Pickard Hall
Characterization Survey Report

University of Missouri
Museum of Art and Archaeology
1 Pickard Hall Columbia, MO 65211-1420

July 16, 2010

Work Performed Under:
Chase Environmental Group, Inc.
Commonwealth of Kentucky
Radioactive Materials
License No. 201-605-90

CHASE
Environmental Group

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

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ACRONYMS

AEC	US Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
CFR	Code of Federal Regulations
DAC	Derived Air Concentration
DQO	Data Quality Objective
DSV	Default Screening Value
GPS	Global positioning System
GSF	Gross Square Feet
HEPA	High Efficiency Particulate Air (Filter)
LAW	Large Area Wipe
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MU	University of Missouri
NRC	U.S. Nuclear Regulatory Commission
NIST	National Institute of Standards and Technology
QA	Quality Assurance

1.0 EXECUTIVE SUMMARY

The University of Missouri (MU) identified residual radioactivity from historical operations in the basement of Pickard Hall located at 1 Pickard Hall, Columbia, MO 65211-1420. Built in 1892 as a Chemistry Building, Pickard is currently being used as the Museum of Art and Archaeology, and houses the Department of Art History and Archaeology. The museum is located on the first and second floors, and the basement is used for storage of museum artifacts. Additionally, faculty offices are located on the first floor and in the basement. The building is listed on the National Register of Historic Places.

MU operates under broad scope license number 24-00513-32. The residual materials had historically been regulated by the State of Missouri, but became licensed by the US Nuclear Regulatory Commission (NRC) under the broad scope license coincidental with implementation of the NRC's expanded definition of byproduct material.

In the early 1900's, the basement of Pickard Hall was used for separation of radium-226 from uranium ores and research with Th-232 daughters. Residual radioactivity on structural surfaces is routinely monitored by MU to ensure personnel exposures from the residual materials do not exceed applicable dose limits. While the presence of these materials was known to MU, the extent and magnitude of residual radioactivity had not been characterized to a degree sufficient to plan decommissioning.

MU procured Chase Environmental Group, Inc. (Chase) to conduct an initial characterization of accessible surfaces of the facility to the extent possible without interfering with operations (moving artifacts, causing excess vibration, etc.). Characterization was performed to determine the extent and magnitude of residual radioactivity for decommissioning planning, and for evaluating radiological exposures to building occupants and visitors. Characterization methods involved invasive activities such as removal of small amounts of concrete and soil. Therefore, all work was performed under the Chase Commonwealth of Kentucky radioactive materials license number 201-605-90 utilizing a reciprocal agreement with the NRC.

Characterization was performed according to a survey plan developed using the applicable guidance provided in NUREG 1757, "Consolidated NMSS Decommissioning Guidance" and NUREG 1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) and provided the approach, methods, and techniques for radiological characterization of the facility. Chase surveyed accessible surfaces of the entire facility including all elevations and outside grounds. Characterization was an iterative process that was performed from December 2009 to June 2010 and involved five separate mobilizations:

- December 7-10, 2009 – indoor surface activity measurements, outdoor gamma scans, air sampling, concrete surface sampling, and surface soil sampling

- February 3, 2010 - sampling of attic materials (wood and brick) and air sampling in the attic and in basement mechanical spaces
- March 30-31, 2010 - roof surveys, global positioning system (GPS) gamma scans, elevated surface soil removal, and steam tunnel feeder soil removal
- May 20, 2010 - surface soil samples based on GPS gamma scan results, and tunnel dose rate measurements
- June 21-23, 2010 - scarification and encapsulation of basement mechanical spaces (Rooms 13 and 15)

Characterization results indicate that the nuclides of concern are U-238, Th-232 and their progeny (particularly Ra-226) and that residual radioactivity exists in the following locations:

- On basement concrete floor surfaces that are covered with vinyl tiles and are effectively encapsulated.
- On concrete floor surfaces in basement mechanical rooms. These surfaces were subsequently encapsulated.
- In the steam tunnel feeder adjacent to Mechanical Room 15. The top foot of soil in the steam tunnel feeder was removed and then geotextile and pavers were placed in the feeder.
- In buried drain lines under the basement floor and probably inside a sewer line from the building.
- In a small inaccessible area under the stage in Room 106 – this area is also detectable in the basement ceiling in Room 1B.
- In a small area inside a wall in Room 213.
- In the attic on one small location on the floor and in open joist areas.
- Inside brick ducts (assumed to be fume hood exhaust ducts) that are open in the attic and likely extend to the basement.
- In surface soils immediately outside the northwest corner of the building and likely in subsurface soils around sewer lines.

