OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

December 19, 2016

Ms. Zahira Cruz
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Mail Stop: T-8 F8
11545 Rockville Pike
Rockville, MD 20852

SUBJECT: DOE Contract No. DE-SC0014664
INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE ZACHRY ENGINEERING CENTER AT TEXAS A&M UNIVERSITY, COLLEGE STATION, TEXAS
RFTA No. 16-013; DCN 5294-SR-01-0

Dear Ms. Cruz:

The Oak Ridge Institute for Science and Education (ORISE) is pleased to provide the enclosed final report detailing the independent confirmatory survey activities of the Zachry Engineering Center at Texas A&M University in College Station, Texas. This report provides the summary and results of the ORISE activities performed during the period of November 14-16, 2016.

You may contact me at 865.574.6273 or Erika Bailey at 865.576.6659 if you have any questions.

Sincerely,

Kathleen Smith for NAA

Nick A. Altic
Health Physicist/
Project Manager
ORAU

NAA:lw

Enclosure

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INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE ZACHRY ENGINEERING CENTER AT TEXAS A&M UNIVERSITY IN COLLEGE STATION, TEXAS

N. A. Altic

FINAL REPORT

Prepared for the U.S. Nuclear Regulatory Commission

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Prepared by
N. A. Altic
ORAU

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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 ZACHRY ENGINEERING CENTER AT TEXAS A&M UNIVERSITY IN COLLEGE STATION, TEXAS

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FINAL REPORT

DECEMBER 2016

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ACRONYMS

Co-60	Cobalt-60
cpm	counts per minute
CU	confirmatory unit
dpm	disintegrations per minute
DQO	Data Quality Objective
FSS	final status survey
H-3	Hydrogen-3 (tritium)
LSC	liquid scintillation counter
MDC	minimum detectable concentration
NaI	sodium iodide
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
PSQ	Principle Study Question
Q	quantile
RAI	request for additional information
REAL	Radiological and Environmental Analytical Laboratory
ROC	radionuclide of concern
TAMU	Texas A&M University

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR THE ZACHRY ENGINEERING CENTER AT TEXAS A&M UNIVERSITY IN COLLEGE STATION, TEXAS

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 Zachry Engineering Center at Texas A&M University in College Station, Texas. Confirmatory activities were conducted to ensure, if supported by the results, that residual surface activity levels for the radionuclides of concern satisfy the screening values approved for use at the site. The confirmatory survey, performed November 14-16, 2016, included surface scans for gamma and alpha-plus-beta radiation, the collection of alpha-plus-beta direct measurements, and the collection of smear samples for the determination of removable radioactivity within the Zachry Engineering Center; rooms 61A, 61B, and 135. At the time of this report, the licensee's FSS report was not available; therefore, ORISE cannot comment on its acceptability or the licensee's overall conclusion regarding the site's final radiological status. However, based on the confirmatory survey results, ORISE is of the opinion that CU-1 and CU-2 satisfy the approved screening values for unrestricted use. ORISE did not collect any data that would refute the licensee's classification of survey units in CU-2 and CU-3, nor was there any indication that these CUs would not meet the criteria for unrestricted use.

INDEPENDENT CONFIRMATORY SURVEY SUMMARY AND RESULTS FOR ZACHRY ENGINEERING CENTER AT TEXAS A&M UNIVERSITY IN COLLEGE STATION, TEXAS

1. INTRODUCTION

The Zachry Engineering Center at Texas A&M University (TAMU) housed the Aerojet General Nucleonics Model No. 201 (AGN-201M) nuclear reactor as well as offices and laboratories in which radiological materials were used in support of reactor operations. The AGN-201M uses a polyethylene and uranium dioxide plate type fuel with a uranium-235 enrichment of less than 20%. The reactor has a power rating of 5 watts, thermal. Natural convection cools the core assembly and therefore, the reactor does not have an external cooling loop. Texas A&M University purchased the AGN reactor in 1957 and moved it to the Zachry Engineering Center in 1972. The 5-watt, thermal AGN-201M reactor was located on the ground floor in the southwest portion of the building. The reactor has not been operated since 2014.

Prior to TAMU beginning Final Status Surveys (FSS), characterization of four core samples were collected from the innermost concrete blocks surrounding the reactor support skirt. Additionally, three concrete core samples were collected from the block wall in line with the sample port. All core samples were analyzed via gamma spectroscopy and liquid scintillation counting (LSC). None of the samples contained radionuclide concentrations above their respective minimum detectable concentrations (MDCs). Additionally, there are no historical reports of leakage from the reactor or spills of radioactive material (TAMU 2016).

The Zachry Engineering Center is being renovated, and the reactor has been packaged and placed in offsite storage pending installation in a new facility. TAMU intends to submit a request for a license amendment allowing for the unrestricted use of the Zachry Engineering Center to the U.S. Nuclear Regulatory Commission (NRC) for approval. Final status survey results generated by TAMU's contractor will be used to support the license amendment request.

The NRC requested that Oak Ridge Institute of Science and Education (ORISE), managed by ORAU for the U.S. Department of Energy, perform confirmatory surveys of the Zachry Engineering Center at TAMU. ORISE performed an independent radiological survey to confirm

that residual surface activity levels for the radionuclides of concern (ROCs) satisfy the screening values. The confirmatory activities and results are discussed in this report

2. SITE DESCRIPTION

The Zachry Engineering Center is located on Bizzell Street near University Drive on the TAMU campus in College Station, Texas. Figure 2.1 is a site map of the TAMU campus, indicating the location of the Zachry Engineering Center.

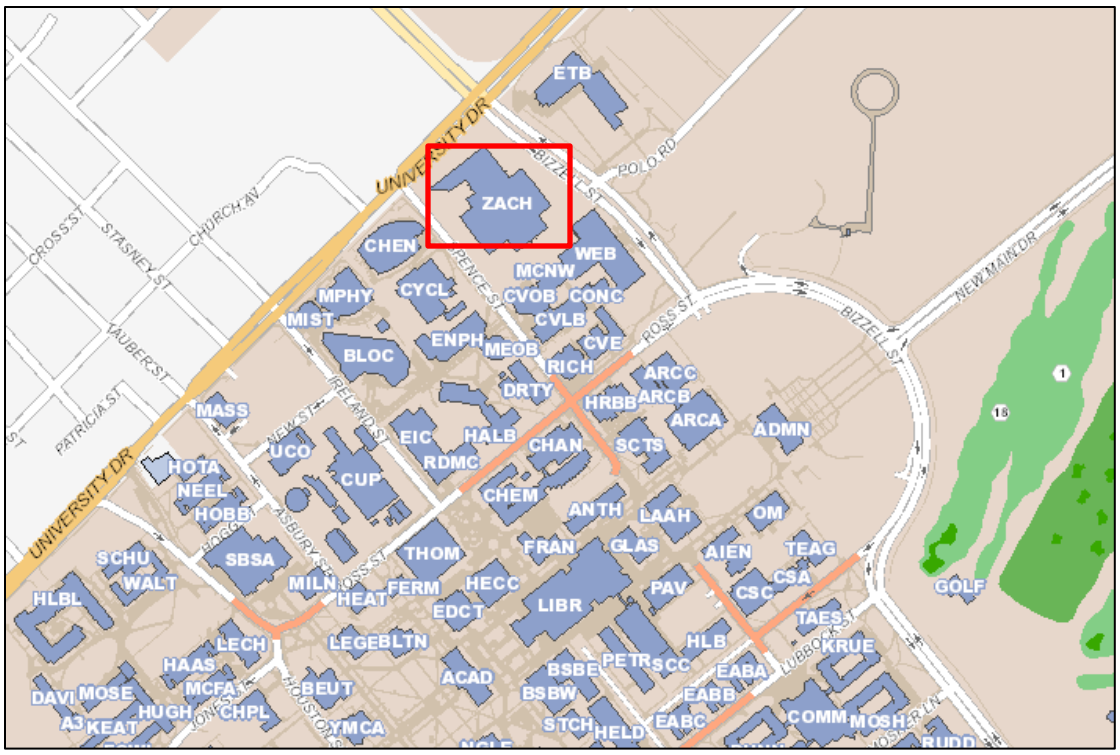

Figure 2.1. Site Map Showing the Zachry Engineering Center

The building is a large concrete structure with a basement level, ground level, and three additional floors. Figure 2.2 shows the Zachry Engineering Center ground floor, which once housed the reactor, and Figure 2.3 shows the first (above ground) floor. Bolded outlined areas indicate the primary reactor site boundary. Room 60C was used for office space and access control. Room 61A was used in support of reactor operations. Room 61B contained the reactor control console and a small inner room where radioactive sources were stored. Access to the top of the reactor was through Room 135. Rooms 60C, 61A, and 135 previously contained an ion-implant particle accelerator and constituted the primary site security boundaries for the reactor. These rooms have

1-meter reinforced concrete walls, and the accelerator room (Rm 135) has a steel plate liner (TAMU 2016).

