163	to	17	0	to	4
Beta	-980	to	1,800	-2	to	6

7.3 Comparison Test

The results of the two-sided sign test are shown below in Table 7.3 for each FSS SU.

Table 7.3. Sign Test Results						
FSS SU	Sign Test Statistic, B		*l-1*	*u*	H_0 Rejected [a]	
	Alpha	Beta			Alpha	Beta
QAL-1-1	2	24	8	21	Yes	Yes
QAL-1-2	1	23	7	19	Yes	Yes
QAL-2-1	4	5	4	13	Yes	No
EAX-2-1	0	3	4	13	Yes	Yes

[a] The null hypothesis is the difference in median surface activity concentrations between ORISE and the licensee's data is zero (i.e., the two populations are similar). The alternative hypothesis is the median difference between ORISE and the licensee's surface activity measurements does not equal zero (i.e., the two populations are different)

The null hypothesis was rejected for all but one case. Rejecting the null hypothesis indicates that the two data populations are different. The data were also graphed with Q-Q plots (quantile-quantile plot), Figures A6 through A9. The plots show that the licensee's data are biased high compared to ORISE's data (i.e., the licensee is reporting higher activities than ORISE).

Two direct measurement locations exceeded the Pb-210 DCGL—both judgmental locations in FSS-EAX-2-1 on the concrete pad in room 11/12. The licensee has previously evaluated this concrete pad through volumetric sampling and the analytical results indicated the elevated measurements were due to NORM in the concrete (EPA 2016b).

8. SUMMARY

At the NRC's request, ORISE conducted confirmatory survey activities at the EPA Harmon Avenue Complex on the UNLV campus during the period of September 26-29, 2016. The survey activities

included gamma radiation surface scans, beta radiation surface scans, alpha and beta total and removable activity measurements. The majority of the areas scanned exhibited radiation levels indistinguishable from specific material type background and were uniform over the material. There were exceptions, and these areas were marked as judgmental locations for direct measurements. The licensee's and ORISE's data populations were compared and determined to be statistically different from one another with the licensee's data being biased high – the licensee reports higher activities than ORISE. Although two judgmental direct measurements exceeded the 550 dpm/100 cm^2 Pb-210 DCGL, this was due to NORM found in the concrete as discussed in Section 7.3. The confirmatory survey did not identify any areas of residual contamination in excess of either the decommissioning criteria or the survey unit classification limits (excluding NORM). ORISE results confirm that the licensee's results demonstrate compliance with the release criteria for unrestricted use as established in 10 CFR 20.1402.

9. REFERENCES

EPA 2016a. *EPA Las Vegas Facilities, Part 1- NRC License Amendment Submittal: Attachment 2 -Final Status Survey Report.* Las Vegas, Nevada. May 2016.

EPA 2016b. *Final Characterization and Decommissioning Report for U.S. Environmental Protection Agency Office of Air & Radiation (OAR) University of Nevada, Las Vegas Facilities Characterization.* EPA-LV-EDDP-P2-Sup.025. Las Vegas, Nevada. May 2016.

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

ORAU 2016a. *Health and Safety Manual.* Oak Ridge, Tennessee. January.

ORAU 2016b. *ORAU Environmental Services and Radiation Training Quality Program Manual.* Oak Ridge, Tennessee. September 8.

ORAU 2016c. *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual.* Oak Ridge, Tennessee. September 8.

ORAU 2016d. *ORAU Radiological and Environmental Survey Procedures Manual.* Oak Ridge, Tennessee. October 24.

APPENDIX A
FIGURES

Figure A-1. Harmon Avenue Complex Areas to be Released (in pink)