Initial characterization results indicate that the facility does not meet current decommissioning criteria for unrestricted release. However, MU is controlling and monitoring impacted areas to comply with occupational and public dose limits. External dose rates and removable contamination are relatively low in occupied areas of the facility. MU is currently conducting radon sampling and external dosimetry monitoring to further assess the impact of residual materials on doses to occupants. Further characterization is needed to define the extent of residual activity in inaccessible areas as well as in subsurface soils. This is complicated by the present use of the building as a museum and the care that must be exercised to protect artifacts.

2.0 SITE DESCRIPTION AND HISTORY

2.1 Building Description

Pickard Hall is located on campus, on Ninth Street in the Francis Quadrangle area, between the Chancellor's residence and the School of Journalism. Figure 1 shows the layout of the site (Pickard is Building 94). The building has a footprint of 8,400 square feet with approximately 24,600 gross square feet of floor area over three elevations (not including the attic). The brick building sits on a stone and mortar foundation. Originally, the building had wooden floors throughout, including the basement. The current basement floor is poured concrete with tile and carpet coverings. It is suspected, but not known for certain, that the concrete floor is original to the building and that the wooden floors were installed on top of the concrete. Floors on the first and second elevations are primarily carpeted with stone/ceramic tiled foyers and restrooms. Interior walls are plaster and sheetrock. The interior of the facility underwent a major interior renovation in 1974 that resulted in minor changes to the layout of the basement. Some windows on the basement and first floors and all windows on the second floor have been covered on the inside to prevent ultraviolet damage to artifacts. The entire ventilation system has been upgraded since the cessation of use of licensed materials; some original ventilation ducts remain, but are not in use. Original drains have been terminated at floor level and grouted.

Facility Floor Plans are provided in Appendix A and photos of the facility are provided in Appendix B.