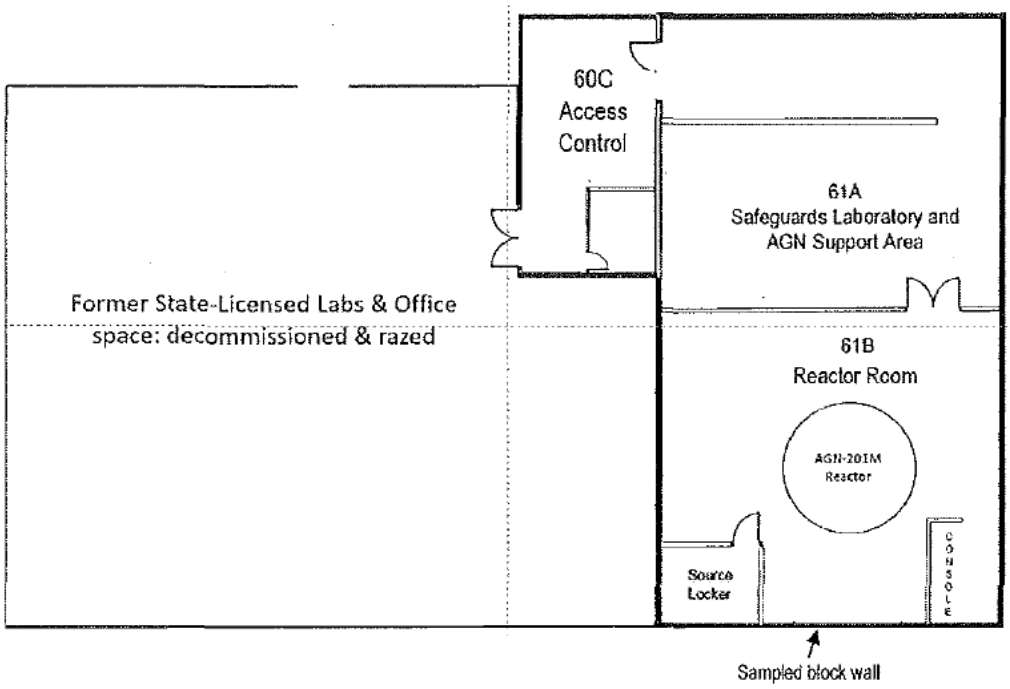

Figure 2.2. Reactor Facility in The Zachry Engineering Center, Ground Floor

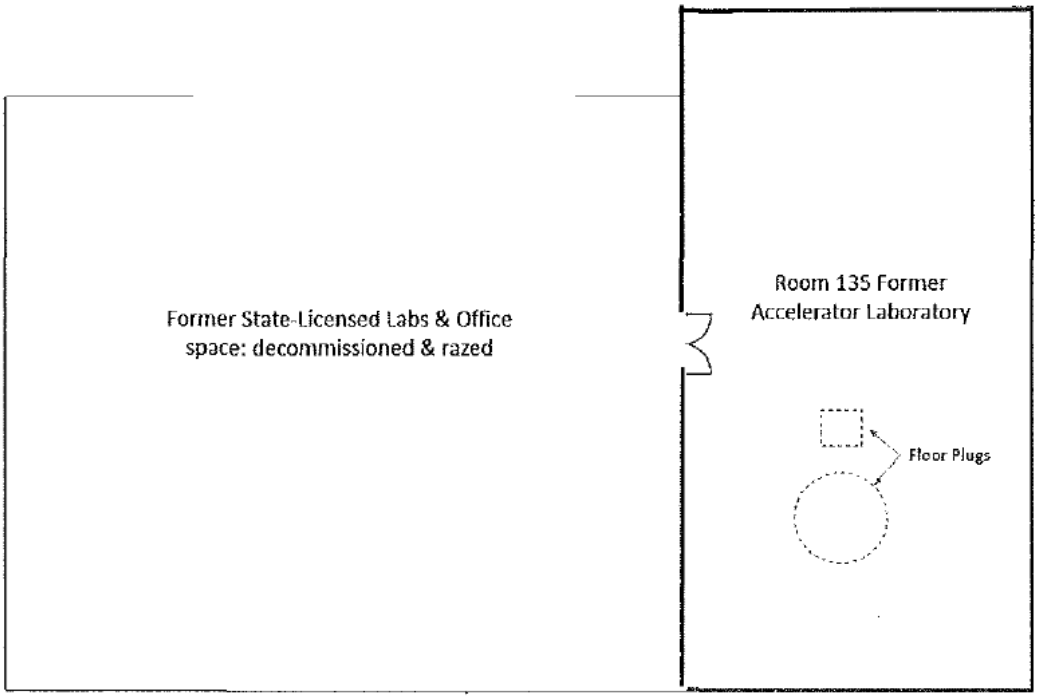

Figure 2.3. Reactor Facility in the Zachry Engineering Center, First Floor

A polyethylene tank, located in the basement directly below the primary reactor facility was connected to a floor drain in room 61B to allow collection of water from the reactor in the event of leakage. The PVC drain line was removed during the licensee's final status survey (FSS). Rooms 135 and 61A contained sink drains connected to a sump in the State-licensed area of the building. Ventilation for the reactor area was provided by a ventilation fan in Room 135, which drew air through a grated opening in Room 61B (TAMU 2016).

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 outlined below:

1. State the problem
2. Identify the decision/objective
3. Identify inputs to the decision/objective
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 STEP 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 budget and schedule. Information related to the team members, budget and schedule is addressed in ORISE's response to the NRC's request for technical assistance, RFTA 16-013, and is not repeated here. ORISE has performed independent document reviews and collected radiological data to ensure that the licensee's FSS data and reports are accurate and adequate for demonstrating that the requirements for radiological release have been met. Based on this, the problem statement is as follows:

An independent confirmatory assessment was required to ensure that residual radioactivity in the Zachry Engineering Center is below the approved screening values.

3.2 STEP 2 – IDENTIFY THE DECISION/OBJECTIVE

The second step in the DQO process identifies the principal study question(s) (PSQs) and alternate actions (AAs), develops a decision statement, and organizes multiple decisions, as appropriate. This is done by specifying AAs that could result from a "yes" response to the PSQ and combining the PSQ and AAs into a decision statement. Table 3.1 presents the PSQ and AAs combined into the decision statement.

Table 3.1. Independent Confirmation Survey Decision

Principal Question	Alternate Actions
In order to select "Yes" from the AAs, the subsequent questions must all be answered "Yes": Are radioactive surface activity levels less than the approved screening values? Were the licensee's survey units appropriately classified?	**Yes:** Residual activity levels are less than the screening values, units are appropriately classified, and the confirmatory survey concludes that no additional actions are required. **No:** Should confirmatory activities identify undocumented and/or unacceptable levels of residual contamination or inappropriate classification is used, determine the magnitude of the finding(s) (number of anomalies identified, size of the anomalies), and the licensee should take action to address contamination above the screening values.
Decision Statements	
The independent confirmatory survey did/did not identify any areas of residual contamination in excess of the screening values, the licensee's classification is/is not appropriate, and additional actions by the licensee are/are not required.	

3.3 STEP 3 – IDENTIFY INPUTS TO THE DECISION/OBJECTIVE

The third step in the DQO process identifies the information needed and the sources for this information, determines the basis for action levels, and identifies sampling and analytical methods that will meet data requirements. For the confirmatory surveys, the decision inputs included the following:

- Review of licensee's final status survey plan (FSSP) (TAMU 2016)
  (ORISE provided suggested requests for additional information [RAIs] to NRC in a separate document [ORAU 2016a]).
- Review of licensee's survey unit designations
- The following confirmatory survey data:
  - Surface scans
  - Total surface activity direct measurements
  - Removable (smear) samples

3.3.1 Radionuclides of Concern

Potential ROCs are those associated with reactor operations, fission and activation products: cesium-137, strontium-90, cerium-144, zirconium-95, cesium-134, cobalt-60 (Co-60), europium-152, europium-154, tritium (H-3), and carbon-14. The *Survey Plan for the Unrestricted Release of the AGN-201M Research Reactor Facility Zachry Engineering Center* provides the NRC's radiological release screening values in NUREG-1757, Volume 2 (TAMU 2016 and NRC 2006). Table 3.2 below provides the screening values selected for the Zachry Engineering Center. Cobalt-60 was chosen as the proxy for most of the ROCs listed above because it has the most restrictive (i.e., smallest) screening value. Tritium is also listed in Table 3.2 because it is a hard-to-detect radionuclide and requires off-site laboratory analysis. Alpha emitting ROCs are not expected; therefore, any indication of alpha activity above background would require further investigation by the licensee.