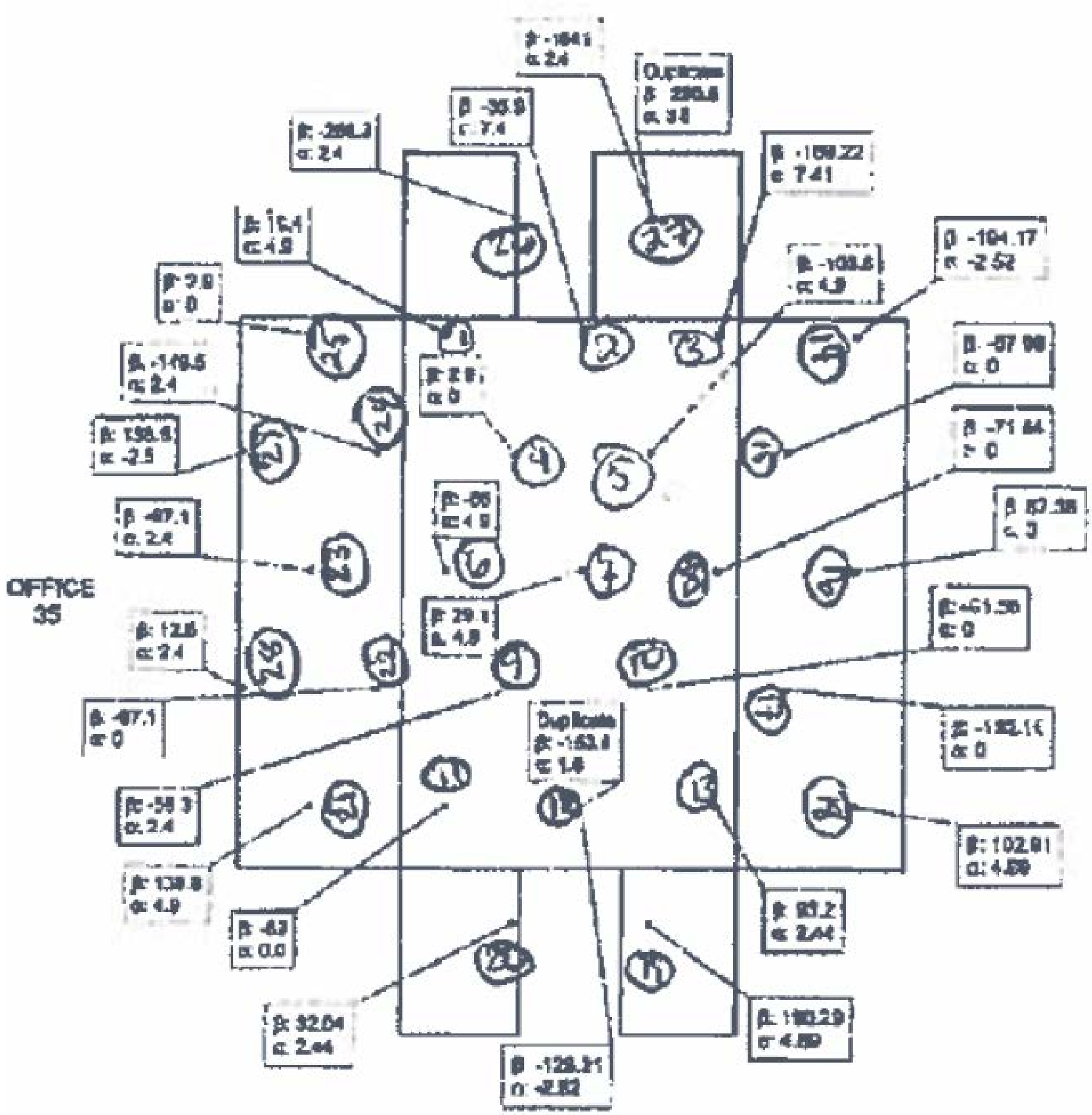


Figure A-2. FSS-QAL-1-1 ORISE Confirmatory Locations

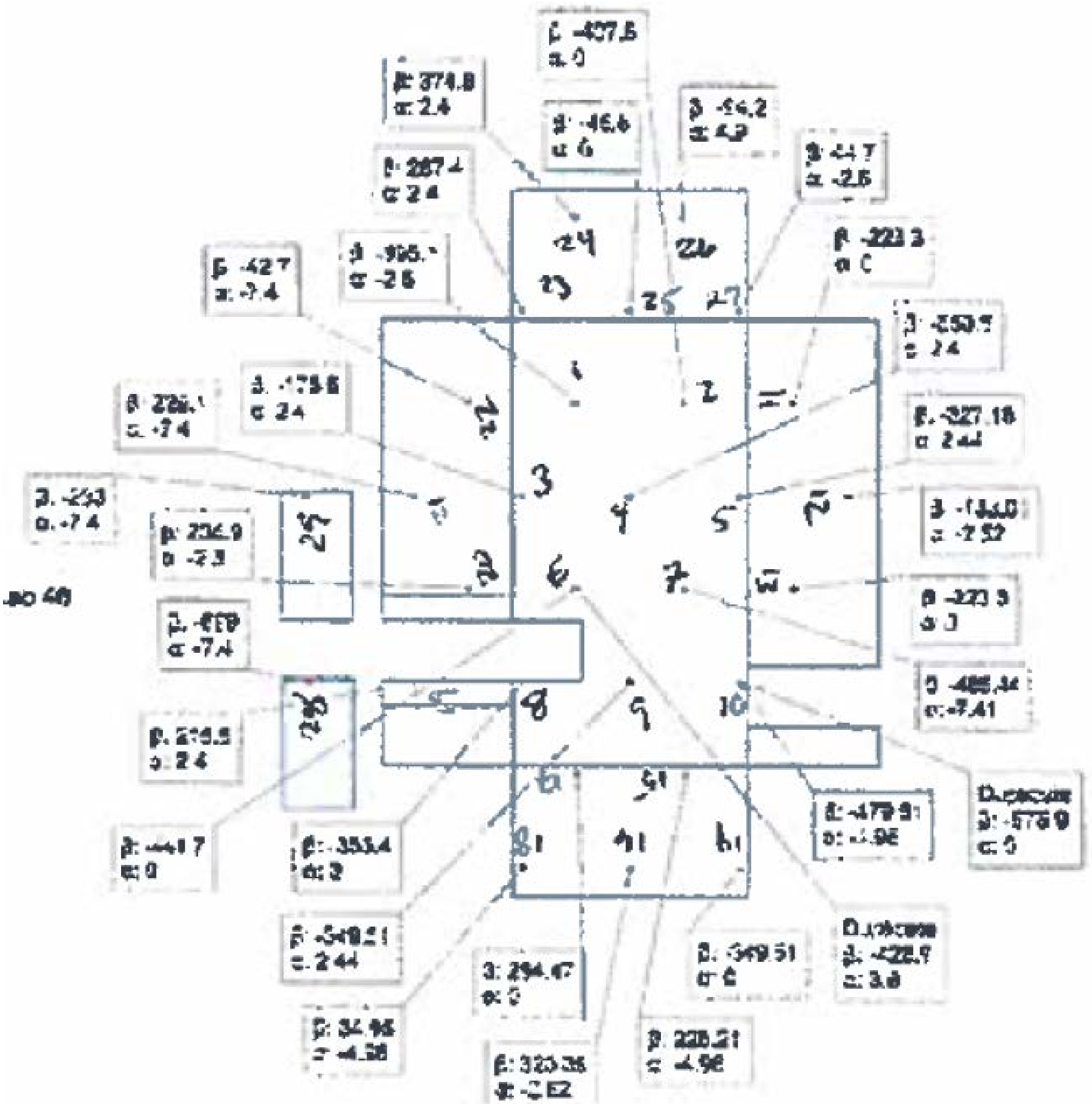


Figure A-3. FSS-QAL-1-2 ORISE Confirmatory Locations

