IUPUI/IUMC
Fesler Hall, Psychiatric Research, and Myers Buildings Decommissioning Final Status Report

NRC License Number 13-02752-03

December 18, 2014

Prepared:	Mike Culp	Project Manager	Date:	12-18-14
Technical Review:	Patrick McDermott	Certified Health Physicist	Date:	
Approved:	Dave Culp	Radiological Engineer	Date:	

Prepared by:
Chase Environmental Group, Inc.
109 Flint Road
Oak Ridge, TN 37830
865-481-8801

TABLE OF CONTENTS

TABLES

APPENDICES

ACRONYMS

ALARA	As Low As Reasonably Achievable
CFR	Code of Federal Regulations
DCGL	Derived Concentration Guideline Level
$DCGL_{EMC}$	Derived Concentration Guideline Level – Elevated Measurement Comparison
$DCGL_W$	Derived Concentration Guideline Level – Wilcoxon Rank Sum
DWP	Decommissioning Work Plan
DQO	Data Quality Objective
DSV	Default Screening Value
FSS	Final Status Survey
FSSR	Final Status Survey Report
HHC	Health and Hospital Corporation of Marion County
HSA	Historical Site Assessment
IUPUI/IUMC	Indiana University at Indianapolis/Indiana University Medical Center
LBGR	Lower Bound of the Gray Region
LSC	Liquid Scintillation Counter
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
NORM	Naturally Occurring Radioactive Materials
NRC	U.S. Nuclear Regulatory Commission
NIST	National Institute of Standards and Technology
PGM	Pancake Geiger-Mueller
QA	Quality Assurance
TEDE	Total Effective Dose Equivalent

1.0 INTRODUCTION

Indiana University at Indianapolis/Indiana University Medical Center (IUPUI/IUMC) has decided to permanently cease licensed activities under US Nuclear Regulatory Commission (NRC) Broad Scope radioactive materials license number 13-02752-03 at the Wishard Hospital Myers Building and the Institute of Psychiatric Research Building. IUPUI/IUMC plans to raze or repurpose the buildings. Additionally, IUPUI/IUMC plans to renovate the fourth floor of Fesler Hall where licensed activities were historically conducted. See Appendix A for a site map. IUPUI/IUMC plans to release these buildings for unrestricted use.

Facilities include research laboratories, offices, and other support areas. Radioactive materials used at the facilities consisted of a variety of beta and gamma emitting radionuclides for medical research and imaging. Primarily these included C-14, H-3, I-125, P-32, and S-35, with much lesser quantities of other tracers and imaging nuclides. Based on an analysis of the default screening values (DSVs), quantities used, physical forms, half-lives, and receipt and distribution records, only C-14, Ca-45, Cl-36, H-3, and Na-22 are of concern for decommissioning.

Over the years, IUPUI/IUMC has conducted closeout surveys of rooms where radioactive materials were used at the conclusion of licensed activities. IUPUI/IUMC retained Chase Environmental Group (Chase) to perform independent third party verification of closeout procedures using current decommissioning protocols. Decommissioning was conducted under the IUPUI/IUMC NRC radioactive materials license number 13-02752-03, and in accordance with a Decommissioning Work Plan (DWP). The DWP was developed using the guidance provided in NUREG 1757, "Consolidated NMSS Decommissioning Guidance"; and NUREG 1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM). Final status surveys (FSS) were designed to implement the protocols and guidance provided in MARSSIM to demonstrate compliance with the DSVs calculated in NRC DandD v.2.1 software using default parameter values. These methods ensured technically defensible data were generated to aid in determining whether or not the facilities meet the release criteria for unrestricted use specified in 10 CFR 20 Subpart E.

IUPUI/IUMC established conservative ALARA goals for building structural surfaces and systems based on the release criteria specified in NUREG 1556, Volume 7, Table Q.2, "Acceptable Surface Contamination Levels for Equipment." Specifically, the following surface contamination limits were used:

- 5,000 dpm/100 cm^2 total surface contamination
- 500 dpm/100 cm^2 removable surface contamination

On-site activities were performed from December 8, 2014 to December 12, 2014. Facility characterization surveys identified several areas on building structural surfaces with residual radioactivity above the ALARA goal of 5,000 dpm/100 cm^2 total surface activity and 200 gross cpm/100 cm^2 removable surface contamination in the Psychiatric Research building. Elevated activity was limited to survey unit PRB-2201 in labs 204, 205, 207, and 209 on the 2nd floor. Areas of elevated activity were wet wiped/scrubbed for ALARA purposes and are described in sections 18.0 and 19.0.

This report presents sufficient data to confirm IUPUI/IUMC's determination that the facility is suitable for unrestricted release in accordance with NRC requirements. Final status surveys demonstrate that building structural surfaces and systems included in the scope of this report are below release criteria and are suitable for unrestricted release. All final status surface contamination measurements were a small fraction of the DSVs. Based on the Building Occupancy Scenario of NRC DandD dose modeling software Version 2.1, **the Total Effective Dose Equivalent (TEDE) to an average member of the critical group is 1.49 mrem/year (<6% of the release criterion of 25 mrem/yr).** This result is very conservative as we use the results of the survey unit with the highest average activity and the DSV of the most limiting nuclide.

2.0 SITE DESCRIPTIONS AND HISTORY

2.1 Historical Site Assessment

IUPUI/IUMC performed a Historical Site Assessment (HSA) to determine nuclides used and locations of usage. Facilities included in the scope of this report consist of the 7th floor of the main portion of Wishard Hospital (aka the Myers Building), the 4th floor of Fesler Hall, and the Institute of Psychiatric Research building. Radioactive materials were used on the 7th floor of the Myers Building[1]; the 4th floor of Fesler Hall[2]; and the Basement through 4th floors of the Psychiatric Research Building. Impacted areas consist of laboratories, offices, and other support areas. Impacted areas are constructed with concrete block or sheetrock walls; metal or plastic casework, fume hoods and sinks; composite or laminate benchtops; and vinyl flooring in lab areas.

Impacted areas are serviced by three impacted systems – fume hood ventilation exhaust, vacuum, and drain systems. Building drains are discharged directly to the sewer system without treatment or retention. Ventilation exhaust is provided primarily via fume hoods to maintain laboratory areas at a negative pressure relative to hallway and office areas. A central vacuum system services a impacted laboratories.

Impacted building floor plans are provided in Appendix B.

2.2 Potential Contaminants

The table below lists the nuclides used in dispersible form in impacted areas. This list was compiled through review of radionuclide receipt and distribution records.

[1] Radioactive materials were also used in the Myers building basement, but the basement was previously decommissioned.

[2] Radioactive materials may have been used on other floors within Fesler, but only the 4th floor is in the scope of this project.

Table 2-1: Radionuclides Used in Dispersible Form

Nuclide	Half-life (years)	Predominant Emissions	Buildings Where Used		
			Myers	PR	Fesler
C-14	5.7E+03	Low Energy Beta	X	X	X
Ca-45	4.5E-01	Beta		X	
Cl-36	3.0E+05	Beta		X	
Cr-51	7.6E-02	Gamma		X	X
Fe-59	1.2E-01	Beta/Gamma			X
H-3	1.2E+01	Low Energy Beta	X	X	X
I-125	1.6E-01	Gamma	X	X	X
I-131	2.2E-02	Beta/Gamma			X
K-42	1.4E-03	Beta/Gamma		X	
Na-22	2.6E+00	Positron/Gamma		X	
P-32	3.9E-02	Beta	X	X	X
P-33	7.0E-02	Beta		X	
Rb-86	5.1E-02	Beta/Gamma		X	
S-35	2.4E-01	Low Energy Beta	X	X	X
Sr-85	1.8E-01	Gamma			X

2.3 License Information

IUPUI/IUMC is currently operating under NRC broad scope materials License Number 13-02752-03.

2.4 Operational and Closeout Radiological Surveys

During the HSA, the radiological status of impacted facilities was determined by reviewing historical survey records and interviewing Radiation Safety personnel. Routine surveys were performed by authorized users during the period of usage. These surveys focused on specific areas of usage within each room as well as surrounding areas to ensure that residual contamination did not exist above their local action level for removable surface contamination (200 cpm/100 cm^2). Additionally, when areas no longer needed to use radioactive materials, closeout surveys were performed consisting of wipe surveys for removable radioactivity and for more recent surveys, direct scan surveys of surfaces with a pancake Geiger-Mueller (PGM) detector. Any identified areas of elevated activity were decontaminated and re-surveyed until the operational limits of background for PGM surveys and background for removable radioactivity measurements were met.

2.5 Previous Decommissioning Activities

There have been no previous decommissioning activities at the facility. However, rooms where radioactive materials were used or stored received closeout surveys per IUPUI/IUMC procedures. Additionally, Chase performed final status surveys in impacted areas of the Myers Building basement in 2013.