Table 3.2. Default Screening Values for the Zachry Engineering Center

Radiation Type	Screening Values (dpm/100 cm^2)	
	Total [a]	Removable [b]
Co-60[v]	7,100	710
H-3	120,000,000	12,000,000

[a] From *Survey Plan for the Unrestricted Radiological Release of the AGN-201M Research Reactor Facility Zachry Engineering Center* (TAMU 2016).
[b] Removable activity screening value is 10% of the total activity screening value.
[c] Used as a proxy for most other ROCs

3.4 STEP 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 boundaries for this confirmatory survey are as follows:

- The target areas for the evaluation are listed in Table 3.3, which includes the survey unit and licensee's assigned classification, based on the *Multi-Agency Radiation Site Survey and Investigation Manual* (NRC 2000).
- The survey was completed the week of November 14, 2016.
- The available on-site project schedule precluded independent investigations of all proposed confirmatory units (CUs); thus, areas with the highest potential for exceeding the screening values were selected based on the licensee's survey plan (TAMU 2016). ORISE personnel prioritized confirmatory data collection from Class 1 areas.

Table 3.3. TAMU Survey Units and MARSSIM Classification [a]

Survey Unit Classification	Level	Room (s)	Surfaces	Confirmatory Unit (CU) #
1	Ground	61A	Floor, lower walls	CU-1
1	Ground	61B	Floor, lower walls	
1	First	135	Floor, lower walls	CU-2
2	Ground	61A and 61B	Upper walls, ceiling	CU-3
2	First	135	Upper walls, ceiling	
3	Ground	60C	All	CU-4

[a] From TAMU 2016.

3.5 STEP 5 – DEVELOP A DECISION RULE

The fifth step in the DQO process specifies appropriate population parameters, confirms action levels are above detection limits, and develops an if…then…decision rule statement. For this survey effort, the parameter of interest was individual surface activity measurements exceeding the screening values listed in Table 3.2. Since the licensee does not have limits for hot spots (i.e., all residual activity must be below the screening values), a statistical test was not used in the analysis of data to determine if a CU "passes" or "fails" based on the mean activity, instead each measurement was compared to the screening levels, and any individual exceedance of a screening level or classification would result in a failure of the CU. The decision rule can be stated as:

If all measurements of residual radioactivity are below the screening levels listed in Table 3.2, then ORISE recommends no further actions; if measurements of residual radioactivity are above the screening levels listed in Table 3.1, then ORISE recommends additional actions to demonstrate compliance with the screening values.

3.6 STEP 6 – SPECIFY LIMITS ON DECISION ERRORS

The sixth step in the DQO process examines the consequences of making an incorrect decision, specifies the range of values where consequences are minor (the gray region), and assigns values that reflect tolerable probability for potential decision errors. Decision errors were controlled both during the on-site investigations and during the data quality assessment phase.

The number of measurements collected in each CU was determined by scan data and professional judgment. Therefore, the scan minimum detectable concentration (MDC) was optimized to ensure a true positive detection proportion of 0.90 and a false positive proportion of no more than 0.15 for beta and gamma radiation. The *a priori* scan MDC for beta radiation was less than 50% of the screening value (approximately 3,100 dpm/100 cm^2). The direct measurement MDCs and counting uncertainties were calculated based on the 95% confidence level. The *a priori* static MDC for beta surface activity was on the order of a few hundred dpm/100 cm^2 (approximately 600 dpm/100 cm^2), thus below the measurement quality objective of 10% of the screening value. (Note that 100% beta activity is presumed). Smear samples have typical MDCs on the order of 11-13 dpm/100 cm^2 for gross alpha/beta and approximately 24 dpm/100 cm^2 for tritium , again below the measurement quality objective.

3.7 STEP 7 – OPTIMIZE THE DESIGN FOR OBTAINING DATA

The seventh step in the DQO process reviews 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 details. Specific survey procedures are presented in Section 4.

4. PROCEDURES

The confirmatory survey activities were conducted during the period of November 14-16, 2016, in accordance with the approved Project-Specific Plan for the Confirmatory Survey, the *ORAU Radiological and Environmental Survey Procedure Manual* and the *ORAU Environmental Services and Radiation Training Quality Program Manual* (ORAU 2016b, ORAU 2016c and 2016d).

4.1 REFERENCE SYSTEM

All direct 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 for floors or the lower left corner of walls. Smear samples for removable activity were numbered/labeled according to ORAU 2015c and referenced to the corresponding direct measurement location.

4.2 SURFACE SCANS

Surface scans for alpha-plus-beta radiation were performed using Ludlum Model 43-68 or the Ludlum Model 43-37 (floor monitor) gas flow proportional detectors coupled to Ludlum Model 2221 ratemeter-scalers with audible indicators. Scans for gamma radiation were performed using Ludlum Model 44-10 sodium iodide (NaI) scintillation detectors coupled to the same ratemeter-scalers. Additionally, the ratemeter-scalers were coupled to data loggers to electronically record all scanning data points.

Scan density was dependent on the MARSSIM classification: Class 1 areas received high-density scans, Class 2 areas received medium-density scans, and Class 3 received judgmental scans. Locations of elevated direct radiation as indicated by an audible increase in response of the ratemeter-scaler were marked for further investigation. Class 2 areas, upper walls (over 2.4 meters) and ceilings, were not scanned due to project schedule and based on the scan results of the Class 1 areas, floors and lower walls in the same rooms.

4.3 SURFACE ACTIVITY MEASUREMENTS

Direct measurements for total alpha-plus-beta surface activity were performed using Ludlum Model 43-68 gas proportional detectors coupled to Ludlum Model 2221 ratemeter-scalers.

Direct measurements were collected at judgmentally selected locations on the floor and lower walls based on surface scans or professional judgment. A total of 20 direct measurements were collected from CU-1 and 10 direct measurements were collected from CU-2. Alpha-only direct measurements were not collected by ORISE since alpha-only ROCs are not expected per the discussion in Section 3.3.1. Ambient "in air" measurements were collected in Rm-135 to use for background subtraction as a conservative measure.

A summary of confirmatory survey activities performed at TAMU is provided in Table 4.1 below.

Table 4.1 TAMU Survey Units

CU #	SU Class	Room(s)	Surfaces	Scans Performed	Direct Measurements Performed	Smear Samples Collected
1	1	61A	Floor, lower walls	Yes	Yes	Yes
	1	61B	Floor, lower walls	Yes	Yes	Yes
2	1	135	Floor, lower walls	Yes	Yes	Yes
3	2	61A and 61B	Upper walls, ceiling	No	No	No
	2	135	Upper walls, ceiling	No	No	No
4	3	60C	All	Yes	No	No

4.4 REMOVABLE ACTIVITY SAMPLING

Dry smear samples were collected from all direct measurement locations to quantify removable activity. Wet smears were collected at every other location, or based on professional judgment, to quantify tritium (H-3). Smears were collected from an area of 100 cm^2.

5. SAMPLE ANALYSIS AND DATA INTERPRETATION

All samples and data collected on site were delivered to the ORISE facility for analysis and interpretation. Analysis methods for samples and field data are discussed below; Appendix D provides more detailed information on survey and analytical procedures

5.1 PHYSICAL SAMPLES

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 2016e). Dry smear samples were analyzed for gross alpha and gross beta activity using a low-background proportional counter. Wet smear samples were analyzed for H-3 using a liquid scintillation counter (LSC). The analytical results and surface activity measurement data were reported in units of dpm/100 cm^2.