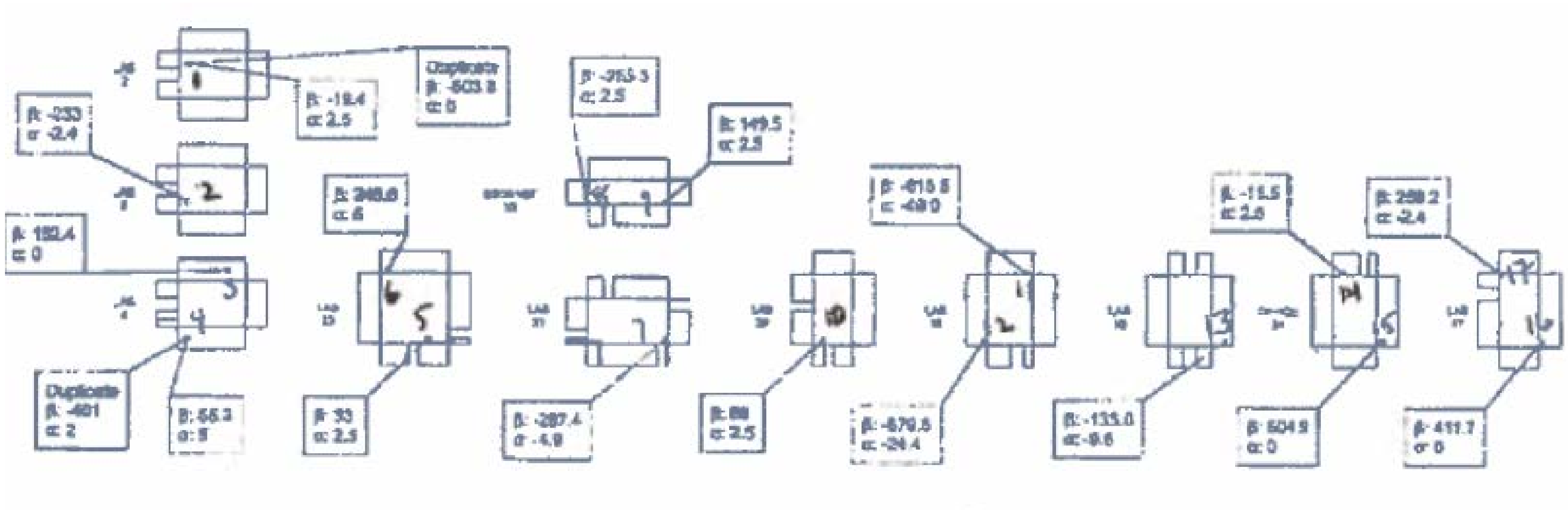


Figure A-4. FSS-QAL-2-1 ORISE Confirmatory Locations

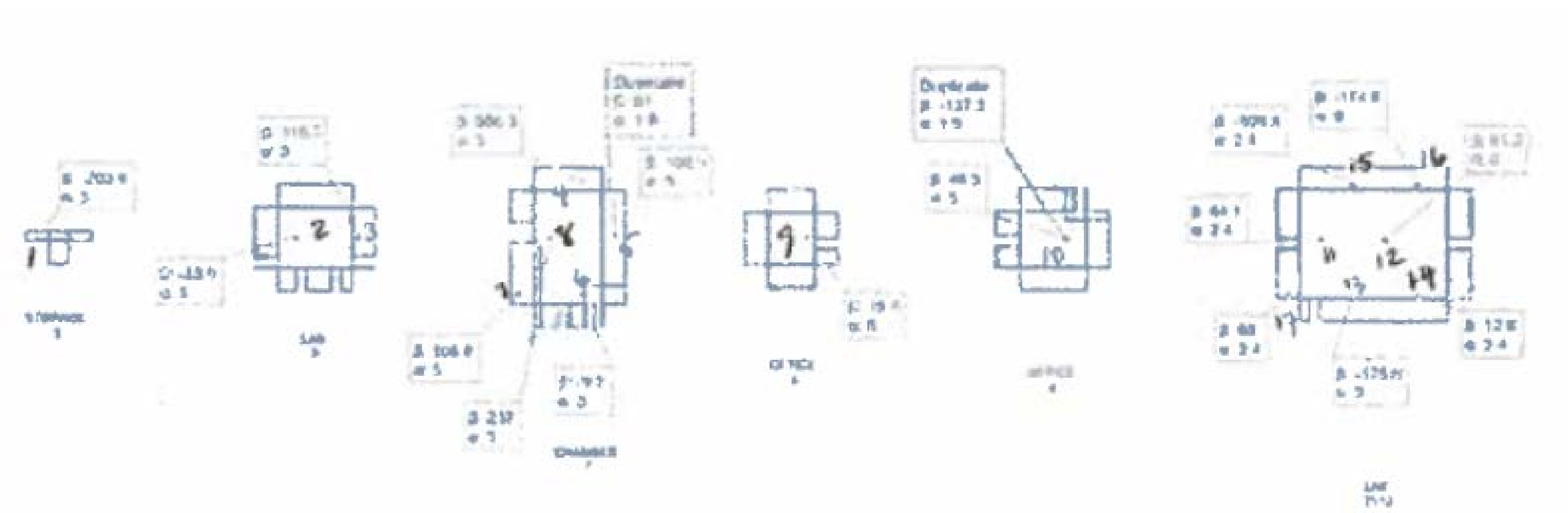
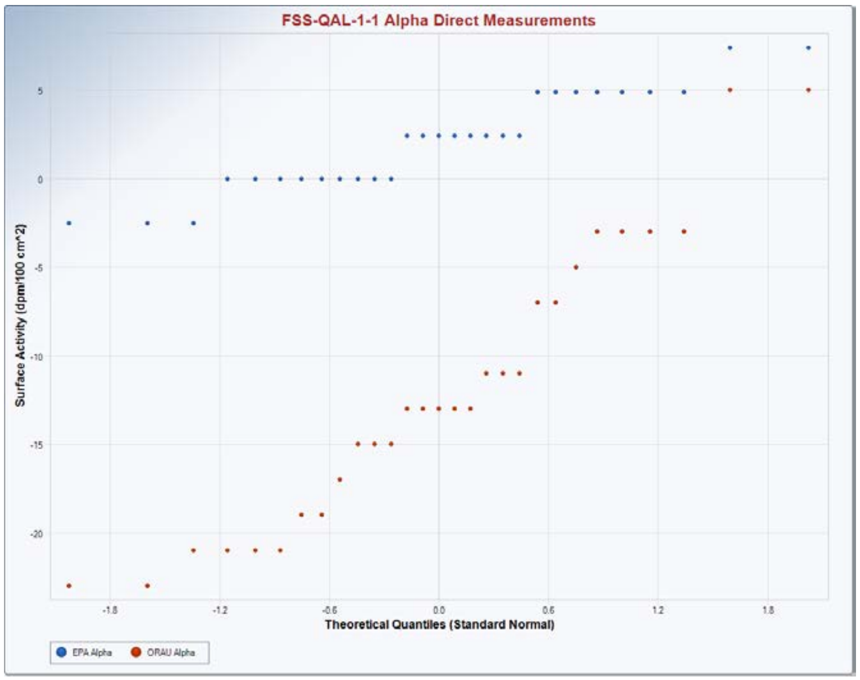