3.0 CURRENT/FUTURE USE

The buildings are being prepared for decommissioning. After decommissioning, the Myers and Psychiatric Research buildings will likely be demolished to accommodate construction of new hospital facilities. The Fesler Hall building is currently occupied and areas of the 4th floor will be renovated for future use.

4.0 FACILITY RELEASE CRITERIA

The unrestricted use radiological release criteria of NRC 10CFR20 Subpart E was used for decommissioning this facility. Specifically, impacted areas of the facility were surveyed in accordance with the guidance contained in MARSSIM to demonstrate compliance with the criteria of 10CFR20.1402, "Radiological Criteria for Unrestricted Use." The criteria are that residual radioactivity results in a TEDE to an average member of the critical group that does not exceed 25 mrem per year, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA).

5.0 NUCLIDES OF CONCERN

All short-lived nuclides ($t_{1/2}$ < 120 days) and nuclides where more than ten half-lives have elapsed since the last usage were eliminated from consideration as nuclides of concern. After eliminating these nuclides, five nuclides are considered for decommissioning as presented in the table below.

Table 5-1: Nuclides of Concern for Decommissioning

Nuclide	Half-life (years)	Predominant Emissions
C-14	5.7E+03	Low Energy Beta
Ca-45	4.5E-01	Beta
Cl-36	3.0E+05	Beta
H-3	1.2E+01	Low Energy Beta
Na-22	2.6E+00	Positron/Gamma

6.0 DERIVED CONCENTRATION GUIDELINE LEVELS

The NRC has published DSVs in NUREG 1757, Volume 1, Appendix B for commonly used radionuclides. DandD v.2.1 software was used to determine DSVs for isotopes not listed in NUREG 1757. Surface contamination limits were derived using the building occupancy scenario together with default parameter values. Screening values were selected such that the 0.9 quantile of projected doses was less than or equal to 25 mrem/year (i.e., when probabilistic dose assessment calculations were performed, there was a 90% probability the calculated dose would be less than 25 mrem/year). For each nuclide of concern, an initial concentration of 1 dpm/100 cm^2 was input into the software to develop a scaling factor in mrem/year per dpm/100 cm^2. Copies of the dose model output reports are presented in Appendix C. Screening values for the nuclides of concern are provided in the table below.

Table 6-1: Default Screening Values for Nuclides of Concern

Nuclide	Half-life (years)	Predominant Emissions	DandD Result (mrem/yr per dpm/100 cm^2)	Default Screening Value[3] (dpm/100 cm^2)
C-14	5.7E+03	Low Energy Beta	6.80E-06	3.7E+06
Ca-45	4.5E-01	Beta	8.92E-06	2.8E+06
Cl-36	3.0E+05	Beta	5.03E-05	5.0E+05
H-3	1.2E+01	Low Energy Beta	2.02E-07	1.2E+08
Na-22	2.6E+00	Positron/Gamma	2.62E-03	9.5E+03

The DSV's are the basis for developing the derived concentration guideline levels (DCGL's). The DCGL is the radionuclide specific surface activity concentration that could result in a dose equal to the release criterion. $DCGL_W$ is the concentration limit if the residual activity is essentially evenly distributed over a large area. For this project, $DCGL_W$ is equal to the DSV. In the case of non-uniform contamination, MARSSIM allows for evaluation of higher levels of permissible activity over small areas using the $DCGL_{EMC}$. Due to the radiological cleanliness of the facility and IUPUI/IUMC's conservative ALARA goal, $DCGL_{EMC}$ is not used. Additionally, due to the conservative ALARA goal, application of the unity rule for multiple radionuclides is not required to demonstrate compliance with the release criteria. An important assumption of the dose model is that removable contamination is <10% of total contamination. Historical survey results as well as characterization, final status and quality assurance (QA) survey results confirm that removable contamination levels are very low and meet this assumption. H-3 cannot be accurately detected directly by field instrumentation due to its low energy. Therefore, H-3 contamination was evaluated by removable contamination measurements only.

For conservatism, the limiting DSV of 9,500 dpm/100 cm^2 (Na-22) was used as a gross beta DCGL and to calculate doses from residual radioactivity. A removable surface activity DCGL of 950 dpm/100 cm^2 was established to ensure a removable fraction of 10% was verified, consistent with the assumptions of the dose model.

<u>Summary of Project Surface Contamination Limits</u>

Compliance with the DSVs is demonstrated by applying gross beta surface contamination limits as presented in the table below.

Table 6-2: Summary of Project Beta Surface Contamination Limits

Total Contamination (dpm/100 cm^2)	Removable Contamination (dpm/100 cm^2)
9,500	950

[3] The default screening value is calculated by dividing the release criterion of 25 mrem/yr by the DandD result in mrem/yr per dpm/100 cm^2.

7.0 ALARA GOALS (INVESTIGATION LEVELS)

IUPUI/IUMC established conservative ALARA goals based on the release criteria for equipment and materials specified in NUREG 1556, Volume 7, Table Q.2, "Acceptable Surface Contamination Levels for Equipment."[4] Specifically, the following surface contamination limits were used:

- 5,000 dpm/100 cm^2 total surface contamination
- 500 dpm/100 cm^2 removable surface contamination[5]

Because of the conservatism of the ALARA goals, these criteria were applied to gross beta measurements and the unity rule was not applied. The number of measurements required by MARSSIM to demonstrate compliance with the release criteria was calculated using the $DCGL_W$ and not the ALARA goal.

8.0 ALARA ANALYSIS

Due to the extremely low doses associated with residual radioactivity at the facility, a quantitative ALARA analysis was not required. Default screening values were used to establish DCGLs. Furthermore, IUPUI/IUMC routinely maintained all laboratory areas of the facility at levels < 200 dpm/100 cm^2 removable activity.

NUREG 1757, Volume 2, Appendix N states in part: "For ALARA during decommissioning, all licensees should use typical good-practice efforts such as floor and wall washing, removal of readily removable radioactivity in buildings or in soil areas, and other good housekeeping practices. In addition, licensees should provide a description in the Final Status Survey Report (FSSR) of how these practices were employed to achieve the final activity levels. In light of the conservatism in the building surface and surface soil generic screening levels developed by NRC, NRC staff presumes, absent information to the contrary, that licensees who remediate building surfaces or soil to the generic screening levels do not need to provide analyses to demonstrate that these screening levels are ALARA. In addition, if residual radioactivity cannot be detected, it may be assumed that it has been reduced to levels that are ALARA. Therefore, the licensee may not need to conduct an explicit analysis to meet the ALARA requirement."

[4] A removable surface contamination limit of 500 dpm/100 cm^2 is used to be consistent with the removable fraction used in the dose model.

[5] Because the LSC was set up to present data in cpm, a conservative investigation level of 200 cpm/100 cm^2 for each LSC channel was used to ensure compliance with the 500 dpm/100 cm^2 removable surface contamination investigation level.

9.0 PROJECT MANAGEMENT AND ORGANIZATION

Decommissioning activities were performed under the IUPUI/IUMC NRC radioactive materials license number 13-02752-09, and in accordance with the Decommissioning Work Plan (DWP). IUPUI/IUMC oversaw decommissioning activities and maintained responsibility for building maintenance, fire, and security functions.

10.0 TRAINING

IUPUI/IUMC provided Chase personnel with site specific Contractor Site Orientation Training and the necessary radiological training/qualification to conduct project operations under the provisions of the IUPUI/IUMC radioactive materials license. Chase provided training for decommissioning-specific programs, plans and procedures.

11.0 RADIATION SAFETY AND HEALTH PROGRAM

Radiological work was performed according to the IUPUI/IUMC NRC radioactive materials license Radiation Safety Program.

12.0 ENVIRONMENTAL MONITORING PROGRAM

Due to the limited scope of the project, a project-specific environmental monitoring program was not required.

13.0 RADIOACTIVE WASTE MANAGEMENT

All radioactive wastes generated during remediation were turned over to IUPU/IUMC for final disposition.

14.0 QUALITY ASSURANCE PROGRAM

Project-specific QA requirements were included in the DWP to meet the guidelines of MARSSIM Section 9.

15.0 SURVEY INSTRUMENTATION

15.1 Instrument Calibration

Laboratory and portable field instruments were calibrated within the previous year with National Institute of Standards and Technology (NIST) traceable sources to radiation emission types and energies to provide detection capabilities similar to the nuclides of concern. Portable instrument calibration records are included as Appendix D. Liquid scintillation counter records are maintained by IUPUI/IUMC.

15.2 Functional Checks

Functional checks were performed at least daily when in use. The background, source check, and field measurement count times for radiation detection instrumentation were specified by procedure to ensure measurements were statistically valid. Background readings were taken as part of the daily instrument check and compared with the acceptance range for instrument and site conditions.