5.2 SURVEY DATA

Direct measurements collected in the field were converted to units of dpm/100 cm^2 for comparison to the screening value. Electronic scan data were downloaded and processed with the U.S. Environmental Protection Agency's ProUCL software. Scan data summary statistics were generated for each CU investigated. Scan data were also graphed in quantile (Q) plots for assessment. The Q plot is a graphical tool for assessing the distribution of a data set. In viewing the Q plots provided in Appendix B, the Y-axis represents instrument response, in units of counts per minute (cpm). The X-axis represents the data quantiles about the mean value. Values less than the mean are represented in the negative quantiles and the values greater than the mean are represented in the positive quantiles. A normal distribution that is not skewed by outliers—i.e., a background radiation population—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.

6. FINDINGS AND RESULTS

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

6.1 SURFACE SCANS

Scan data Q-plots and summary statistics are presented in Appendix A for each of the confirmatory units investigated.

Alpha-plus-beta scans in CU-1 did not identify areas of elevated direct radiation on the floor or lower walls, as indicated by the fairly straight line in the Q-plots. The alpha-plus-beta scan data are representative of a background population. The shape of the Q-plot for the gamma scan of the floor is indicative of a background population as well. Gamma scans of the lower walls identified several areas that had a slight increase of direct radiation. These areas were near corners, in the smaller rooms located in 61B, or were near cement blocks, which had a higher instrument response than the poured concrete; due to naturally occurring radioactive materials in the composition of the block and not due to contamination.

During the alpha-plus-beta radiation scans in Rm 135 of CU-2, several spikes—up to three times background—were noticed on the Ludlum 43-37 floor monitor and the Ludlum 43-68 hand-held. These spikes did not exhibit periodicity and were not reproducible. The spikes are clearly visible in the floor and lower wall Q-plots (page A-3 and A-4), taking the shape of an exponential increase function. Instrumentation was investigated on-site and was determined to be functioning properly. The cause of the spikes could not be identified. Moreover, the area of the initial spike was marked for further investigation via direct measurements. The Q-plot for the gamma scan data of the floor takes the shape of a step function. Given that the surveyor noted an increase in response around pipe penetrations, exposing concrete through the steel liner, this step function is attributed to two separate background populations from detector geometry and NORM in the concrete.

As indicated by the straight line in the Q-plots, surface scans did not identify any areas of elevated direct alpha-plus beta radiation in CU-4 (Class 3 survey units).

6.2 SURFACE ACTIVITY MEASUREMENTS

A summary of ORISE's total and removable direct measurement data is provided below in Table 6.1. The complete data set is provided in Table B-1. None of the 30 direct measurements collected exceeded the default screening value for Co-60. Similarly, none of the smear samples exceeded the screening values for removable surface activity.

Table 6.1 Surface Activity Ranges (dpm/100 cm^2)												
CU No.	Total Alpha-Plus-Beta			Removable								
				Alpha			Beta			H-3		
CU-1	-34	to	1,500	0	to	2	-2	to	8	-7	to	17
CU-2	-340	to	710	0	to	2	-2	to	8	-3	to	19

7. SUMMARY AND CONCLUSION

At the NRC's request, ORISE conducted confirmatory survey activities at the Zachry Engineering Center at Texas A&M University campus during the period of November 14-16, 2016. The survey activities included gamma radiation surface scans, alpha-plus-beta radiation surface scans, alpha-plus-beta total activity measurements, and removable activity measurements. The majority of the areas scanned exhibited radiation levels indistinguishable from background and were uniform over the surfaces surveyed. There were exceptions, and these areas were marked as judgmental locations for direct measurements. All of the judgmental direct measurements for total surface activity were below 21% default screening values. At the time of this report the licensee's FSS report was not available, therefore ORISE cannot comment on its acceptability or the licensee's overall conclusion regarding the site's final radiological status. However, based on the confirmatory survey results, ORISE is of the opinion that CU-1 and CU-2 satisfy release criteria for unrestricted use. ORISE did not collect any data that would refute the licensee's classification of survey units in CU-2 and CU-3, nor was there any indication that these CUs would not meet the criteria for unrestricted use.

8. REFERENCES

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

NRC 1997. *Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions.* NUREG-1507. U.S. Nuclear Regulatory Commission. Washington, DC. December.

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

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ORAU 2016a. *Independent Technical Review of the Final Status Survey Plan for the Unrestricted Release of the Zachry Engineering Center*. 5294-DR-01-0. Oak Ridge, Tennessee. November 2.

ORAU 2016b. *Project-Specific Plan for the Confirmatory Survey of the Zachry Engineering Center at Texas A&M University in College Station, Texas*. Oak Ridge, Tennessee. November 9.

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

ORAU 2016d. *ORAU Environmental Services and Radiation Training Quality Program Manual*. Oak Ridge, Tennessee. November 9.

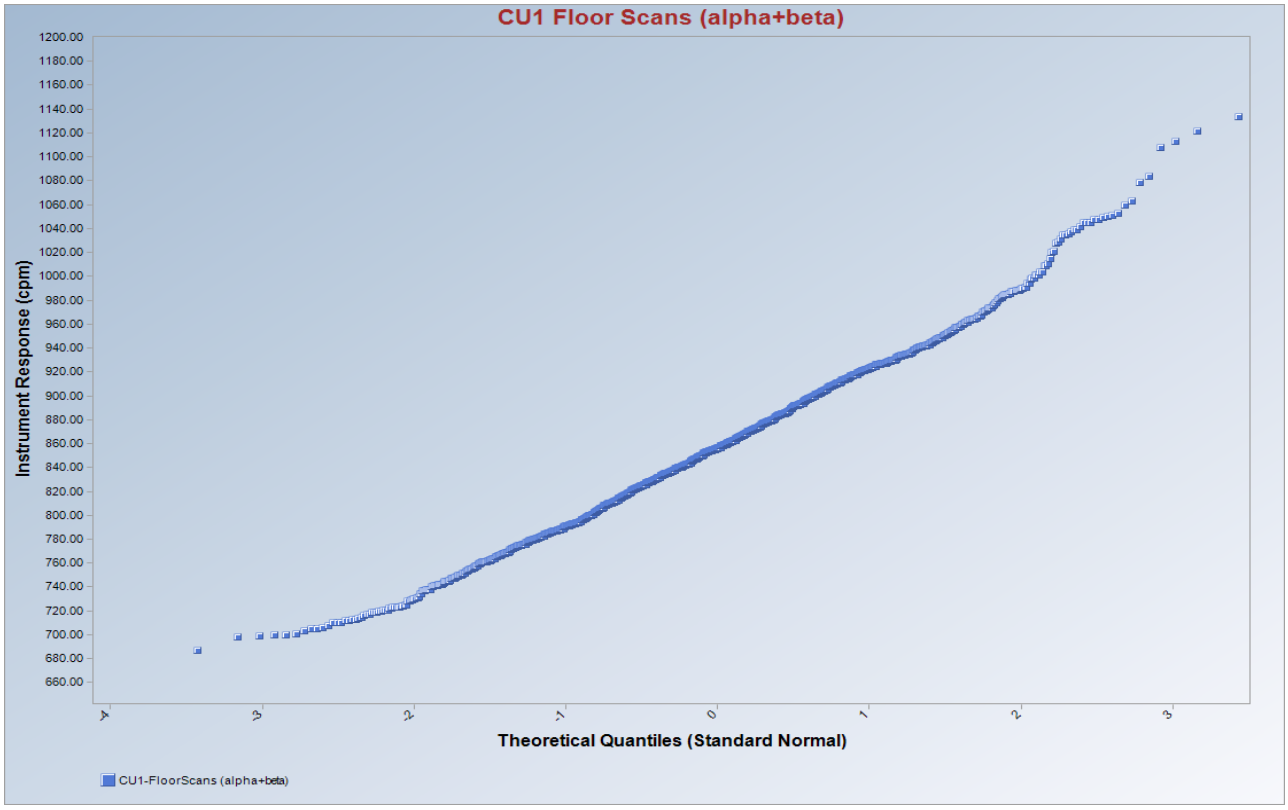
ORAU 2016e. *ORAU Radiological and Environmental Analytical Laboratory Procedures Manual*. Oak Ridge, Tennessee. November 9.