Figure A-5. FSS-EAX-2-1 ORISE Confirmatory Locations



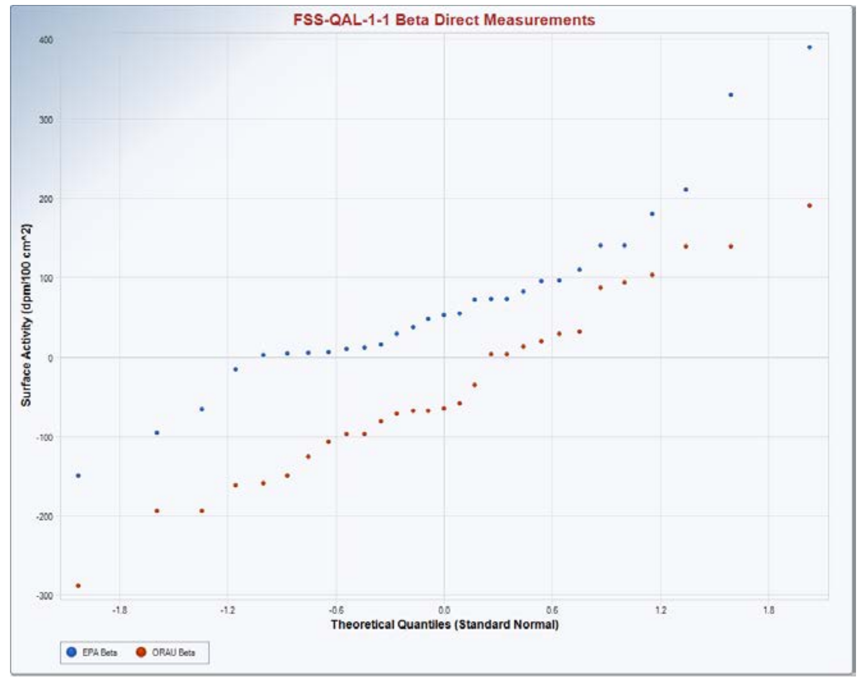
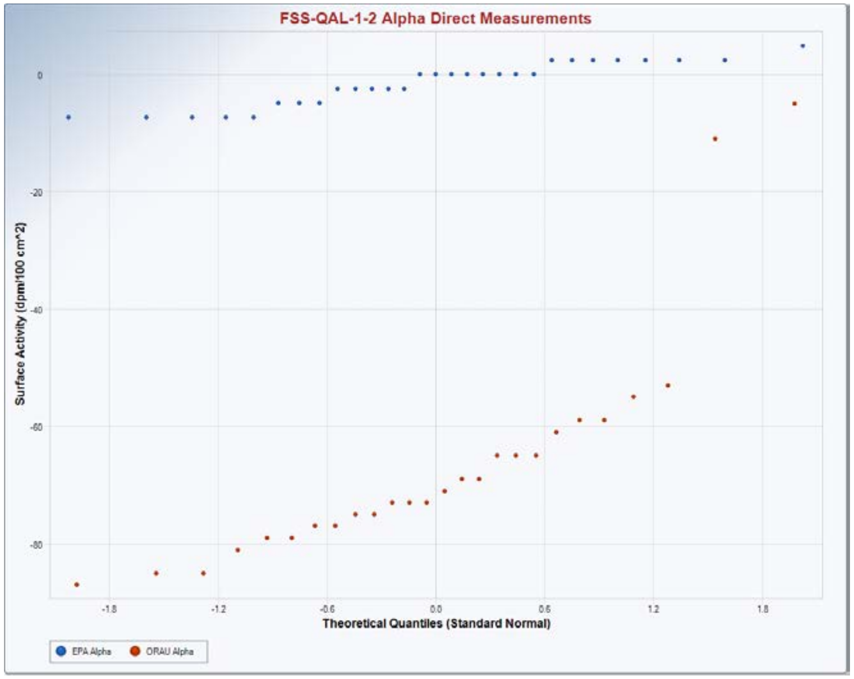