15.3 Determination of Counting Times and Minimum Detectable Concentrations

Minimum counting times for background determinations and measurement of total and removable contamination were chosen to provide a minimum detectable concentration (MDC) that met the data quality objectives (DQOs). MARSSIM equations relative to building surfaces have been modified to convert to units of dpm/100 cm^2. Count times and scanning rates are determined using the following equations:

15.3.1 Static Counting

Static counting Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is an expansion of NUREG 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions", Table 3.1 (Strom & Stansbury, 1992):

$$MDC_{static} = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E_{tot} \cdot \frac{A}{100cm^2}}$$

Where:

MDC_{static} = minimum detectable concentration (dpm/100 cm^2)
B_r = background count rate (counts per minute)
t_b = background count time (minutes)
t_s = sample count time (minutes)
E_{tot} = total detector efficiency for radionuclide emission of interest (cpm/dpm)
A = detector probe area (cm^2)

A typical static MDC calculation for the Ludlum Model 43-37 gas flow proportional detector is shown below:

$$MDC_{STATIC} = \frac{3 + 3.29\sqrt{(1500)(.1)\left(1 + \frac{0.1}{0.1}\right)}}{(0.1)(0.2)\frac{582}{100}} = 515\,\text{dpm/100cm}^2$$

15.3.2 Ratemeter Scanning

Scanning Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is a combination of MARSSIM equations 6-8, 6-9, and 6-10:

$$MDC_{scan} = \frac{d'\sqrt{b_i}\left(\frac{60}{i}\right)}{\sqrt{p} \cdot E_{tot} \cdot \frac{A}{100cm^2}}$$

Where:

MDC_{scan} = minimum detectable concentration (dpm/100 cm^2)
d' = desired performance variable (1.38)
b_i = background counts during the residence interval (counts)
i = residence interval (seconds)
p = surveyor efficiency (0.5)
E_{tot} = total detector efficiency for radionuclide emission of interest (cpm/dpm)
A = detector probe area (cm^2)

A typical MDC_{SCAN} calculation for the Ludlum 43-37 gas flow proportional detector is shown below:

$$\text{i} = 13.3\,\text{cm} \cdot \frac{\text{inch}}{2.54\,\text{cm}} \cdot \frac{\text{sec}}{20\,\text{inch}} \cdot = 0.262\,\text{sec}$$

$$\text{b}_\text{i} = 0.262\,\text{sec} \cdot \frac{1500\,\text{counts}}{\text{minute}} \cdot \frac{\text{minute}}{60\,\text{sec}} = 6.55\,\text{counts}$$

$$MDC_{SCAN} = \frac{1.38\sqrt{6.55}\left(\frac{60}{0.262}\right)}{\left(\sqrt{0.5}\right)(0.2)\left(\frac{582}{100}\right)} = 983\,\text{dpm/100cm}^2$$

15.3.3 Smear Counting

Smear counting Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is NUREG 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions", Table 3.1 (Strom & Stansbury, 1992):

$$MDC_{smear} = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E}$$

Where:

MDC_{smear} = minimum detectable concentration level (dpm/smear)
B_r = background count rate (counts per minute)
t_b = background count time (minutes)
t_s = sample count time (minutes)
E = instrument efficiency for radionuclide emission of interest (cpm/dpm)

The MDC calculation for each LSC channel using conservative parameters is shown below.

$$^{3}\text{H MDC}_{\text{SMEAR}} = \frac{3 + 3.29\sqrt{(25)(1)\left(1 + \frac{1}{1}\right)}}{(1)(0.60)} = 44 \text{ dpm}$$

$$^{14}\text{C MDC}_{\text{SMEAR}} = \frac{3 + 3.29\sqrt{(15)(1)\left(1 + \frac{1}{1}\right)}}{(1)(0.80)} = 26 \text{ dpm}$$

$$\text{Channel 3 MDC}_{\text{SMEAR}} = \frac{3 + 3.29\sqrt{(50)(1)\left(1 + \frac{1}{1}\right)}}{(1)(0.95)} = 38 \text{ dpm}$$

Because the counting efficiency is different for each LSC measurement depending on quench characteristics, and in consideration of the errors associated with wipe counting (i.e., area wiped, wiping pressure, etc.), the *a priori* estimates of smear

MDCs calculated above are applied to all removable contamination measurements.

15.4 Uncertainty

The uncertainty for each static measurement is calculated using equation 6-15 from MARSSIM:

$$\sigma = 1.96\sqrt{\frac{C_{s+b}}{T_{s+b}^{\ 2}} + \frac{C_b}{T_b^{\ 2}}}$$

where:

σ = uncertainty
1.96 = multiplier to achieve a 95% confidence level
C_{s+b} = gross sample counts
T_{s+b} = sample count time (min.)
C_b = gross background counts
T_b = background count time (min.)

Uncertainties presented with total surface activity results are additionally corrected for detection efficiency and probe area for presentation in the same units as total surface activity results.

15.5 Instrumentation Specifications

The instrumentation used for facility decommissioning surveys is summarized in the following tables.

Table 15-1: Instrumentation Specifications

Detector Model	Detector Type	Detector Area	Meter Model	Window Thickness	Typical Efficiency
Ludlum 43-68	Gas Flow Proportional	126 cm^2	Ludlum 2241-3	0.8 mg/cm^2	20 % (Tc-99)
Ludlum 43-37 Floor Monitor	Gas Flow Proportional	582 cm^2	Ludlum 2241-3	0.8 mg/cm^2	20 % (Tc-99)
Packard TriCarb (or Equivalent)	Liquid Scintillation	N/A	N/A	N/A	60% (H-3) 80% (C-14) 95% (Ch 3)

Table 15-2: Typical Instrument Operating Parameters and Sensitivities

Measurement Type	Detector Model	Max. Scan Rate[6]	Count Time	Background (cpm)	MDC (dpm/100 cm^2)
Surface Scans	Ludlum 43-68	10 in./sec.	N/A	500	2,279 (Tc-99)
Surface Scans	Ludlum 43-37	20 in./sec.	N/A	1,500	983 (Tc-99)
Total Surface Activity	Ludlum 43-68	N/A	6 sec.	500	1,425 (Tc-99)
Total Surface Activity	Ludlum 43-37	N/A	6 sec.	1,500	515 (Tc-99)
Removable Activity	Packard TriCarb	N/A	60 sec.	25 (H-3) 15 (C-14) 50 (Ch 3)	44 (H-3) 26 (C-14) 38 (Ch 3)

15.6 Efficiency Determination

ISO 7503-1 methods were used for the limiting nuclide (Na-22) to determine field concentrations for final status data and calculation of resultant doses from residual radioactivity. MARSSIM protocols for building structures use ISO-7503-1 methodology that takes into account the texture of the surface and the 2π detector efficiency. Under MARSSIM, the default surface efficiency for beta emitters with maximum energies greater than 400 keV is conservatively set at 0.5.

15.7 Datalogging

Structural surface scans and static measurements were performed using datalogging instrumentation. While scanning, in addition to the surveyor listening to the audible output, integrated counts were recorded. Logged data were downloaded and processed using data management software to perform data analyses and reporting. Reporting includes graphical (4-plot) presentation of scan data as well as summary statistics functions. The 4-Plot is described in the NIST e-Handbook of Statistical Methods (http://www.itl.nist.gov/div898/handbook/index.htm).

A 4-plot consists of the following:

- A run **sequence plot** presents logged data in chronological order, providing a time history of the survey data.
- A **lag plot** checks whether a data set or time series is random or not. Random data should not exhibit any identifiable structure in the lag plot. Non-random structure in the lag plot indicates that the underlying data are not random.

[6] Maximum scan rates are calculated based on the instrument MDCs. Actual scan rates will be much slower.

- A **histogram plot** graphically summarizes the distribution of a univariate data set, showing center (i.e., the location) of the data, spread (i.e., the scale) of the data, skewness of the data, presence of outliers, and presence of multiple modes.
- A **probability plot** is a goodness-of-fit test used to verify the distributional model. The normal probability plot is a graphical technique for assessing whether or not a data set is approximately normally distributed. The data are plotted against a theoretical normal distribution in such a way that the points should form an approximate straight line. Departures from this straight line indicate departures from normality

16.0 DATA QUALITY OBJECTIVES (DQO)

The following is a list of the major DQOs for the survey design:

- Static measurements were taken to achieve an MDC_{static} of less than 4,750 dpm/100 cm^2.
- Scanning was conducted at a rate to achieve an MDC_{scan} of less than 4,750 dpm/100 cm^2.
- Removable contamination measurements were counted to achieve an MDC_{smear} of less than 200 dpm/100 cm^2 per channel.
- Individual measurements were made to a 95% confidence interval.
- Decision error probability rates were set at 0.05 for both α and β.
- The null hypothesis (H_0) and alternative hypothesis (H_A) are that of NUREG 1505 scenario A:
  H_0 is that the survey unit does not meet the release criteria
  H_A is that the survey unit meets the release criteria
- Quality assurance surveys were conducted at a rate of 5%.
- Characterization surveys were conducted under the same quality assurance criteria as final status surveys such that the data were used as final status survey data to the maximum extent possible.