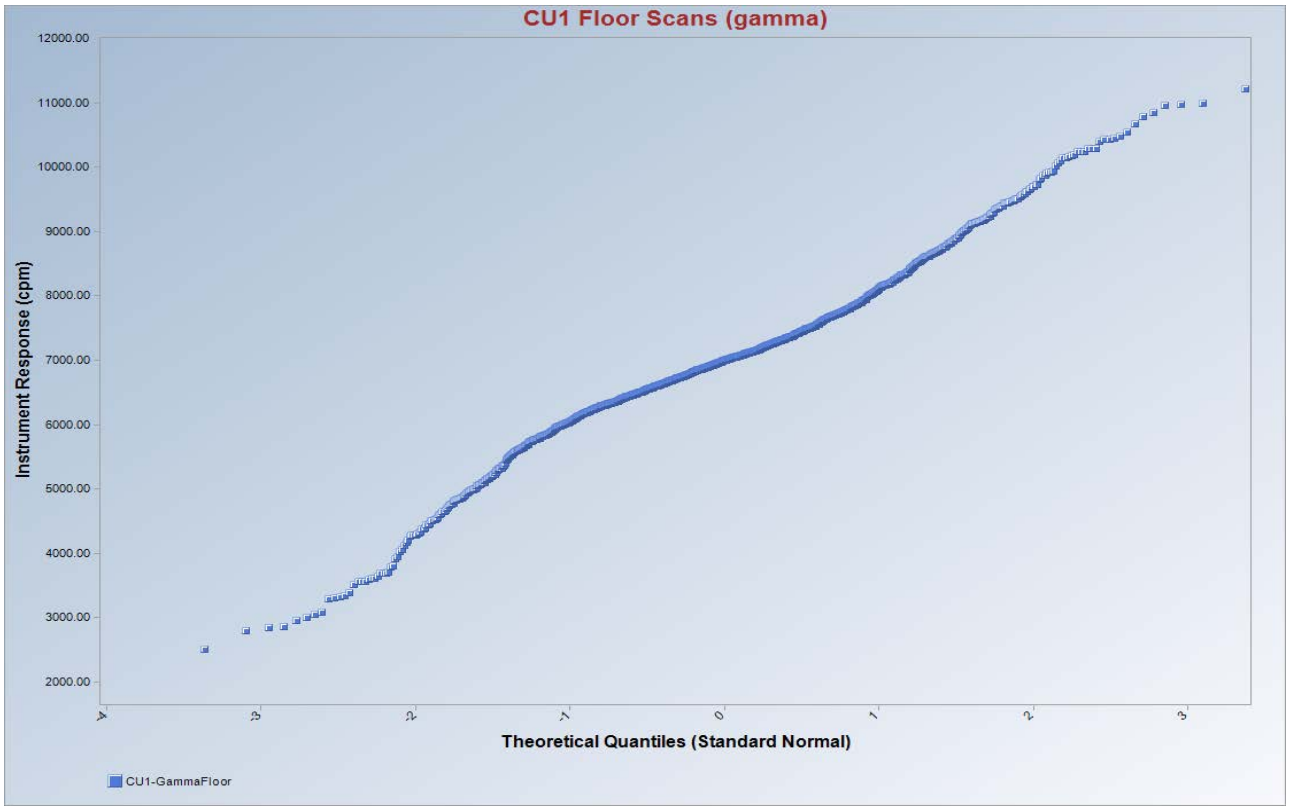
ORAU 2016f. *ORAU Health and Safety Manual*. Oak Ridge, Tennessee. January.

TAMU 2016. *Survey Plan for the Unrestricted Radiological Release of the AGN-201M Research Reactor Facility Zachry Engineering Center. TAMU/TEES AGN-08, Rev. 0. Texas A&M University*. College Station, Texas. September 2.