Figure A-6. Q-Q Plot for Alpha and Beta Direct Measurements in FSS-QAL-1-1



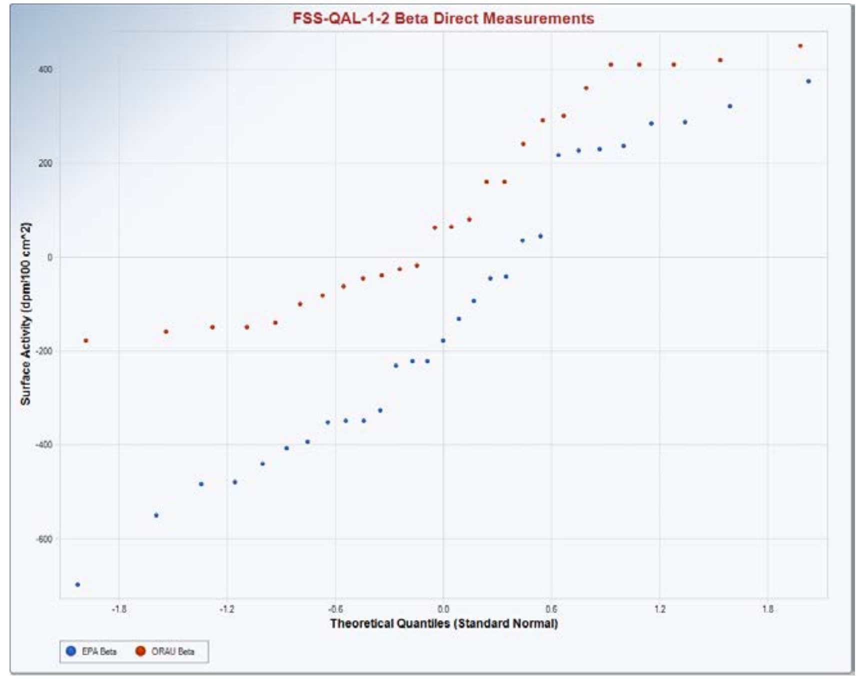


Figure A-7. Q-Q Plot for Alpha and Beta Direct Measurements in FSS-QAL-1-2

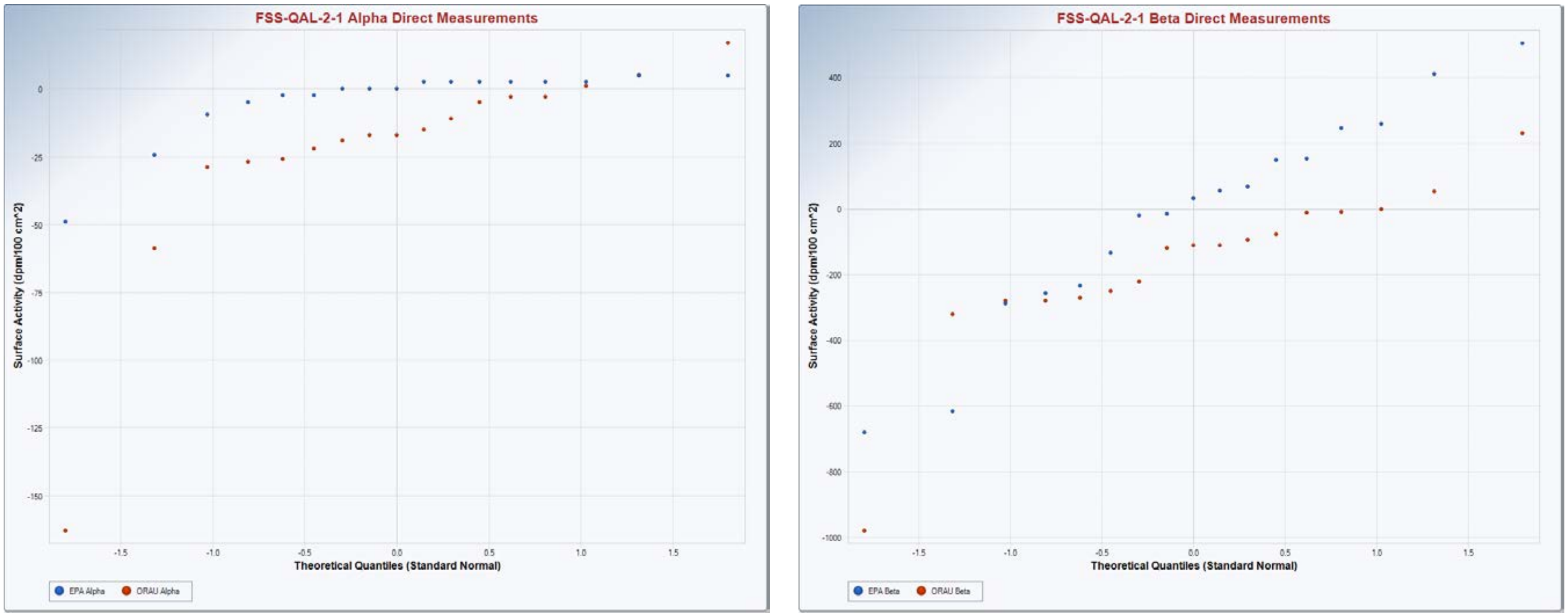
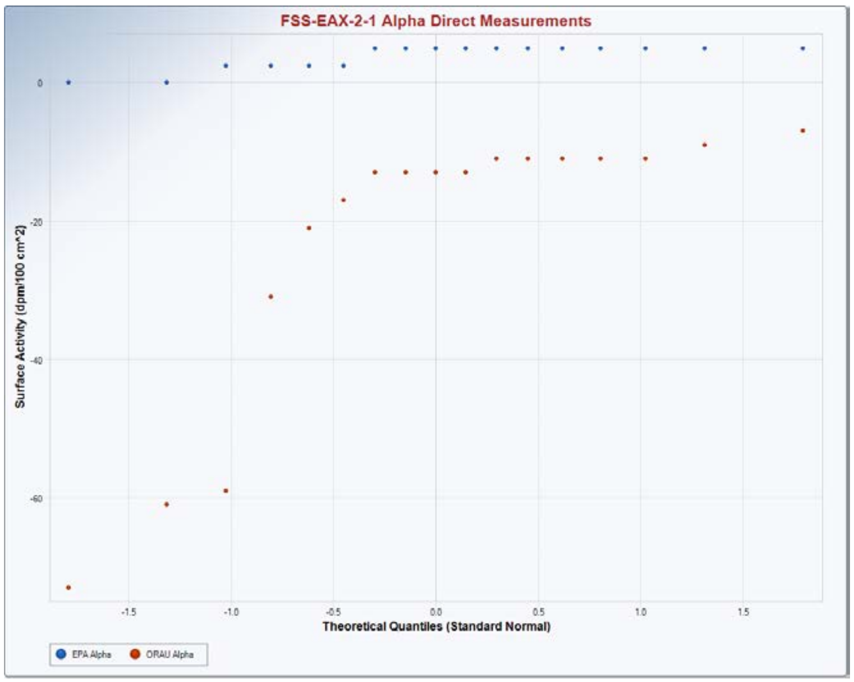


Figure A-8. Q-Q Plot for Alpha and Beta Direct Measurements in FSS-QAL-2-1



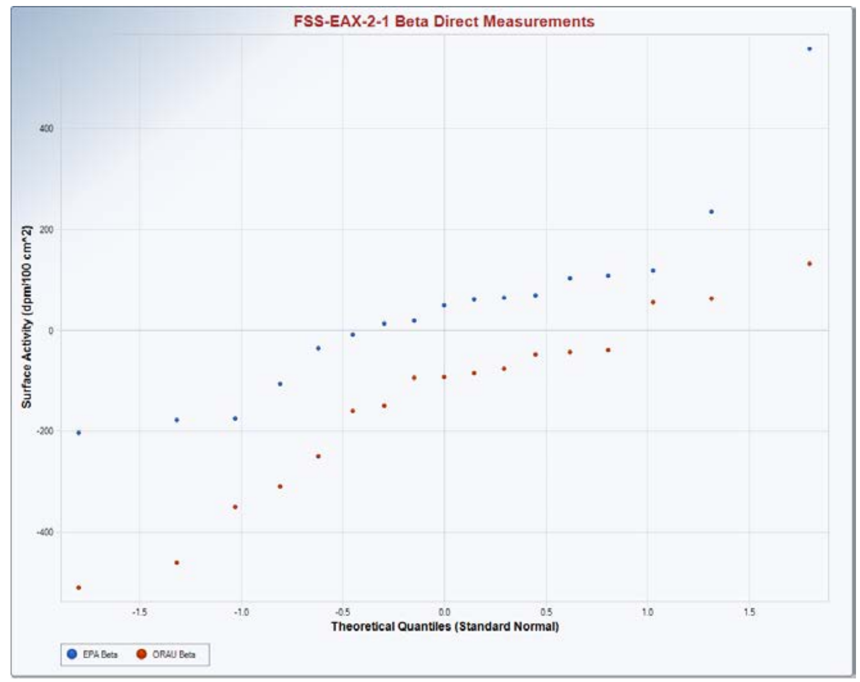


Figure A-9. Q-Q Plot for Alpha and Beta Direct Measurements in FSS-EAX-2-1

APPENDIX B
DATA TABLE

Table B.1 Surface Activity Levels for IV Measurements in the QAL and EAX Buildings													
FSS Survey Unit	**ORISE Location ID**	**Licensee Location ID**	**Smear ID**	**Coordinates (feet)**		**Surface**	**Material**	**ORISE's Measurements Total Surface Activity (dpm/100 cm²)**		**Licensee's Measurements Total Surface Activity (dpm/100 cm²)**		**ORISE's Measurements Removable Surface Activity (dpm/100 cm²)**	
				X	**Y**			**Alpha**	**Beta**	**Alpha**	**Beta**	**Alpha**	**Beta**
Random Locations													
FSS-QAL-1-1	1	6	5297R0001	21.2	12.8	Floor	Linoleum Tile	-11	10	4.89	19.42	2	4
	2	12	5297R0002	20.3	6.0	Floor	Linoleum Tile	-3	53	7.41	-35.92	0	-1
	3	18	5297R0003	20.0	1.5	Floor	Linoleum Tile	-23	72	7.41	-159.22	0	4
	4	11	5297R0004	14.7	7.9	Floor	Linoleum Tile	-15	73	0.00	2.91	0	2
	5	17	5297R0005	13.0	3.9	Floor	Linoleum Tile	-13	110	4.89	-106.80	0	4
	6	10	5297R0006	10.7	11.1	Floor	Linoleum Tile	-21	48	4.89	-65.05	0	2
	7	16	5297R0007	9.4	7.1	Floor	Linoleum Tile	-3	330	4.89	29.13	0	-1
	8	22	5297R0008	9.7	1.6	Floor	Linoleum Tile	-13	96	0.00	-71.84	0	4
	9	15	5297R0009	6.0	7.9	Floor	Linoleum Tile	-19	140	2.44	-58.25	4	3
	10	21	5297R0010	6.3	3.8	Floor	Linoleum Tile	-11	55	0.00	-81.55	2	0
	11	14	5297R0011	2.3	11.2	Floor	Linoleum Tile	-7	82	0.00	-67.96	4	2
	12	20	5297R0012	3.7	5.7	Floor	Linoleum Tile	5	95	-2.52	-126.21	0	5
	13	26	5297R0013	3.3	1.7	Floor	Linoleum Tile	-21	73	2.44	93.20	0	5
	14	24	5297R0014	0.8	5.3	S. Wall	Drywall	-21	16	-2.52	-194.17	0	-2
	15	23	5297R0015	4.7	2.5	S. Wall	Drywall	-7	12	0.00	-67.96	2	0
	16	28	5297R0016	10.0	4.7	S. Wall	Drywall	5	4	0.00	87.38	0	-1
	17	27	5297R0017	13.9	2.4	S. Wall	Drywall	-19	5	0.00	-162.14	0	2