17.0 AREA CLASSIFICATIONS

Based on the results of the historical site assessment and previous survey results, facility areas were classified as impacted or non-impacted.

17.1 Non-Impacted Area

Non-impacted areas were areas without residual radioactivity from licensed activities and were not surveyed during final status surveys. The following areas were classified as non-impacted:

- Structural surfaces above a two meter height
- Building elevations and wings without a history of radioactive materials usage
- Internal surfaces of positively pressurized systems (air, gas, water, etc.)

- Building exterior surfaces
- Surface and subsurface soils of outside grounds

Based on historical operations, a potential existed for residual contamination from spills or tracking on surfaces less than two meters in height. Thorough surveys of impacted area entrances/exits and ventilation exhausts were conducted during characterization to provide adequate assurance that any residual contamination was contained within impacted areas. These surveys were performed to verify the non-impacted classification of surrounding areas.

17.2 Impacted Areas

Impacted areas were those areas that had potential residual radioactivity from licensed activities. Impacted areas are subdivided into Class 1, Class 2 or Class 3 areas. Class 1 areas have the greatest potential for contamination and therefore receive the highest degree of survey effort for the final status survey using a graded approach, followed by Class 2, and then by Class 3. Impacted sub-classifications are defined as follows:

17.2.1 Class 1 Area

Areas with the highest potential for contamination, and meet the following criteria: (1) impacted; (2) potential for delivering a dose above the release criterion; (3) potential for small areas of elevated activity; and (4) insufficient evidence to support classification as Class 2 or Class 3.

There are no Class 1 areas.

17.2.2 Class 2 Area

Areas that meet the following criteria: (1) impacted; (2) low potential for delivering a dose above the release criterion; and (3) little or no potential for small areas of elevated activity.

Areas with a history of radioactive materials usage were classified as Class 2.

17.2.3 Class 3 Area

Areas that meet the following criteria: (1) impacted; (2) little or no potential for delivering a dose above the release criterion; and (3) little or no potential for small areas of elevated activity.

Areas surrounding areas of usage were classified as Class 3 areas.

17.3 Survey Units

A survey unit is a geographical area of specified size and shape for which a separate decision is made whether or not that area meets the release criteria. A survey unit is normally a portion of a building or site that is surveyed, evaluated, and released as a single unit. For the purposes of this project, areas of similar construction and composition were grouped together as survey units and tested individually against the DCGLs and the null hypothesis to show compliance with the release criteria. Survey units were homogeneous in construction, contamination potential, and contamination distribution.

The number of discrete sampling locations needed to determine if a uniform level of residual radioactivity exists within a survey unit does not depend on the survey unit size. However, the sampling density should reflect the potential for small elevated areas of residual radioactivity. Survey units were sized according to the potential for small elevated areas of residual radioactivity. Recommended maximum survey unit sizes for building structures, based on floor area, is Class 1: up to 100 m^2 , Class 2: 100 m^2 to 1000 m^2 and Class 3: no limit.

Survey Unit Numbering Protocol
Each survey unit is assigned a unique number consisting of the building number followed by a dash and a four digit identifier. The four digit identifier consists of one digit for the elevation, one digit for the classification, and two digits as a numerical identifier in the event the first 2 digits are the same for two or more survey units using the format below:

Building Number – Elevation/Classification/Numerical Identifier

The default numeric identifier is 01

Buildings:
FHB = Fesler Hall Building, MYR = Myers Building, and PRB = Psychiatric Research Building

Elevations:
B = Basement, 1 = 1st Floor, 2 = 2nd Floor, 3 = 3rd Floor, 4 = 4th Floor, and 7 = 7th Floor

Building systems survey units were arranged by building and system type. There are three types of systems – ventilation, vacuum, and drain. Each system survey unit encompasses all of a certain type within the building.

Systems Components:
DR – Drain
VA – Vacuum
VE – Ventilation

Examples:
FHB-4201 is Fesler Hall Building, fourth floor, Class 2
PRB-B301 is Psychiatric Research Building, basement, Class 3
MYR-DR01 is Myers Building drains

Survey unit classifications and designations were determined from the HSA and are listed in the tables below. Survey unit designations are presented graphically on the building floor plans presented in Appendix B.

Table 17-1: **Building Structural Survey Units**

Building	Elevation	Survey Unit Numbers
FHB	Fourth	4201, 4202, 4301
MYR	Seventh	7201, 7202, 7203, 7204, 7205, 7206, 7301, 7302
PRB	Basement	B201, B301
	First	1201, 1202, 1301
	Second	2201
	Third	3201
	Fourth	4201, 4202, 4301

Table 17-2: Building Systems Survey Units

Building	Drain	Vacuum	Ventilation
FHB	DR01	VA01	VE01
MYR	DR01	VA01	VE01
PRB	DR01	VA01	VE01

18.0 CHARACTERIZATION SURVEYS

The survey protocol for building surfaces consisted of performing the scanning portion of the final status survey protocol, with judgmental smears and static measurements on areas of highest probability for residual radioactivity. Judgmental static measurements and smears were also taken on vertical surfaces as part of the Class 2 and Class 3 final status survey protocols described in section 20.3.5.

The purpose of scanning was to identify locations of elevated activity. The minimum scan percentages are presented in section 20.2. Scanning was performed by moving the probe over surfaces at a distance of approximately 0.5 cm or less and at a rate less than the maximum allowable scan rate necessary to achieve DQOs.

The survey protocol for building system surveys consisted of performing removable contamination measurements of accessible internal surfaces of ventilation, vacuum, and drain systems. Fume hood baffles were removed, and static measurements performed in addition to the removable contamination measurements. Static measurements were not possible in vacuum and drain systems due to geometry.

No elevated activity from residual licensed materials was detected during characterization surveys of Fesler Hall 4th floor, Myers Building 7th floor, and all elevations of the Psychiatric Research Building except the 2nd floor.

Characterization scan surveys identified several areas on building structural surfaces with residual radioactivity above the ALARA goals in Psychiatric Research Building survey unit PRB-2201. Elevated activity was limited to labs 204, 205, 207, and 209. All areas of elevated activity were determined to be C-14 based on historical usage information, qualitative analysis of the emissions, and removable radioactivity results. For more accurate assessment of residual radioactivity, total activity measurements results were calculated using ISO 7503-1 C-14 efficiencies (2pi calibration efficiency x 0.25 surface efficiency).

Elevated areas in labs 204, 205, and 209 consisted of small, discrete areas ranging up to 47,303 dpm/100 cm^2 total C-14 activity. In lab 207, elevated activity was identified in two separate contiguous areas of distributed activity that each contained small discrete areas of higher activity levels. One contiguous area covered an area of approximately 16 ft^2 of laboratory casework with three discrete locations up 297,803 dpm/100 cm^2 total C-14 activity; and the other contiguous area covered approximately 27 ft^2 on the west wall with four discrete locations up to 224,324 dpm/100 cm^2 total C-14 activity. Due to the extensive areas involved, the scan survey coverage for all impacted surfaces in lab 207 was increased to 100% and upper walls were included to ensure the extent of contamination was properly bound. Because the maximum total activity was only 6% of the C-14 DSV, the room was not upgraded to a higher classification. Areas of elevated activity were remediated as described in section 19.0.

Several thermostats that are believed to contain radium-painted dials were identified during characterization surveys of the Myers building 7th floor. The Chase PM informed the IUPUI/IUMC RSO of the presence of the thermostats.

19.0 REMEDIATION

Remediation consisted of simple decontamination (i.e. wet wiping with a mild detergent). All remediation activities were conducted to control the spread of contamination and to maintain personnel exposures ALARA. No remediation of impacted area systems was required.

The goal of remediation was to reduce removable contamination levels for ALARA purposes since C-14 is primarily an internal exposure concern. All post remediation total and removable surface activity results are below the applicable DCGL. Additionally, the removal of readily removable radioactivity is consistent with 1757 Vol 2, Appendix N as described in section 8. All remediated areas meet the removable contamination ALARA goal of 200 cpm/100 cm^2 except for one location on casework exterior in Room 207 with 294 dpm/100 cm^2 removable H-3. Because the result is less than 0.003% of the H-3 removable DCGL of 1.2E+07 dpm/100 cm^2, no further remediation was performed.

Remediation performed on building surfaces is summarized in the table below.