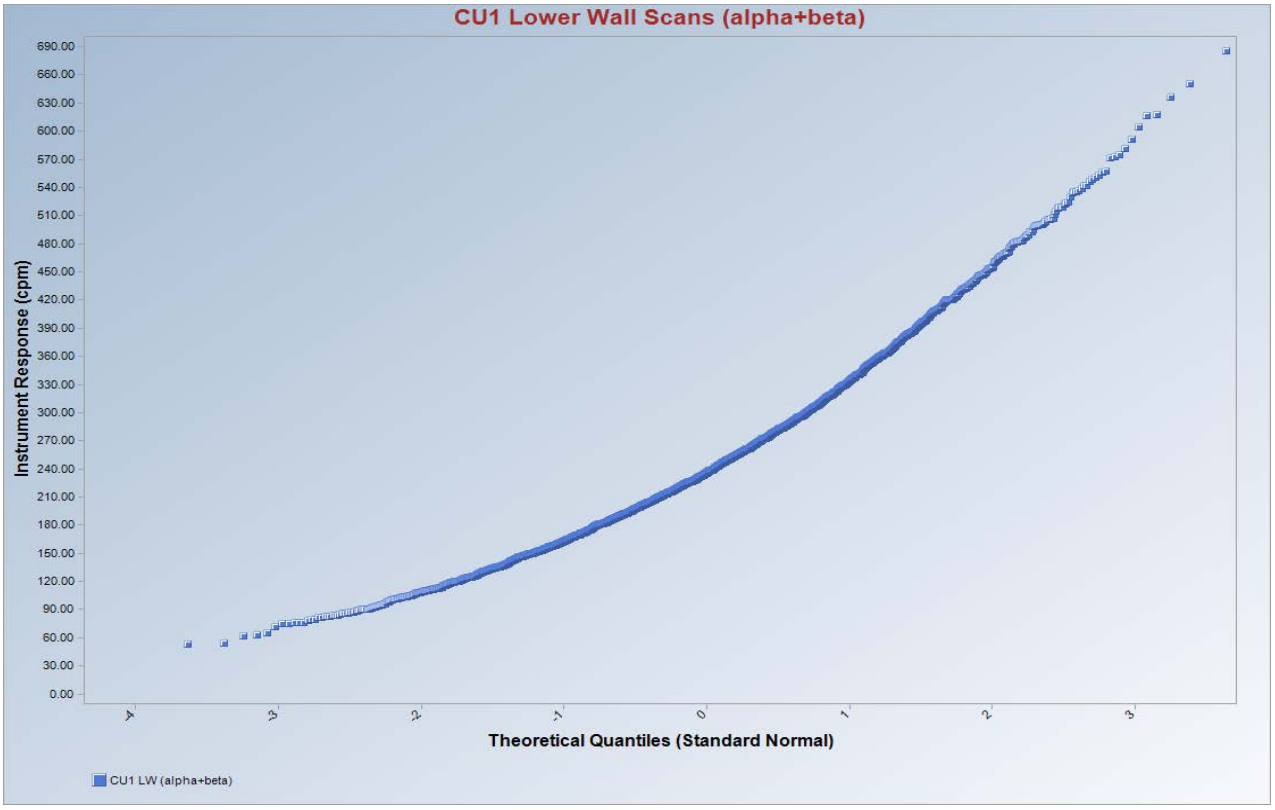
APPENDIX A

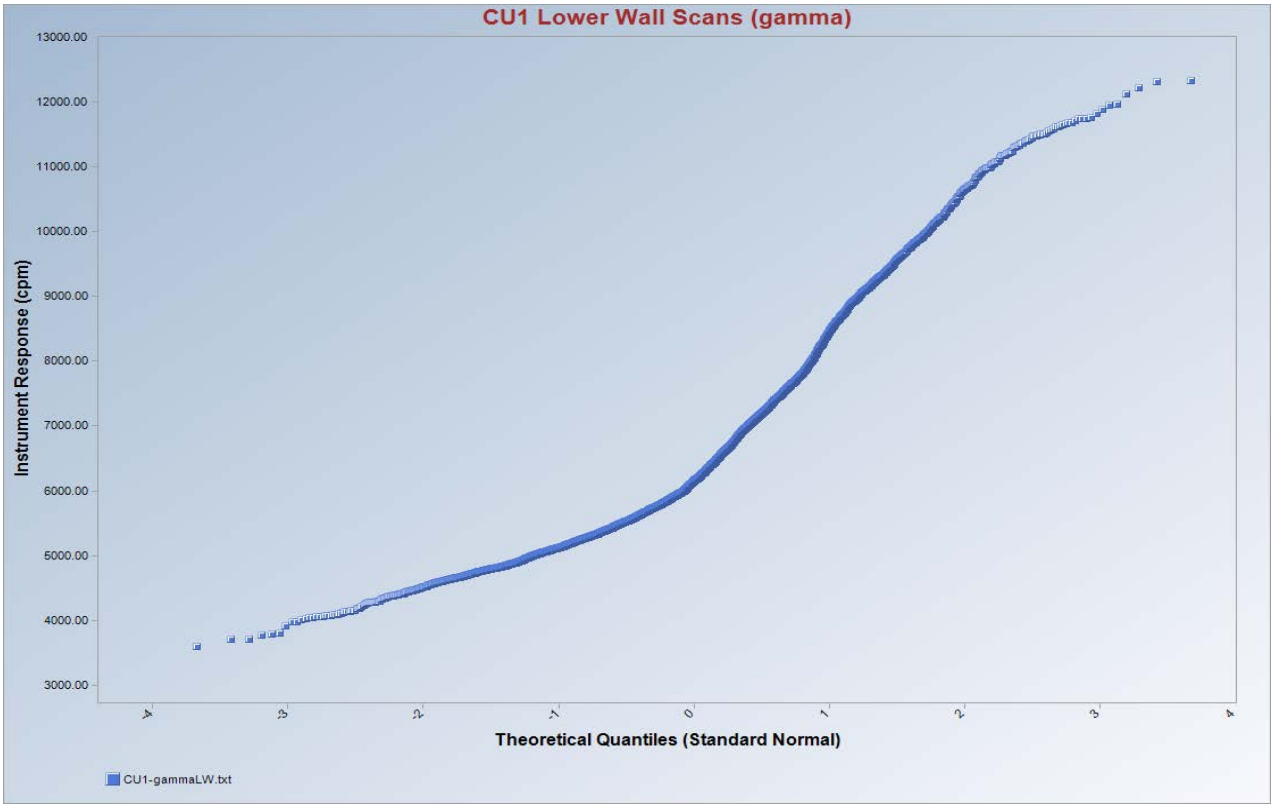
Q-PLOTS AND SCAN STATISTICS



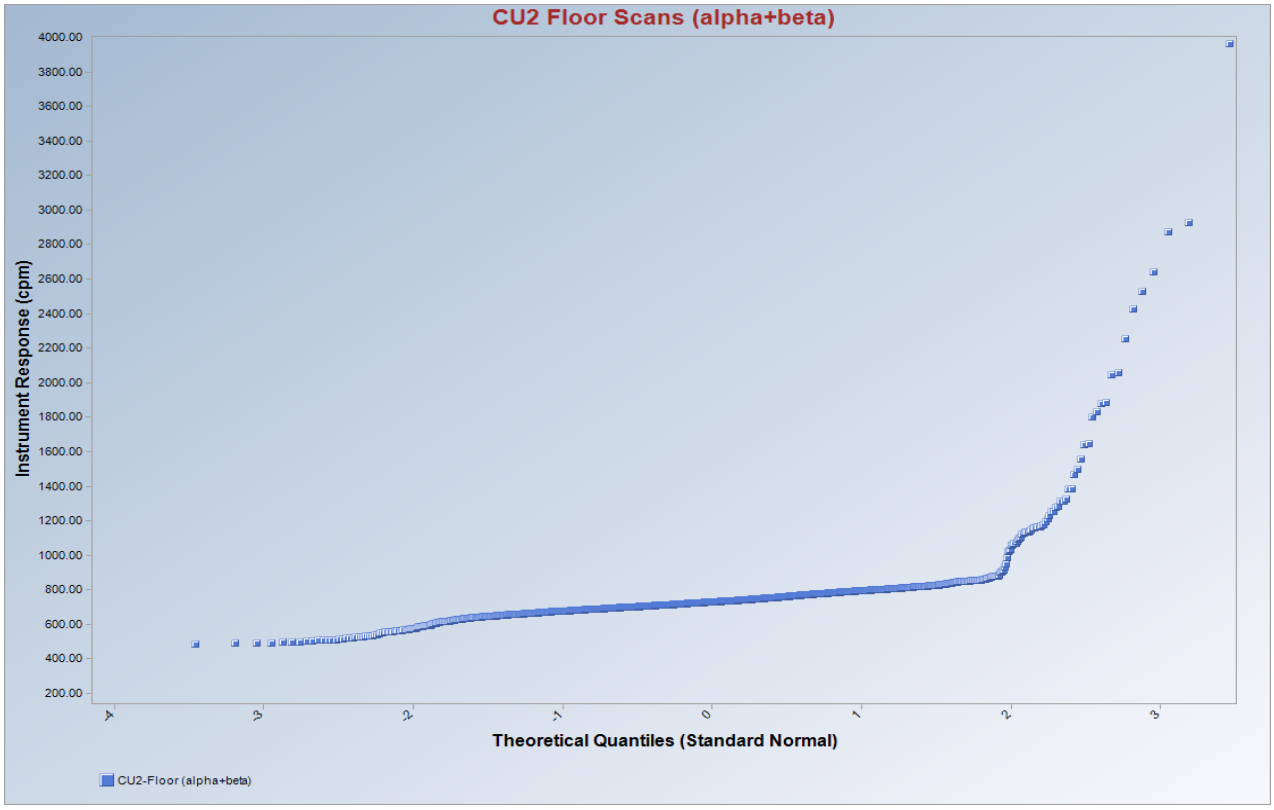


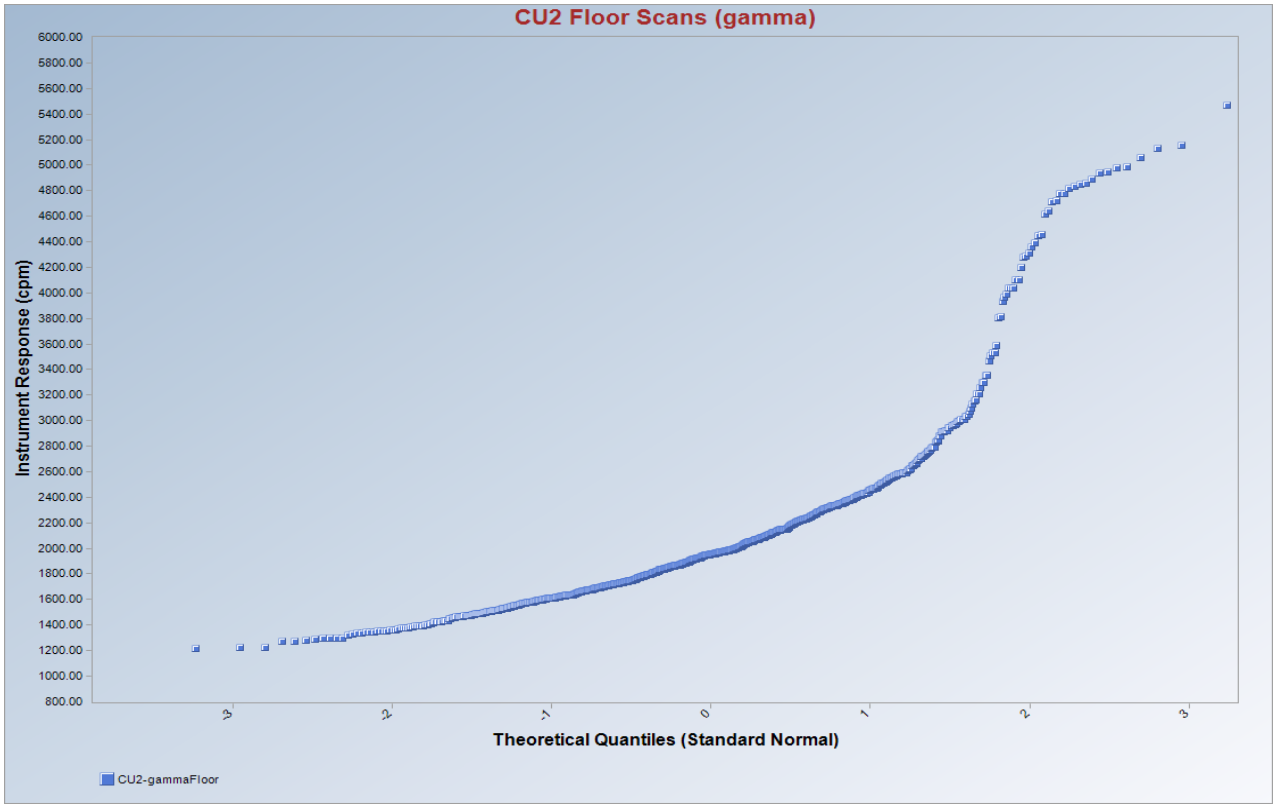
Scan Statistics for CU 1 Floor (cpm)				
Radiation	**Minimum**	**Maximum**	**Mean**	**SD**
Alpha+Beta	687	1,134	858	65
Gamma	2,519	11,224	7,026	1,216