Table B.1 Surface Activity Levels for IV Measurements in the QAL and EAX Buildings													
FSS Survey Unit	**ORISE Location ID**	**Licensee Location ID**	**Smear ID**	**Coordinates (feet)**		**Surface**	**Material**	**ORISE's Measurements**		**Licensee's Measurements**		**ORISE's Measurements**	
								Total Surface Activity (dpm/100 cm²)		**Total Surface Activity (dpm/100 cm²)**		**Removable Surface Activity (dpm/100 cm²)**	
				X	**Y**			**Alpha**	**Beta**	**Alpha**	**Beta**	**Alpha**	**Beta**
	18	29	5297R0018	19.4	4.6	S. Wall	Drywall	-13	210	4.89	102.91	2	4
	19	25	5297R0019	3.8	3.8	W. Wall	Drywall	-13	390	4.89	190.29	0	-1
	20	19	5297R0020	8.9	3.9	W. Wall	Drywall	-5	180	2.44	32.04	0	5
	21	8	5297R0021	2.6	5.2	N. Wall	Drywall	-15	140	4.89	138.83	0	3
	22	9	5297R0022	7.6	1.7	N. Wall	Drywall	-13	29	0.00	-97.09	0	4
	23	4	5297R0023	10.4	5.3	N. Wall	Drywall	-3	-66	2.44	-97.09	0	2
	24	5	5297R0024	17.7	1.7	N. Wall	Drywall	-15	6	2.44	-149.51	0	-1
	25	2	5297R0025	21.6	5.3	N. Wall	Drywall	-21	-95	0.00	2.91	0	-1
	26	7	5297R0026	4.3	5.2	E. Wall	Drywall	-23	-150	2.44	-288.35	0	-1
	27	13	5297R0027	11.7	5.1	E. Wall	Drywall	-17	2	2.44	-194.17	0	4
	28	3	5297R0028	7.1	7.1	N. Wall	Drywall	-11	38	2.44	12.62	0	-1
	29	1	5297R0029	16.3	7.1	N. Wall	Drywall	-3	-16	-2.52	138.83	0	0
	Mean							-12	67	2.10	-40.44	0	2
FSS-QAL-1-2	1	10	5297R0030	19.4	8.3	Floor	Painted Concrete	-77	-140	-2.52	-395.15	0	-2
	2	16	5297R0031	18.7	3.0	Floor	Painted Concrete	-69	-150	0.00	-407.77	0	2
	3	9	5297R0032	16.2	10.4	Floor	Painted Concrete	-71	-150	2.44	-178.64	0	-2
	4	15	5297R0033	16.5	5.1	Floor	Painted Concrete	-69	-180	2.44	-550.49	0	-1
	5	22	5297R0034	16.0	0.6	Floor	Painted Concrete	-85	-160	2.44	-327.18	0	1
	6	14	5297R0035	9.3	7.9	Floor	Painted Concrete	-75	-40	0.00	-441.75	0	0
	7	21	5297R0036	10.0	2.6	Floor	Painted Concrete	-87	-63	-7.41	-485.44	2	4

Table B.1 Surface Activity Levels for IV Measurements in the QAL and EAX Buildings													
FSS Survey Unit	ORISE Location ID	Licensee Location ID	Smear ID	Coordinates (feet)		Surface	Material	ORISE's Measurements		Licensee's Measurements		ORISE's Measurements	
								Total Surface Activity (dpm/100 cm²)		Total Surface Activity (dpm/100 cm²)		Removable Surface Activity (dpm/100 cm²)	
				X	Y			Alpha	Beta	Alpha	Beta	Alpha	Beta
	8	13	5297R0037	2.5	11.2	Floor	Painted Concrete	-79	-45	0.00	-353.40	0	3
	9	20	5297R0038	2.4	4.8	Floor	Painted Concrete	-79	-83	2.44	-349.51	0	2
	10	26	5297R0039	2.5	0.6	Floor	Painted Concrete	-65	160	-4.96	-479.61	--	--
	11	23	5297R0040	3.7	3.4	S. Wall	Painted Concrete	-53	63	0.00	-223.30	0	-1
	12	28	5297R0041	10.0	5.5	S. Wall	Painted Concrete	-81	62	-2.52	-133.01	0	3
	13	27	5297R0042	15.5	3.3	S. Wall	Painted Concrete	-65	160	0.00	-223.30	0	4
	14	29	5297R0043	1.3	6.7	W. Wall	Painted Concrete	-59	410	0.00	-349.51	0	-1
	15	25	5297R0044	3.7	2.3	W. Wall	Painted Concrete	-61	410	-4.96	226.21	0	2
	16	24	5297R0045	6.3	6.6	W. Wall	Painted Concrete	-85	360	-2.52	320.39	2	0
	17	19	5297R0046	9.0	2.3	W. Wall	Painted Concrete	-73	420	0.00	284.47	0	0
	18	18	5297R0047	10.4	6.5	W. Wall	Painted Concrete	-77	450	-4.96	34.95	0	3
	19	7	5297R0048	1.9	6.0	N. Wall	Painted Concrete	-73	300	2.44	216.50	0	2
	20	8	--	--	--	--	--	--	--	-2.52	235.92	--	--
	21	3	5297R0050	13.2	6.4	N. Wall	Painted Concrete	-59	410	-7.41	229.13	0	-1
	22	4	5297R0051	19.6	1.1	N. Wall	Painted Concrete	-73	-100	-7.41	-42.72	2	5
	23	5	5297R0052	1.8	0.2	E. Wall	Painted Concrete	-55	-18	2.44	287.38	0	-2