Table 19-1 Remediated Building Surfaces [7]

Survey Unit (Room #)	Location (Area ft^2)	Maximum Activity		Remediation Method	Post-Remediation Maximum Activity	
		Total (dpm/100 cm^2)	Removable (cpm/100 cm^2)		Total (dpm/100 cm^2)	Removable (cpm/100 cm^2)
PRB-2201 (204)	Laboratory Drawer (<1)	44,044 (C-14)	10 – ^{3}H 23 – ^{14}C 19 – Ch 3	Wet Wipe/ Scrub	69,149 (C-14)	9 – ^{3}H 12 – ^{14}C 7 – Ch 3
PRB-2201 (205)	Casework Exterior (<1)	47,303 (C-14)	664 – ^{3}H 637 – ^{14}C 9 – Ch 3	Wet Wipe/ Scrub	5,592 (C-14)	18 – ^{3}H 18 – ^{14}C 10 – Ch 3
PRB-2201 (205)	Laboratory Drawer (<1)	30,169 (C-14)	34 – ^{3}H 24 – ^{14}C 10 – Ch 3	Wet Wipe/ Scrub	28,713 (C-14)	8 – ^{3}H 10 – ^{14}C 8 – Ch 3
PRB-2201 (207) [8]	Casework Exterior (<1)	297,803 (C-14)	9,050 – ^{3}H 1,608 – ^{14}C 5 – Ch 3	Wet Wipe/ Scrub	27,423 (C-14)	294 – ^{3}H 125 – ^{14}C 6 – Ch 3
PRB-2201 (207) [8]	Casework Exterior (<1)	24,177 (C-14)	46 – ^{3}H 38 – ^{14}C 9 – Ch 3	Wet Wipe/ Scrub	17,637 (C-14)	66 – ^{3}H 59 – ^{14}C 15 – Ch 3
PRB-2201 (207) [8]	Casework Exterior (<1)	17,029 (C-14)	131 – ^{3}H 91 – ^{14}C 14 – Ch 3	Wet Wipe/ Scrub	45,812 (C-14)	11 – ^{3}H 12 – ^{14}C 12 – Ch 3
PRB-2201 (207) [8]	Wall (<1)	155,366 (C-14)	1,056 – ^{3}H 755 – ^{14}C 8 – Ch 3	Wet Wipe/ Scrub	17,852 (C-14)	145 – ^{3}H 89 – ^{14}C 18 – Ch 3
PRB-2201 (207) [8]	Wall (<1)	224,324 (C-14)	13 – ^{3}H 6 – ^{14}C 9 – Ch 3	Wet Wipe/ Scrub	12,152v	14– ^{3}H 8– ^{14}C 16– Ch 3
PRB-2201 (207) [8]	Wall (<1)	96,920 (C-14)	26 – ^{3}H 24 – ^{14}C 10 – Ch 3	Wet Wipe/ Scrub	50,006 (C-14)	75 – ^{3}H 70 – ^{14}C 17 – Ch 3
PRB-2201 (207) [8]	Wall (<1)	11,458 (C-14)	6,869 – ^{3}H 3,309 – ^{14}C 15 – Ch 3	Wet Wipe/ Scrub	27,315 (C-14)	9 – ^{3}H 16 – ^{14}C 6 – Ch 3
PRB-2201 (209)	Benchtop/ Sink (<1)	22,390 (C-14)	16 – ^{3}H 11 – ^{14}C 9 – Ch 3	Wet Wipe/ Scrub	7,743 (C-14)	2 – ^{3}H 10 – ^{14}C 6 – Ch 3
PRB-2201 (209)	Benchtop (<1)	8,514 (C-14)	10 – ^{3}H 21 – ^{14}C 12 – Ch 3	Wet Wipe/ Scrub	6,237 (C-14)	9 – ^{3}H 11 – ^{14}C 7 – Ch 3

[7] All areas of elevated activity were determined to be due to C-14, therefore activity results presented in the table are corrected using the C-14 efficiency.

[8] Residual radioactivity identified on casework in PRB Room 207 consisted of one 16 ft^2 contiguous area of distributed radioactivity with three discrete areas of elevated activity within. Residual radioactivity identified on the wall consisted of one 27 ft^2 contiguous area of distributed radioactivity with four discrete areas of elevated activity within. Each discrete area of elevated activity is presented separately.

19.1 Remedial Action Surveys

Remedial action surveys were conducted in support of remediation activities to help determine when an area was ready for a final status survey and to provide updated estimates for final status survey planning. Remedial action surveys served to monitor the effectiveness of decontamination efforts and to ensure that surrounding areas were not cross-contaminated from remediation.

Remedial action surveys consisted of scan surveys and removable contamination measurements. These were conducted following remediation activities to establish the success or failure of decontamination efforts. Results of the survey were the decision basis for continued remediation or conduct of final status surveys. Remedial action surveys were designed to meet the objectives of the final status surveys and, to the extent allowed by MARSSIM, the results of the remedial action surveys were used to supplement the final status survey.

20.0 FINAL STATUS SURVEYS

Final status surveys were performed using the DQO process to demonstrate that residual radioactivity in each survey unit satisfied the predetermined criteria for release for unrestricted use. Final status surveys were conducted by performing the appropriate combination of scan surveys, total activity measurements and removable activity measurements as discussed further in this section. All final status surveys were performed according to written instructions. Survey data were documented on survey maps and/or associated data information sheets.

20.1 Background Determination

The use of reference background areas or paired background comparisons was not necessary. Material and ambient background values were not significant in comparison to the DCGLs or ALARA goals. For direct measurements, an ambient background was determined for each survey, was subtracted from gross measurements, and was used to calculate the actual survey MDCs and associated count errors. Material-specific background determinations were not performed. Background was not subtracted from removable activity measurements and all results are reported in gross cpm/100 cm^2.

20.2 Surface Scans

Scanning was used to identify locations within the survey unit that exceed the investigation level. The table below summarizes the minimum scan percentage of accessible building structural surfaces based on classification.

Table 20-1: Scan Survey Coverage by Classification

Structure	Class 2	Class 3
Laboratory Floors	75%	10%
Fume Hoods	100%	100%
Benchtops	75%	10%
Laboratory Walls	20%	10%
Other Laboratory Structures	50%	10%
Non-Laboratory Surfaces	10%	10%

For surfaces that received less than 100% scan survey, the surfaces scanned were those with the highest potential to contain residual radioactivity at the discretion of the surveyor.

20.3 Total Surface Activity Measurements

Direct surveys (static measurements) for total surface activity were taken on building surfaces in impacted areas utilizing instrumentation of the best geometry based on the surface at the survey location. Additionally, locations of elevated activity identified and marked during the scan survey received direct survey measurements. Static measurements were taken in impacted areas at each identified sample location. Scaler count times were determined to achieve the detection sensitivities stated in the DQOs. Field measurements were converted to activity concentrations using the following equation:

$$Activity\ (dpm/100\ cm^2) = \frac{R_{s+b} - R_b}{E_{total} \times \frac{A}{100\ cm^2}}$$

Where:

R_{s+b} = The gross count rate of the measurement in cpm
R_b = The background count rate in cpm
E_{total} = Total Efficiency
A = Area of the detector window (cm^2)

20.3.1 Determining the Number of Samples

The minimum number of samples required for the Sign Test was calculated using equations in Section 5 of MARSSIM. A conservative estimate of the standard deviation of total surface activity measurements (1,000 dpm/100 cm^2) was used. The LBGR was set at one half of the DCGL. The calculations performed to determine the required numbers of samples are provided below.

20.3.2 Determination of the Relative Shift

The number of required samples depends on the ratio involving the activity level to be measured relative to the variability in the concentration. The ratio to be used is called the Relative Shift, Δ/σ_S, and is defined in MARSSIM as:

$$\Delta / \sigma_S = \frac{DCGL - LBGR}{\sigma_S}$$

Where:

DCGL = derived concentration guideline level (dpm/100 cm^2)

LBGR = concentration at the lower bound of the gray region. The LBGR is the average concentration to which the survey unit should be cleaned in order to have an acceptable probability of passing the test (dpm/100 cm^2)

σ_S = an estimate of the standard deviation of the residual radioactivity in the survey unit (dpm/100 cm^2)

The actual calculation is provided below:

$$\Delta / \sigma_S = \frac{9{,}500 - 4{,}750}{1{,}000} = 4.75$$

Since MARRSIM Table 5.5 does not include relative shifts above 3 and the number of samples required decreases with an increasing relative shift, the relative shift was conservatively set at 3.

20.3.3 Determination of Acceptable Decision Errors

A decision error is the probability of making an error in the decision on a survey unit by passing a unit that should fail (α decision error) or failing a unit that should pass (β decision error). MARSSIM uses the terminology α and β decision errors; this is the same as the more common terminology of Type I and Type II errors, respectively. The decision errors are 0.05 for Type I errors and 0.05 for Type II errors.