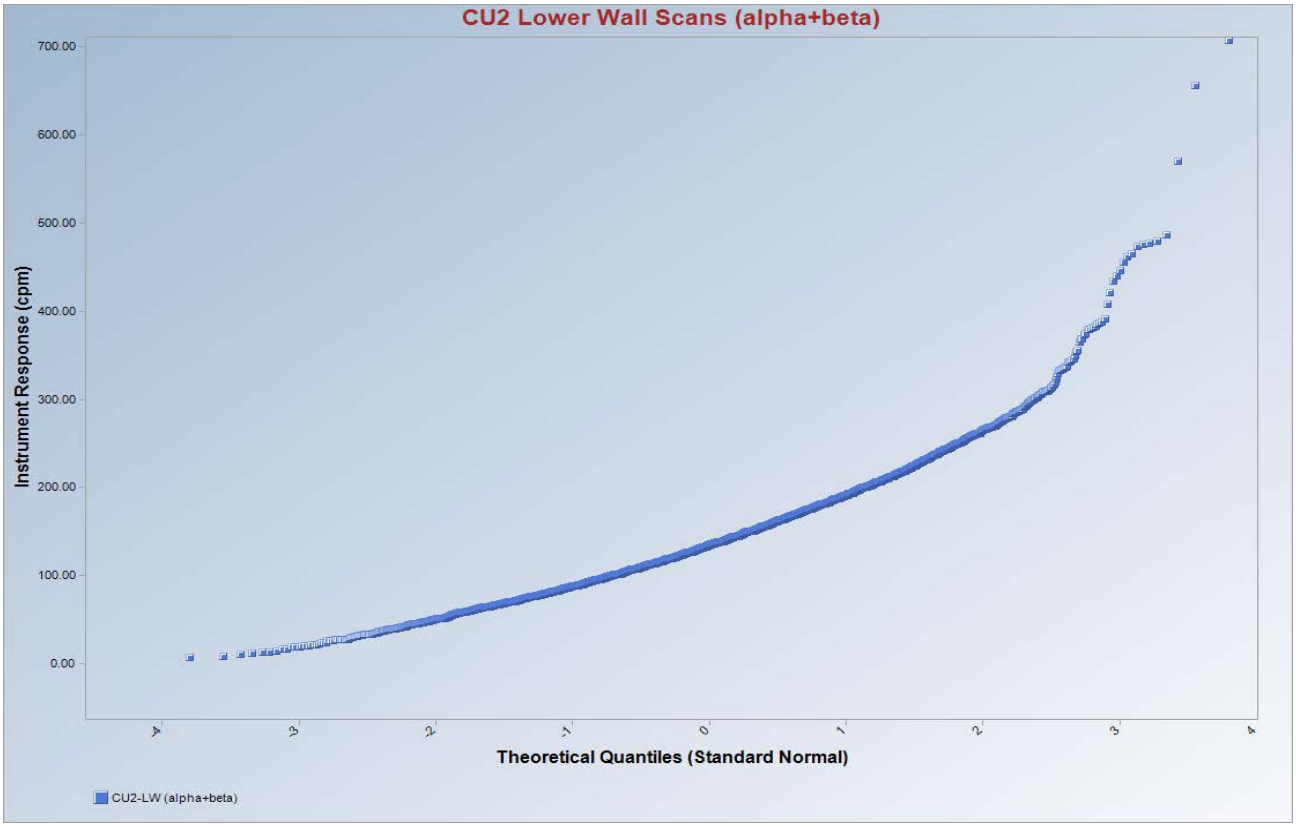


Scan Statistics for CU 1 Lower Walls (cpm)				
Radiation	**Minimum**	**Maximum**	**Mean**	**SD**
Alpha+Beta	53	686	248	88
Gamma	3,600	12,336	6,621	1,630