Table B.1 Surface Activity Levels for IV Measurements in the QAL and EAX Buildings												
FSS Survey Unit	ORISE Location ID	Licensee Location ID	Smear ID	Coordinates (feet)		Surface	Material	ORISE's Measurements Total Surface Activity (dpm/100 cm²)		Licensee's Measurements Total Surface Activity (dpm/100 cm²)		ORISE's Measurements Removable Surface Activity (dpm/100 cm²)	
				X	Y			Alpha	Beta	Alpha	Beta	Alpha	Beta
	24	6	5297R0053	2.5	7.4	E. Wall	Painted Concrete	-65	240	2.44	374.76	0	-1
	25	11	5297R0054	4.9	0.2	E. Wall	Painted Concrete	-75	-26	0.00	-45.63	0	3
	26	12	--	--	--	--	--	--	--	4.89	-94.17	--	--
	27	17	--	--	--	--	--	--	--	-2.52	44.66	--	--
	28	2	5297R0057	10.2	6.6	E. Wall	Drywall	-11	290	-7.41	-699.03	0	2
	29	1	5297R0058	8.6	1.2	W. Wall	Drywall	-5	79	-7.41	-233.01	0	6
	Mean							-66	102	-1.63	-151.72	0	1
FSS-QAL-2-1	1	1	5297R0059	9.1	18.3	Floor	Rolled Laminate	-17	-78	2.52	-19.42	0	6
	2	2	5297R0060	3.9	18.9	Floor	Rolled Laminate	-3	-110	-2.44	-233.01	2	6
	3	4	--	17.9	6.5	E. Wall	Drywall	-17	-120	0.00	152.43	--	--
	4	3	5297R0061	19.2	6.7	W. Wall	Drywall	-11	-110	4.96	55.34	0	-2
	5	6	--	20.2	5.9	Floor	Poured Concrete	-22	-250	2.52	33.01	--	--
	6	5	5297R0062	0.9	5.5	N. Wall	Metal	-3	-270	4.96	246.6	0	3
	7	9	--	0.7	0.7	Floor	Rolled Laminate	-15	-95	-4.89	-287.38	--	--
	8	7	5297R0063	22.8	2.0	W. Wall	Drywall	-19	-280	2.52	-255.34	0	-1
	9	8	--	0.6	2.0	W. Wall	Drywall	-27	-320	2.52	149.51	--	--
	10	10	5297R0064	1.4	8.7	Floor	Poured Concrete	-26	-280	2.52	67.96	0	0
	11	12	--	11.8	3.9	E. Wall	White Tile	-5	-220	-49.04	-615.53	--	--
	12	11	5297R0065	2.4	12.4	Floor	Brown Tile	-163	-980	-24.37	-679.61	0	3

Table B.1 Surface Activity Levels for IV Measurements in the QAL and EAX Buildings													
FSS Survey Unit	ORISE Location ID	Licensee Location ID	Smear ID	Coordinates (feet)		Surface	Material	ORISE's Measurements		Licensee's Measurements		ORISE's Measurements	
								Total Surface Activity (dpm/100 cm²)		Total Surface Activity (dpm/100 cm²)		Removable Surface Activity (dpm/100 cm²)	
				X	Y			Alpha	Beta	Alpha	Beta	Alpha	Beta
	13	13	--	20.6	4.2	S. Wall	White Tile	-29	-11	-9.56	-133.01	--	--
	14	14	5297R0066	4.0	1.8	E. Wall	Drywall	17	-8	2.52	-15.53	0	-2
	15	15	--	20.4	4.8	S. Wall	Drywall	5	0	0.00	504.85	--	--
	16	17	--	21.2	2.4	S. Wall	Painted Concrete	-59	54	0.00	411.65	--	--
	17	16	5297R0067	21.1	11.1	Floor	Metal	1	230	-2.44	259.22	0	5
	Mean							-23	-168	-3.98	-21.07	0	2
FSS-EAX-2-1	1	1	--	1.3	2.8	N. Wall	Wood	-13	-350	4.96	-203.88	--	--
	2	2	5297R0068	16.5	6.7	Floor	Linoleum Tile	-9	-44	4.96	-35.92	0	3
	3	3	--	7.1	2.4	S. Wall	Painted Concrete	-73	-510	4.96	116.5	--	--
	4	6	5297R0069	13.8	5.6	E. Wall	Painted Concrete	-61	-310	4.96	556.31	4	-1
	5	8	--	12.3	5.6	S. Wall	Drywall	-13	-94	4.96	102.91	--	--
	6	7	5297R0070	5.1	5.6	Floor	Linoleum Tile	-21	-86	4.96	-9.71	0	6
	7	4	--	1.0	5.7	N. Wall	Painted Concrete	-59	-460	4.96	106.8	--	--
	8	5	5297R0071	17.3	14.4	Floor	Linoleum Tile	-11	55	4.96	233.01	0	2
	9	9	--	3.1	9.4	Floor	Linoleum Tile	-11	-40	4.96	19.42	--	--
	10	10	5297R0072	2.3	8.1	Floor	Linoleum Tile	-7	-48	4.96	48.54	0	4
	11	12	--	33.3	15.5	Floor	Linoleum Tile	-11	-95	2.44	64.08	--	--
	12	15	5297R0073	15.0	15.7	Floor	Linoleum Tile	-11	-77	0.00	61.17	2	5

Table B.1 Surface Activity Levels for IV Measurements in the QAL and EAX Buildings													
FSS Survey Unit	ORISE Location ID	Licensee Location ID	Smear ID	Coordinates (feet)		Surface	Material	ORISE's Measurements		Licensee's Measurements		ORISE's Measurements	
								Total Surface Activity (dpm/100 cm²)		Total Surface Activity (dpm/100 cm²)		Removable Surface Activity (dpm/100 cm²)	
				X	Y			Alpha	Beta	Alpha	Beta	Alpha	Beta
	13	14	--	24.6	0.1	Floor	Linoleum Tile	-11	130	4.96	-178.64	--	--
	14	17	5297R0074	7.0	0.1	Floor	Linoleum Tile	-13	62	2.44	12.62	0	5
	15	13	--	19.0	1.3	E. Wall	Drywall	-17	-160	2.44	-106.8	--	--
	16	16	5297R0075	29.0	1.3	E. Wall	Drywall	-31	-150	0.00	-174.76	4	0
	17	11	--	2.5	5.6	N. Wall	Drywall	-13	-250	2.44	67.96	--	--
	Mean							-23	-143	3.78	39.98	1	2
Judgmental Locations													
FSS-QAL-1-1	49	--	5297R0049	3.0	3.9	Floor	Linoleum Tile	13	450	--	--	4	4
	55	--	5297R0055	4.7	6.8	Floor	Linoleum Tile	-17	480	--	--	0	2
	56	--	5297R0056	2.6	3.8	W. Wall	Drywall	-23	460	--	--	0	0
FSS-EAX-2-1	77	--	5297R0077	19.8	21.2	Floor	Poured Concrete	2	1,800	--	--	0	4
	78	--	5297R0078	24.3	4.2	Floor	Poured Concrete	-12	1,300	--	--	0	4

APPENDIX C
MAJOR INSTRUMENTATION

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the author or her employer.