20.3.4 Determination of Number of Data Points (Sign Test)

The number of direct measurements for a particular survey unit, employing the Sign Test, is determined from MARSSIM Table 5.5, which is based on the following equation (MARSSIM equation 5-2):

$$N = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{4\left(SignP - 0.5\right)^2}$$

Where:

N = number of samples needed in the survey unit
$Z_{1-\alpha}$ = percentile represented by the decision error α
$Z_{1-\beta}$ = percentile represented by the decision error β
SignP = estimated probability that a random measurement will be less than the DCGL when the survey unit median is actually at the LBGR

Note: SignP is determined from MARSSIM Table 5.4

MARSSIM recommends increasing the calculated number of measurements by 20% to ensure sufficient power of the statistical tests and to allow for possible data losses. MARSSIM Table 5.5 values include an increase of 20% of the calculated value. The approach for this project was to predetermine a number of samples to be applied to all survey units. This approach provides sufficient power for the statistical test while streamlining the survey planning process. The following calculations were made to determine this number:

$$N = \frac{(1.645 + 1.645)^2}{4(0.998650 - 0.5)^2} = 11$$

$Z_{1-\alpha}$ and $Z_{1-\beta}$ are equal to 1.645 using the error rate of 0.05 from MARSSIM Table 5.2. SignP is equal to 0.998650 from MARSSIM Table 5.4. Adding an additional 20% to account for data losses resulted in a value of 14.

Therefore, the determined number of samples per survey unit for the final status surveys for planning purposes was **14**.

20.3.5 Determination of Sample Locations

Class 2 and Class 3 survey units generally consist of multiple rooms. The process to identify, map and locate measurement coordinates in survey units with many rooms is complicated due to the noncontiguous nature of the survey unit once walls are “folded-out”. Therefore, the MARSSIM sample measurement locations (i.e., random static and wipe measurements) were determined only on horizontal surfaces as determined on floor plans. This protocol increases the sample density on the surfaces with the highest probability for residual contamination (floors, benchtops, fume hood working surfaces, etc.). The appropriate percentage of all survey unit surfaces (including vertical surfaces) was scanned according to the survey unit classification. In laboratory areas, permanent counter tops and other horizontal surfaces that block floor surfaces were included as a replacement to the blocked floor surface. Internal surfaces of permanent furnishings (i.e., drawer or cabinetry interior surfaces) were not included in the systematic measurement location placement. However, these surfaces were included in the scan surveys. Additional total surface activity measurements were collected at each area of elevated activity identified during the scan surveys.

As part of characterization, the survey technician judgmentally selected locations with the highest probability of contamination on vertical surfaces for a static measurement and smear, such as light switches, door knobs, door pulls, push plates, and other locations. These measurements were in addition to and were not included in the statistical analysis of the locations selected by MARSSIM protocols.

Determination of Class 2 survey unit sample locations was accomplished by first determining sample spacing and then systematically plotting the sample locations from a randomly generated start location. MARSSIM recommends random sampling (random x, random y) for Class 3 areas. However, in this survey design, Class 3 areas are sampled on a systematic grid pattern in the same manner as MARSSIM recommends for Class 1 and Class 2 areas. Sample spacing was determined from MARSSIM equation 5-8:

$$L = \sqrt{\frac{A}{N}} \text{ for a square grid}$$

Where:

L = sample spacing interval
A = the survey unit floor area
N = number of samples needed in the survey unit

A random starting point was determined using computer-generated random numbers coinciding with the x and y coordinates of the total survey unit. A grid was plotted across the survey unit surfaces based on the random start point and the determined sample spacing. A measurement location was plotted at each intersection of the grid. Maps of final status survey locations for all survey units are included in Appendix E.

20.4 Removable Contamination Measurements

Removable contamination measurements were collected by wiping an area of approximately 100 cm^2 on structural surfaces, ventilation systems, and drain systems. An area of approximately 10 cm^2 was wiped inside building vacuum nozzles, therefore results were multiplied by a factor of 10. The smears/swabs were counted to achieve the detection sensitivities stated in the DQOs. The LSC was set up for three channels without background subtraction at the following energies:

Channel 1 (^{3}H cpm):	3.0 – 18.6 keV
Channel 2 (^{14}C cpm):	18.6 – 169 keV
Channel 3 (cpm):	170 – 2,000 keV

20.5 Surveys of Building Mechanical System Internals

Surveys of various building system components were performed. Survey design for these systems is out of the scope of MARSSIM. For the purposes of identifying potential residual contamination within these systems, a survey protocol was established and is presented in the table below.

Table 20-2: System Survey Coverage

System Component	Coverage
Vacuum Nozzles, Pumps, Accumulators	100% Class 2, 10% Class 3[9]
Fume Hood Vent Ducts and Fans	100% Class 2, 10% Class 3
Drain Openings/Traps	100% Class 2, 10% Class 3

20.6 Survey Documentation

A survey package was developed for each survey unit containing the following:

- Survey Unit number (e.g., Building and Room Number, System Number, etc.)
- Survey Instruction Sheets
- General survey requirements
- Percentage of surfaces requiring scan surveys
- Number of total and removable contamination measurements required, instrument requirements with associated MDCs, count times and scan rates
- Overview maps detailing survey locations and placement methodology
- Survey Data Sheets
- Any additional specific survey instruction
- Signature of Data Collector and Reviewer

To ensure proper data management and organization, a unique location code system was used so that survey data could be properly entered and organized in the Final Status Survey Database. A breakdown of the location code and specific code components are provided in the table below.

[9] A central pump/accumulator located in the basement of Riley Hospital supplies vacuum to multiple buildings on campus, including Fesler Hall. The pump/accumulator supplying Fesler Hall was not sampled due to the negative impact of hospital operations associated with loss of service during sampling. However, all sample results taken at vacuum system inlets in Fesler Hall are below the investigation level of 200 cpm/100 cm^2 per LSC channel.

Table 20-3: Location Code Description

A unique location code was assigned to each individual survey location to ensure proper data management of the survey results. The following format was used to ensure consistency throughout the final status survey process:

BBB-RRRR-SS-M-LLL

Where:

BBB:	=	Building Code. This field represents the building number. (3 characters) FHB: Fesler Hall Building MYR: Myers Building PRB: Psychiatric Research Building
RRRR:	=	Survey Unit Number. This is the assigned survey unit number. (4 characters)
SS:	=	Structural Surface Code. This field represents the structural surface such as floor, wall, ceiling, etc. (2 characters) B1 = Benchtop F1 = Floor H1 = Fume Hood S1 = Sink D1 = Fumehood Drains D2 = Floor Drains D3 = Sink Drains D4 = Other Drains E1 = Hood Exhaust Duct E3 = Hood Exhaust Fan / Component V1 = Vacuum Nozzle V2 = Vacuum Component
M:	=	Structural Material Code. This field represents the type of structural material on which a particular measurement is taken. (1 character) C = Concrete M = Miscellaneous T = Tile V = Vinyl Tile
LLL:	=	Numerical Identifier. This field represents the survey location number. The field "001" means survey point location number 1. Numerical identifiers are unique within a survey unit. (3-characters)

21.0 SURVEY RESULTS AND DATA QUALITY ASSESSMENT

The statistical guidance contained in Section 8 of MARSSIM was used to determine if areas are acceptable for unrestricted release and whether additional surveys or sample measurements were required.

21.1 Data Validation

Field data were reviewed by the Project Manager and validated to ensure:

- Completeness of forms
- Proper types of surveys were performed
- The MDCs for measurements met the established data quality objectives
- Independent calculations were performed on a representative sample of data sheets
- Satisfactory instrument calibrations and daily functionality checks were performed as required

Additionally, all final status survey data were entered into the Final Status Survey Database. This provided the means to sort survey data, verify activity calculations, and to compute the associated MDC and counting errors. Once data entry for a survey unit was complete, a verification report was printed and compared to original data sheets to ensure correct data entry.

21.2 Preliminary Data Review

A preliminary data review was performed for each survey unit to identify any patterns, relationships or anomalies. Additionally, measurement data were reviewed and compared with the DCGLs and investigation levels to confirm the correct classification of survey units.

The following preliminary data reviews were performed for each survey unit:

- Review of the 4-Plot graphs of scan data
- Calculations of the survey unit mean, median, maximum, minimum, and standard deviation for each type of reading
- Comparison of the actual standard deviation to the assumed standard deviation used for calculating the number of measurements
- Comparison of survey data with applicable investigation levels

The actual standard deviation for all survey units were less than the assumed standard deviation used for calculating the number of measurements, therefore an adequate number of samples were collected for each survey unit.

21.3 Building Structural Surfaces Scan Data

No elevated activity was identified by listening to the audible detector response during surface scan surveys except for in survey units PRB-2201 as described in Section 18.0. Additionally, a 4-Plot was produced of scan survey data for each survey instrument used within each survey unit. 4-Plots are separated in this manner because combining all populations into one 4-Plot for each survey unit introduces additional variability in the results due to instrument-specific systematic errors (i.e., differences in calibration efficiency, background count rate, etc.). This additional variability reduces the usefulness of the 4-Plot for identifying anomalies in the scan data.