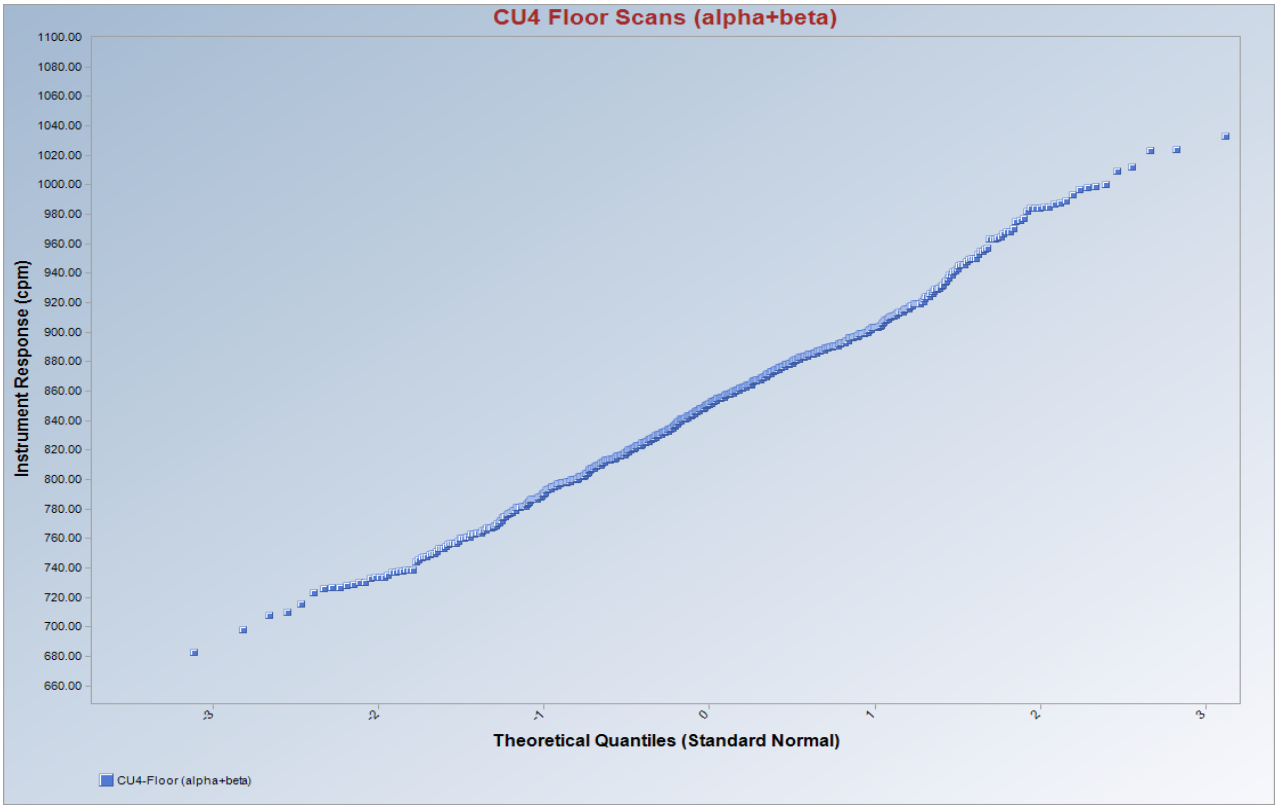




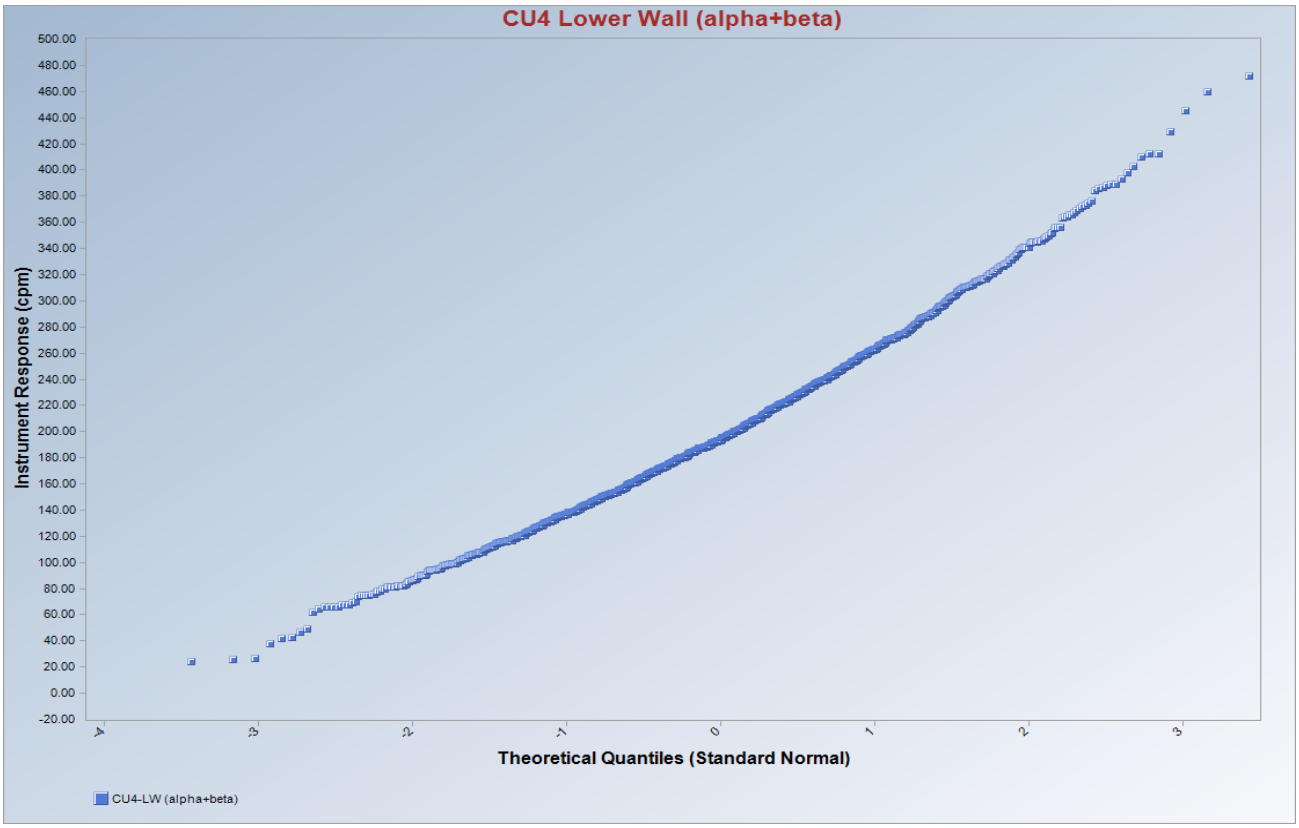
Scan Statistics for CU 2 Floor (cpm)				
Radiation	**Minimum**	**Maximum**	**Mean**	**SD**
Alpha+Beta	488	3,962	747	161
Gamma	1,216	5,472	2,085	628



Scan Statistics for CU 2 Lower Walls (cpm)				
Radiation	**Minimum**	**Maximum**	**Mean**	**SD**
Alpha+Beta	7	708	140	55



Scan Statistics for CU 4 Floor (cpm)				
Radiation	**Minimum**	**Maximum**	**Mean**	**SD**
Alpha+Beta	683	1,033	850	60



Scan Statistics for CU 4 Lower Walls (cpm)				
Radiation	**Minimum**	**Maximum**	**Mean**	**SD**
Alpha+Beta	24	472	200	64

APPENDIX B
DATA TABLES

Table B.1. Confirmatory Survey Surface Activity Measurement Resutls									
Smear ID	H-3 Smear ID	Coordinates (meters)		Room	Surface	Surface Activity Measurements (dpm/100 cm²)			
		X	Y			Total	Removable		
							Alpha	Beta	H-3
Confirmatory Unit 1									
5294R0001	5294R0002	5.9	3.1	61B	Floor	1,100	0	8	1
5294R0003	--	3.0	0.7	61B	W. Wall	1,500	2	-2	--
5294R0004	5294R0005	5.5	1.9	61B	Floor	1,000	0	4	5
5294R0006	--	2.3	0.2	61B	Floor	880	0	0	--
5294R0007	5294R0008	0.5	1.4	61B	N. Wall	1,000	2	5	-2
5294R0009	--	4.4	5.1	61B	Floor	850	0	0	--
5294R0010	5294R0011	3.3	6.7	61B	Floor	45	0	0	1
5294R0012	--	4.1	1.1	61B	N. Wall	1,300	2	2	--
5294R0013	5294R0014	5.5	6.1	61B	Floor	230	0	4	5
5294R0015	--	4.6	7.3	61B	Floor	980	2	0	--
5294R0016	5294R0017	4.7	1.1	61A	S. Wall	1,100	0	-1	-1
5294R0018	--	0.4	3.4	61A	Floor	-5	0	2	--
5294R0019	5294R0020	3.5	2.8	61A	Floor	760	0	0	-7
5294R0021	--	4.0	2.0	61A	N. Wall	-34	0	2	--
5294R0022	5294R0023	5.9	4.3	61A	Floor	-12	0	3	0
5294R0024	--	5.5	0.5	61A	E. Wall	220	0	2	--
5294R0025	4184R0026	7.9	6.5	61A	Floor	570	0	0	17
5294R0027	--	3.0	0.6	61A	S. Wall	53	0	6	--
5294R0028	5294R0029	3.3	1.6	61A	N. Wall	350	0	0	2
5294R0030	--	0.5	6.0	61A	Floor	560	0	-1	--
Confirmatory Unit 2									
5294R0031	5294R0032	3.3	1.7	135	Floor	710	0	2	19
5294R0033	--	5.4	10.6	135	Floor	640	0	2	--
5294R0034	5294R0035	4.6	0.7	135	N. Wall	-270	0	0	-3
5294R0036	--	2.6	1.6	135	N. Wall	-340	0	0	--
5294R0037	5294R0038	11.8	0.9	135	W. Wall	-210	0	0	-1
5294R0039	--	4.5	0.4	135	W. Wall	-210	0	-2	--
5294R0040	5294R0041	7.7	2.1	135	S. Wall	-260	2	-2	7
5294R0042	--	2.0	1.5	135	S. Wall	-220	0	8	--
5294R0043	5294R0044	8.6	1.0	135	E. Wall	-210	0	-1	0
5294R0045	--	5.8	0.6	135	E. Wall	-92	0	-1	--

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)
coupled to:
Trimble Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

C.1.2 Alpha-Plus-Beta

Ludlum Gas-flow Proportional Detector Model 43-68, 126 cm^2 physical area, 0.8 mg/cm^2 mylar window, coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to:
Trimble Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

Ludlum Gas-flow Proportional Detector Model 43-37, 584 cm^2 physical area, 0.8 mg/cm^2 mylar window, coupled to:
Ludlum Ratemeter-scaler Model 2221
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to:
Trimble Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

C.2 LABORATORY ANALYTICAL INSTRUMENTATION

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

Tri-Carb Liquid Scintillation Analyzer
Model 3100
(Packard Instrument Co., Meriden, CT)

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 2016f, and ORAU 2016c). 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 2016d)
- ORAU Radiological and Environmental Analytical Laboratory Procedures Manual (ORAU 2016e)
- ORAU Radiological and Environmental Survey Procedures Manual (ORAU 2016c)

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 Background Measurements

Material-specific background measurements were not collected from the Zachry Engineering Center due to time constraints. Instead, ambient radiation measurements were collected from Rm 135, in CU-2, with the Model 43-68 gas-flow proportional detector. A total of 10 ambient measurements were recorded yielding and average of 166 cpm. This average ambient background yielded a conservative calculation of total surface activity relative to determining a material specific background.

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 efficiency for alpha-plus-beta was 0.11, based on Co-60. Alpha-only 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

The scan MDC for a nominal instrument background of 350 cpm was 2,400 dpm/100 cm^2 for the Model 43-68.

D.3.2 Surface activity measurements

Measurements of gross alpha-plus-beta surface activity levels were performed using hand-held gas proportional detectors coupled to portable ratemeter-scalers. Count rates (cpm), which were a one-minute count 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 efficiency of 0.11, for Co-60, was used for surface activity calculations. 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 = 1.26 (for the Model 43-68)

The static MDC was 650 dpm/100 cm^2, based on a nominal instrument background of 350 cpm.

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. For removable tritium determinations, a second smear was moistened with deionized water, and an adjacent 100 cm^2 was wiped. The smear was then sealed in a labeled liquid scintillation vial with the location and pertinent information 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 13 dpm/100 cm^2 for beta.

D.4.3 Tritium Analysis

Analyses for tritium were performed by placing a smear or a representative portion of the samples into a scintillation cocktail and counting on a liquid scintillation analyzer. Samples were then spiked with a known amount of the appropriate standard and recounted. The MDA of the procedure was 24 dpm/100 cm^2.

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.