C.1 SCANNING AND MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

C.1.1 GAMMA

Ludlum NaI Scintillation Detector Model 44-10, Crystal: 5.1 cm × 5.1 cm
(Ludlum Measurements, Inc., Sweetwater, Texas)
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, Texas)

C.1.2 ALPHA

Ludlum ZnS(Ag) Scintillation Detector Model 43-92, 100 cm^2 physical area
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)

C.1.3 BETA

Ludlum Plastic Scintillation Detector Model 44-142, 100 cm^2 physical area
coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)

C.2 LABORATORY ANALYTICAL INSTRUMENTATION

Low Background Gas Proportional Counter
Model LB-5100-W
(Tennelec/Canberra, Meriden Connecticut)

APPENDIX D
SURVEY AND ANALYTICAL PROCEDURES

D.1 PROJECT HEALTH AND SAFETY

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

D.2 CALIBRATION AND QUALITY ASSURANCE

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

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

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

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

D.3 SURVEY PROCEDURES

D.3.1 MATERIAL SPECIFIC BACKGROUND MEASUREMENTS

Material-specific background measurements were collected for the following material types: linoleum tile, poured concrete, painted concrete, drywall, and white wall tile. While other material types were encountered (i.e., red floor tile, rolled laminate flooring, etc.), these materials could not be located in non-impacted areas, and therefore, background measurements were not collected. For these material types, a material-specific background was selected with similar radiation characteristics (i.e., linoleum tile was used for rolled laminate). The material-specific backgrounds for the painted concrete block and white tile were collected in the same location where the licensee collected their material-specific backgrounds. One area, EXC-105, had higher than expected background measurements. This area was a small, enclosed, poorly ventilated room underneath a stairwell. Due to the higher count rates, the location for the poured concrete background measurements was moved into the main stairwell - where counts decreased and were similar to what was encountered during the survey. Material-specific background data are provided in the table below.

Table D.1 Material Specific Backgrounds				
Material Type	Count Rate (cp5m/100 cm²)		Mean (cp5m/100 cm²)	
	Alpha	Beta	Alpha	Beta
Poured Concrete	22	2081	21	2,000
	22	1989		
	25	1969		
	16	1853		
	18	1994		
	23	1862		
White Tile/Brown Tile	98	4633	95	4,200
	106	3802		
	83	4490		
	88	4159		
	96	4227		
	96	4022		
Linoleum Tile/Rolled Laminate	16	1654	16	1,500
	21	1662		
	6	1550		
	17	1441		
	15	1447		
	19	1406		
Drywall/Metal/Wood	9	1840	18	1,700
	12	1630		
	8	1796		
	9	1529		
	9	1557		
	15	1499		
	47	1720		
	31	1636		
Painted Concrete Block	51	2385	46	2,300
	46	2232		
	45	2476		
	52	2057		
	36	2435		
	48	2376		

D.3.2 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 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.

Surface scan MDCs for the detectors were estimated using the approach described in NUREG-1507 (NRC 1997). The scan MDC is a function of many variables, including a two-second observation interval, a specified level of performance at the first scanning stage of 90% true positive and 15% false positive rate, which yields a d' value of 2.32 (NUREG-1507, Table 6.1), and a surveyor efficiency of 0.5. The total weighted efficiency for beta was 0.28. Alpha scans were not performed. The scan MDC was calculated using the following equation:

$$Scan\ MDC = \frac{d' \times \sqrt{C_b \times (i/60)} \times (60/i)}{\sqrt{p} \times \varepsilon_t \times \frac{Probe\ Area}{100\ cm^2}}$$

Where:

- d' = index of sensitivity
- C_b = background (cpm)
- i = observation interval (sec)
- p = surveyor efficiency
- ε_t = total efficiency

Scans MDCs are provided in Table D.2 below (Section D.3.2).

D.3.2 SURFACE ACTIVITY MEASUREMENTS

Measurements of gross alpha surface activity levels were performed using hand-held ZnS(Ag) scintillator detectors coupled to portable ratemeter-scalers. Measurements of gross beta surface activity levels were performed using hand-held plastic scintillator detectors coupled to portable

ratemeter-scalers. Count rates (cpm), which were integrated over five minutes 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 (ε_i x ε_s) and correcting for the physical area of the detector plus background. The total weighted alpha and beta efficiencies were 0.10 and 0.28, respectively. The MDC for static survey activity measurements was calculated using the following equation:

$$MDC = \frac{3 + (4.65\sqrt{B})}{TG\varepsilon_{tot}}$$

Where:

B = background in time interval, T

T = count time (min) used for field instruments

ε_{tot} = total efficiency = $\varepsilon_i \times \varepsilon_s$

G = geometry correction factor (1.0)

Table D.2 Minimum Detectable Concentrations					
Material	Background (cpm)		Scan MDC (dpm/100 cm²)	Static MDC (dpm/100 cm²)	
	Alpha	Beta	Beta	Alpha	Beta
Poured Concrete	4	390	1267	48	149
White Tile/Brown Tile	19	840	1860	97	217
Linoleum Tile/Rolled Laminate	3	310	1130	42	133
Drywall/Metal/Wood	4	330	1166	48	137
Painted Concrete Block	9	470	1391	68	163

D. 3.3 REMOVABLE ACTIVITY SAMPLING

Smear samples for removable gross alpha and gross beta contamination were obtained from most independent confirmatory measurement locations. Removable activity samples were collected using numbered filter paper disks. Moderate pressure was applied to the smear and approximately 100 cm^2 of the surface was wiped. Smears for gross alpha and gross beta analysis were placed in labeled envelopes. Locations and other pertinent data were recorded. All samples were transferred under chain-of-custody to the ORISE Radiological and Environmental Analytical Laboratory.

D.4 RADIOLOGICAL ANALYSIS

D.4.1 GROSS ALPHA/BETA

Smears were counted on a low-background proportional counter for gross alpha and beta activity. The minimum detectable activity of the procedures is approximately 11 dpm/100 cm^2 for alpha and 14 dpm/100 cm^2 for beta.

D.5 DETECTION LIMITS

Detection limits, referred to as MDCs, were based on 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.