4-Plots indicate the expected variability of various building structural materials and all scan survey results are less than the investigation level except for survey unit PRB-2201 where elevated activity was identified during characterization scans. Scan data was recorded in one second intervals. Some graphs indicate spikes above the investigation level (5,000 dpm/100 cm^2). These spikes were not sustained and are most likely normal statistical variations due to the short sampling interval. Survey unit PRB-2201 4-Plot presents data prior to remediation and indicates spikes at lower activity than the elevated areas described in section 18.0. This is due to the application of the C-14 efficiency for determination of elevated activity in section 18.0, while the 4-plot data are corrected using the Na-22 efficiency. 4-Plot graphs of scan results are provided in Appendix F.

21.4 Data Summary Tables

All calculations of means, standard deviations, minimum and maximum values and comparisons between survey data and investigation levels are presented in the following tables. Building structural surface activity reports for each survey unit are included as Appendix G. Reports for building systems surveys are presented in Appendix H.

Table 21-1: Structural Surfaces Total Beta Surface Activity Summary

Survey Unit	# of Sample Locations	Mean	MDC	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(dpm/100 cm^2)						
FHB-4201	14	214	991	278	-230	883	5,000	NO
FHB-4202	14	297	984	257	-150	824	5,000	NO
FHB-4301	17	-68	1,083	176	-300	225	5,000	NO
MYR-7201	15	194	830	229	-154	576	5,000	NO
MYR-7202	15	306	985	154	78	583	5,000	NO
MYR-7203	14	211	946	213	-311	545	5,000	NO
MYR-7204	15	120	830	189	-77	538	5,000	NO
MYR-7205	15	371	985	246	-39	778	5,000	NO
MYR-7206	16	353	926	231	-78	817	5,000	NO
MYR-7301	14	58	894	151	-154	384	5,000	NO
MYR-7302	16	70	894	316	-269	1,114	5,000	NO
PRB-1201	15	278	985	248	-117	739	5,000	NO
PRB-1202	16	175	1,039	198	-233	467	5,000	NO
PRB-1301	16	58	1,106	273	-320	841	5,000	NO
PRB-2201	12	568	1,018	689	-300	1,986	5,000	NO
PRB-3201	14	-214	1,275	288	-661	272	5,000	NO
PRB-4201	15	270	1,074	234	-233	778	5,000	NO
PRB-4202	14	-197	1,275	183	-583	156	5,000	NO
PRB-4301	14	69	1,141	156	-120	400	5,000	NO
PRB-B201	14	501	1,051	586	-450	1,536	5,000	NO
PRB-B301	14	-220	1,282	717	-974	1,574	5,000	NO

Table 21-2: Building Structural Surfaces Removable H-3 Summary

Survey Unit	# of Sample Locations	Mean	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(gross cpm/100 cm^2)					
FHB-4201	14	12	3	8	17	200	NO
FHB-4202	14	10	4	5	20	200	NO
FHB-4301	17	10	3	4	16	200	NO
MYR-7201	15	8	3	3	15	200	NO
MYR-7202	15	10	3	5	15	200	NO
MYR-7203	14	11	3	5	17	200	NO
MYR-7204	15	9	3	5	14	200	NO
MYR-7205	15	11	2	8	17	200	NO
MYR-7206	16	12	4	6	19	200	NO
MYR-7301	14	12	4	8	23	200	NO
MYR-7302	16	9	3	5	15	200	NO
PRB-1201	15	10	2	7	13	200	NO
PRB-1202	16	10	3	5	15	200	NO
PRB-1301	16	11	5	5	20	200	NO
PRB-2201	12	11	4	4	18	200	NO
PRB-3201	14	10	3	5	15	200	NO
PRB-4201	15	11	3	7	18	200	NO
PRB-4202	14	10	4	5	16	200	NO
PRB-4301	14	11	3	7	17	200	NO
PRB-B201	14	10	4	4	18	200	NO
PRB-B301	14	8	3	2	14	200	NO

Table 21-3: Building Structural Surfaces Removable C-14 Summary

Survey Unit	# of Sample Locations	Mean	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(gross cpm/100 cm^2)					
FHB-4201	14	9	4	2	18	200	NO
FHB-4202	14	9	3	4	14	200	NO
FHB-4301	17	9	2	2	11	200	NO
MYR-7201	15	9	3	2	14	200	NO
MYR-7202	15	10	2	4	15	200	NO
MYR-7203	14	9	3	3	15	200	NO
MYR-7204	15	12	3	7	18	200	NO
MYR-7205	15	12	4	5	20	200	NO
MYR-7206	16	10	2	5	14	200	NO
MYR-7301	14	9	2	4	13	200	NO
MYR-7302	16	11	4	6	18	200	NO
PRB-1201	15	9	3	4	15	200	NO
PRB-1202	16	9	4	4	17	200	NO
PRB-1301	16	10	3	6	18	200	NO
PRB-2201	12	12	5	5	23	200	NO
PRB-3201	14	11	5	5	21	200	NO
PRB-4201	15	11	3	6	17	200	NO
PRB-4202	14	9	2	5	12	200	NO
PRB-4301	14	10	4	4	18	200	NO
PRB-B201	14	10	3	5	17	200	NO
PRB-B301	14	10	3	3	14	200	NO

Table 21-4: Building Structural Surfaces Removable Channel 3 Summary

Survey Unit	# of Sample Locations	Mean	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(gross cpm/100 cm^2)					
FHB-4201	14	8	2	5	11	200	NO
FHB-4202	14	8	3	3	13	200	NO
FHB-4301	17	9	3	3	13	200	NO
MYR-7201	15	11	4	5	21	200	NO
MYR-7202	15	11	3	5	17	200	NO
MYR-7203	14	10	3	6	16	200	NO
MYR-7204	15	9	3	4	13	200	NO
MYR-7205	15	9	2	4	12	200	NO
MYR-7206	16	10	2	5	12	200	NO
MYR-7301	14	9	3	5	15	200	NO
MYR-7302	16	9	3	5	14	200	NO
PRB-1201	15	10	3	5	16	200	NO
PRB-1202	16	9	3	4	15	200	NO
PRB-1301	16	10	3	4	16	200	NO
PRB-2201	12	10	2	6	13	200	NO
PRB-3201	14	8	3	5	14	200	NO
PRB-4201	15	10	4	6	19	200	NO
PRB-4202	14	9	4	5	19	200	NO
PRB-4301	14	10	2	7	13	200	NO
PRB-B201	14	9	2	6	12	200	NO
PRB-B301	14	9	3	4	14	200	NO

Table 21-5: Building Systems Total Beta Surface Activity Summary

Survey Unit	# of Sample Locations	Mean	MDC[10]	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(dpm/100 cm^2)						
FHB-VE01	2	212	1,083	352	-37	461	5,000	NO
MYR-VE01	22	114	892	175	-154	450	5,000	NO
PRB-VE01	28	260	1,088	339	-200	1,037	5,000	NO

Table 21-6: Building Systems Removable H-3 Summary

Survey Unit	# of Sample Locations	Mean	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(gross cpm/100 cm^2) [11]					
FHB-DR01	28	12	11	3	67	200	NO
FHB-VA01	18	101	27	40	150	200	NO
FHB-VE01	3	9	3	7	12	200	NO
MYR-DR01	57	10	3	1	17	200	NO
MYR-VA01	15	114	98	30	450	200	YES[12]
MYR-VE01	22	11	4	3	19	200	NO
PRB-DR01	98	10	3	3	18	200	NO
PRB-VA01	24	100	35	30	180	200	NO
PRB-VE01	28	11	4	6	22	200	NO

[10] The most conservative MDC is presented.
[11] Vacuum nozzle removable activity results were multiplied by a factor of 10 to correct for the area wiped (10 cm^2). Because background is not subtracted from results prior to performing the area correction, vacuum nozzle smear results are overestimated by the quantity of 10x the background count rate.
[12] One result was above the investigation level. Because the result is less than 0.004% of the H-3 removable DCGL of 1.2E+07 dpm/100 cm^2, no further action was required.