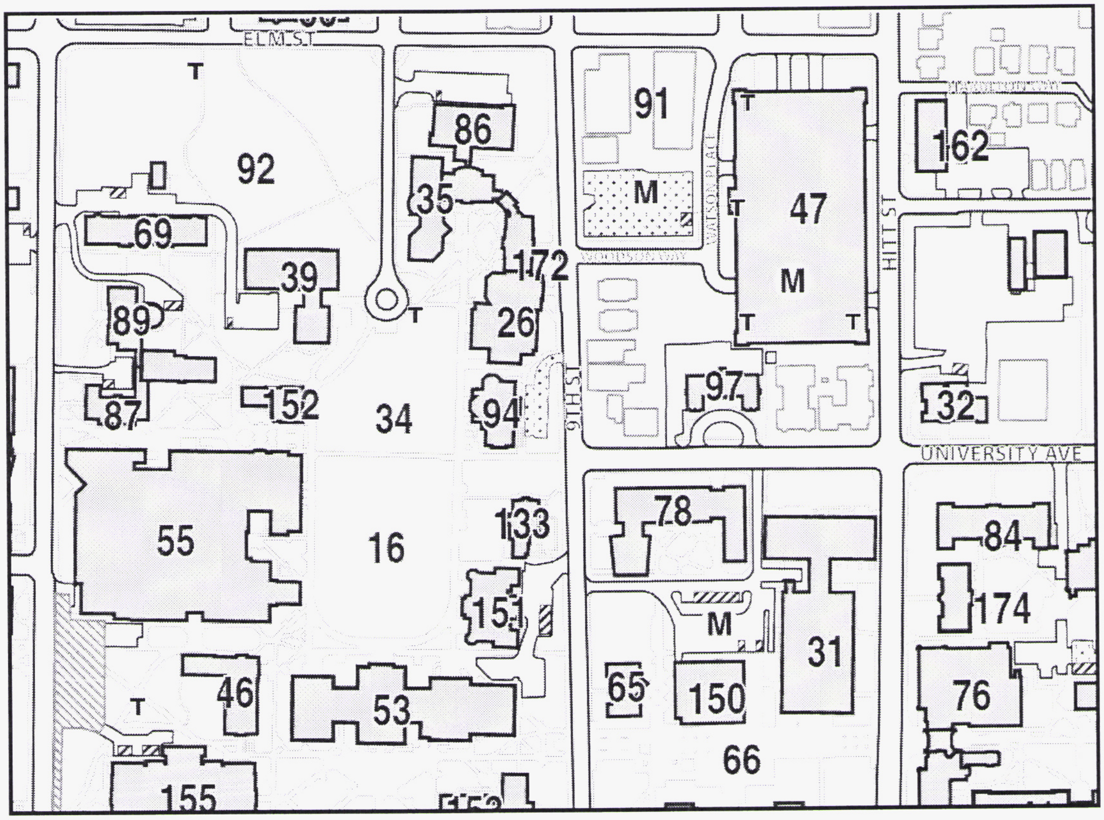

Figure 1, Site Layout

2.2 History

Pickard Hall, built in 1892 was originally the Chemical Building. In the early 1900s, a faculty researcher extracted and purified salts of radioactive elements from ores (extracted radium-226 from uranium ores), and conducted research involving Th-232 daughters in basement laboratories. The processes and areas of usage are generally known to MU staff. Other areas of the building were also laboratories. A major renovation was conducted in 1974 and the Museum of Art and Archaeology moved to Pickard in 1976.

2.3 License History

Operations were performed in the early 1900s. The state of Missouri regulated the materials until recently when the NRC expanded the definition of byproduct material, resulting in the materials being licensed under the MU broad scope byproduct materials license.

2.4 Current/Future Use

Pickard Hall is currently used as a museum and for faculty offices. It is expected that the use will not change in the foreseeable future.

3.0 Facility Release Criteria

Facility release criteria for unrestricted use are that of NRC 10 CFR 20.1402, "Radiological Criteria for Unrestricted Use." The criteria is that residual radioactivity results in a TEDE to an average member of the critical group that does not exceed 25 mrem per year, and that the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA).

4.0 Nuclides of Concern

Based on gamma spectroscopy and alpha spectroscopy analysis of soil and concrete samples collected during characterization, the nuclides of concern are U-238, Th-232 and their progeny, particularly Ra-226.

5.0 Investigation Levels

Investigation levels for surface activity were established to determine appropriate data quality objectives for characterization surveys. Because the facility used alpha emitting nuclides with very restrictive default screening values and volumetric contamination is probable, it is expected that a site-specific dose model will be used to decommission the site and surface contamination limits will be greater than NRC Policy and Guidance Directive FC 83-23[1]. However, FC 83-23 limits for Ra-226 are used as investigation levels to ensure adequate detection sensitivity for future use of characterization data. Surface contamination quantification is based on alpha measurements. However, because contamination exists under coverings that would shield alphas, beta-gamma measurements were qualitatively performed to detect contamination under floor and wall coverings that would not be detected by alpha measurements. Beta-gamma investigation levels were conservatively set at ten times the alpha investigation levels. The investigation levels are:

- Alpha: 100 dpm/100cm^2 total and 20 dpm/100cm^2 removable
- Beta-Gamma: 1,000 dpm/100cm^2 total and 200 dpm/100cm^2 removable

To demonstrate the appropriateness of the gross alpha investigation levels, nuclides of concern and progeny were modeled using NRC-approved DandD, Version 2.1 software. DandD output reports are included as Appendix C. Each nuclide was modeled at an activity concentration of 1 dpm/100cm^2. Implicit progeny doses were not included in parent doses and the initial activity was not distributed. All default parameter values were used except that the recommended Resuspension Factor (RF). The RF of 1E-6/m (as recommended in NUREG 1720 "Re-evaluation of the Indoor Resuspension Factor for the Screening Analysis of the Building Occupancy Scenario for NRC's License Termination Rule") is used, as opposed to the DandD, Version 2.1 default RF of 1.42E-

[1] These are the same limits as Regulatory Guide 1.86

5/m. This method was chosen because it is simple and conservative. Higher screening values could be obtained using RESRAD-BUILD with ICRP 72 dose conversion factors and site-specific parameter values.