Table 21-7: Building Systems Removable C-14 Summary

Survey Unit	# of Sample Locations	Mean	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(gross cpm/100 cm^2) [11]					
FHB-DR01	28	11	6	5	36	200	NO
FHB-VA01	18	81	23	50	150	200	NO
FHB-VE01	3	10	4	6	13	200	NO
MYR-DR01	57	9	3	4	17	200	NO
MYR-VA01	15	85	23	50	120	200	NO
MYR-VE01	22	11	3	4	15	200	NO
PRB-DR01	98	10	3	3	17	200	NO
PRB-VA01	24	96	41	20	200	200	NO[13]
PRB-VE01	28	13	4	7	21	200	NO

Table 21-8: Building Systems Removable Channel 3 Summary

Survey Unit	# of Sample Locations	Mean	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(gross cpm/100 cm^2) [11]					
FHB-DR01	28	9	3	3	15	200	NO
FHB-VA01	18	90	23	50	150	200	NO
FHB-VE01	3	8	2	6	10	200	NO
MYR-DR01	57	9	3	2	17	200	NO
MYR-VA01	15	112	24	50	140	200	NO
MYR-VE01	22	9	2	4	14	200	NO
PRB-DR01	98	9	3	3	16	200	NO
PRB-VA01	24	90	31	40	160	200	NO
PRB-VE01	28	8	3	1	13	200	NO

21.5 Determining Compliance for Building Surfaces and Structures

Final status survey results were initially compared to the investigation levels. All total and removable surface activity results on building structural surfaces were less than investigation levels and an adequate number of samples were obtained, therefore all survey units pass the Sign test.

The results of the data quality assessment and calculations of the dose from each structural surface survey unit are presented in the table below.

[13] One result was equal to the investigation level. Because the result includes background, the net activity is less than the investigation level.

Table 21-9: Structural Surfaces Total Beta Surface Activity Dose Calculations

Survey Unit	Standard Deviation (dpm/100 cm^2)	# Samples Required	Actual # of Samples	Adequate # of Samples?	Mean (dpm/100 cm^2)	Calculated Annual TEDE[14] (mrem/yr)
FHB-4201	278	11	14	YES	214	0.56
FHB-4202	257	11	14	YES	297	0.78
FHB-4301	176	11	17	YES	-68	-0.18
MYR-7201	229	11	15	YES	194	0.51
MYR-7202	154	11	15	YES	306	0.81
MYR-7203	213	11	14	YES	211	0.56
MYR-7204	189	11	15	YES	120	0.32
MYR-7205	246	11	15	YES	371	0.98
MYR-7206	231	11	16	YES	353	0.93
MYR-7301	151	11	14	YES	58	0.15
MYR-7302	316	11	16	YES	70	0.18
PRB-1201	248	11	15	YES	278	0.73
PRB-1202	198	11	16	YES	175	0.46
PRB-1301	273	11	16	YES	58	0.15
PRB-2201	689	11	12	YES	568	1.49
PRB-3201	288	11	14	YES	-214	-0.56
PRB-4201	234	11	15	YES	270	0.71
PRB-4202	183	11	14	YES	-197	-0.52
PRB-4301	156	11	14	YES	69	0.18
PRB-B201	586	11	14	YES	501	1.32
PRB-B301	717	11	14	YES	-220	-0.58
					Maximum:	**1.49**

[14] The TEDE shown is conservatively calculated by multiplying 25 mrem/yr by the ratio of the mean total surface activity to the limiting nuclide (Na-22) DCGL of 9,500 dpm/100 cm^2.

To demonstrate that the calculation of annual dose based on the limiting nuclide (Na-22) in the table above is conservative; the dose from residual C-14 surface activity remaining in survey unit PRB-2201 after remediation is evaluated. The highest post-remediation survey result in PRB-2201 is 69,146 dpm/100 cm^2 and is within a small area (< 1 ft^2). Even under the conservative assumption that this level of residual radioactivity were distributed over a large area, the modeled dose would be less than 0.5 mrem/yr (69,146 / 3,700,000 x 25 mrem/yr), which is less than the dose calculated above using the limiting nuclide method.

All measurement results are less than the DCGL and an adequate number of measurements were taken; therefore the null hypothesis is rejected and all survey units meet the release criterion and are suitable for release for unrestricted use.

21.6 Determining Compliance for Building Systems

Final status survey results were initially compared to the investigation levels. One vacuum nozzle in survey unit MYR-VA01 had a removable H-3 result of 450 dpm/100 cm^2, because this is less than 0.004% of the H-3 removable DCGL of 1.2E7 dpm/100 cm^2, no action was taken.

All total and removable surface activity measurement results are less than the applicable DCGL; therefore all systems survey units meet the release criteria and are suitable for release.

22.0 QUALITY ASSURANCE SURVEYS

Quality assurance surveys consisted of re-performing the FSS protocol for building structural surfaces to achieve a minimum of 5% duplication of scans, static measurements and smears. The Project Manager implemented QA surveys by re-performing judgmentally selected survey locations as survey unit QA01. The locations of QA survey total and removable surface activity measurements are presented in the table below.

Table 22-1: Fesler Hall QA Survey Locations

QA Survey Location	FSS Location
FHB-QA01-F1-V-001	FHB-4201-F1-V-009
FHB-QA01-F1-V-002	FHB-4201-F1-V-010
FHB-QA01-F1-V-003	FHB-4301-F1-V-013
FHB-QA01-F1-V-004	FHB-4202-F1-V-007

Table 22-2: Myers Building QA Survey Locations

QA Survey Location	FSS Location
MYR-QA01-F1-V-001	MYR-7201-F1-V-010
MYR-QA01-F1-V-002	MYR-7202-F1-V-008
MYR-QA01-H1-M-003	MYR-7203-H1-M-002
MYR-QA01-F1-V-004	MYR-7204-F1-V-013
MYR-QA01-F1-V-005	MYR-7205-F1-V-004
MYR-QA01-F1-V-006	MYR-7206-F1-V-007
MYR-QA01-F1-V-007	MYR-7301-F1-V-004
MYR-QA01-F1-V-008	MYR-7302-F1-V-010

Table 22-3: Psychiatric Research Building QA Survey Locations

QA Survey Location	FSS Location
PRB-QA01-F1-V-001	PRB-B201-F1-V-007
PRB-QA01-F1-V-002	PRB-B301-F1-V-003
PRB-QA01-F1-M-003	PRB-1201-F1-M-005
PRB-QA01-F1-M-004	PRB-1202-F1-M-001
PRB-QA01-F1-V-005	PRB-1301-F1-V-013
PRB-QA01-B1-M-006	PRB-2201-B1-M-001
PRB-QA01-F1-V-007	PRB-3201-F1-V-013
PRB-QA01-F1-V-008	PRB-4201-F1-V-003
PRB-QA01-F1-V-009	PRB-4202-F1-V-004
PRB-QA01-F1-V-010	PRB-4301-F1-V-003

22.1 QA Survey Results

All QA survey results were similar to FSS data and the conclusions were the same as those based on the initial surveys. QA survey results are presented in Appendix I and are summarized in the tables below.

Table 22-4: QA Survey Building Structural Surfaces Total Activity Summary

Survey Unit	# of Sample Locations	Mean	MDC	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(dpm/100 cm^2)						
FHB-QA01	4	234	911	236	-37	450	5,000	NO
MYR-QA01	8	309	831	211	0	562	5,000	NO
PRB-QA01	10	216	1,033	210	-80	521	5,000	NO

Table 22-5: QA Survey Building Structural Surfaces Removable H-3 Summary

Survey Unit	# of Sample Locations	Mean	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(gross cpm/100 cm^2)					
FHB-QA01	4	8	1	8	9	200	NO
MYR-QA01	8	10	4	5	14	200	NO
PRB-QA01	10	13	7	5	32	200	NO

Table 22-6: QA Survey Building Structural Surfaces Removable C-14 Summary

Survey Unit	# of Sample Locations	Mean	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(gross cpm/100 cm^2)					
FHB-QA01	4	11	3	9	15	200	NO
MYR-QA01	8	10	4	6	16	200	NO
PRB-QA01	10	10	3	6	13	200	NO

Table 22-7: QA Survey Building Structural Surfaces Removable Channel 3 Summary

Survey Unit	# of Sample Locations	Mean	Standard Deviation	Min.	Max.	Investigation Level	Any Result Exceeding Investigation Level?
		(gross cpm/100 cm^2)					
FHB-QA01	4	8	3	3	11	200	NO
MYR-QA01	8	8	2	6	12	200	NO
PRB-QA01	10	9	3	3	14	200	NO

23.0 REFERENCES

- NRC Regulations 10 CFR 20 Subpart E
- NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM)
- NUREG 1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions"
- NUREG 1757, Volume 1 "Consolidated NMSS Decommissioning Guidance," September, 2002
- NUREG 1757, Volume 2 "Consolidated NMSS Decommissioning Guidance," September, 2006
- ISO-7503-1, "Evaluation of Surface Contamination – Part 1: Beta Emitters and Alpha Emitters." 1988
- IUPUI/IUMC Fesler Hall, Psychiatric Research, and Myers Buildings Decommissioning Work Plan
- IUPUI/IUMC Radioactive Materials License Number 13-02752-03
- NUREG 1556, Volume 7, Table Q.2, "Acceptable Surface Contamination Levels for Equipment," December 1999
- IUPUI/IUMC Wishard Hospital Decommissioning Final Status Report, December 27, 2013