The nuclides of concern have decay chains that emit a variety of different types of radiation. It is important to understand the equilibrium state of the chain in order to convert from activity of the parent to gross alpha activity (the number of alphas per decay). Because the nuclides of concern were chemically separated nearly a century ago, all nuclides are assumed to be in secular equilibrium. The RESRAD-BUILD default deterministic radon emanation fraction (EF) of 0.2 is used to estimate the presence of progeny below radon. Calculations of gross alpha screening values are presented in Table 5-1.

Table 5-1 Basis for Alpha Investigation Levels

Nuclide	Dose[3] per dpm/100cm^2 (mrem)	Screening Value[4] (dpm/100cm^2)	Alphas per Decay Before Rn	Alphas per Decay Rn+C	1-EF	Corrected Alphas per Decay Rn+C[5]	Total Alphas per Decay[6]	Gross Alpha Screening Value[7] (dpm/100cm^2)
Th-232	0.303	83	3	3	0.8	2.4	5.4	448
Th-230	0.0661	378	2	4	0.8	3.2	5.2	1,966
Ra-226	0.0172	1,453	1	4	0.8	3.2	4.2	6,103
U-238	0.103	243	4	4	0.8	3.2	7.2	1,750

The lowest gross alpha screening value is 448 dpm/100cm^2. DandD assumes a removable fraction of 10% such that a removable contamination limit of 45 dpm/100cm^2 alpha is implied. Therefore, the investigation levels are appropriate for determining adequate detection sensitivities for characterization surveys.

6.0 Data Quality Objectives (DQO)

The Data Quality Objective process as described in MARSSIM is used throughout the design and implementation of characterization surveys. The following is a list of the major DQOs for the survey design:

- Alpha scanning will be conducted at a rate to achieve an MDC_{scan} of less than the investigation level of 100 dpm/100cm^2.
- Beta scanning will be conducted at a rate to achieve an MDC_{scan} of less than the investigation level of 1,000 dpm/1000cm^2.

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[3] Values obtained from DandD reports
[4] 25 mrem / (dose per dpm/100cm^2)
[5] (alphas per decay Rn +C)*(1-EF)
[6] (alphas per decay before Rn) + (corrected alphas per decay of Rn + C)
[7] Screening value * total alphas per decay

- Alpha static measurements will be taken to achieve an MDC_{static} of less than the investigation level of 100 dpm/100cm^2.
- Beta static measurements will be taken to achieve an MDC_{static} of less than the investigation level of 1,000 dpm/100cm^2.
- Alpha removable contamination measurements will be counted to an MDC_{smear} of less than the investigation level of 20 dpm/100cm^2.
- Beta removable contamination measurements will be counted to an MDC_{smear} of less than the investigation level of 200 dpm/100cm^2.
- Individual measurements will be made to a 95% confidence interval.
- Characterization data will be of sufficient quality to provide useful information regarding the site's ability to meet a site-specific dose model.

7.0 SURVEY INSTRUMENTATION

7.1 Instrument Calibration

Laboratory and portable field instruments were calibrated within the previous year with National Institute of Standards and Technology (NIST) traceable sources. Portable instrument calibration records are included as Appendix D.

7.2 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.

7.3 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 DQOs. MARSSIM equations relative to building surfaces have been modified to convert to units of dpm/100cm^2. Count times and scanning rates are determined using the following equations:

7.3.1 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/100cm²)
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 (cm²)

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

$$MDC_{STATIC} = \frac{3 + 3.29\sqrt{(20)(1)\left(1 + \frac{1}{1}\right)}}{(1)(0.10)\frac{582}{100}} = 41\,\text{dpm/100cm}^2$$

7.3.2 Ratemeter Scanning

Per MARSSIM section 6.7.2.2 it is not practical to determine a fixed MDC for alpha scanning at background rates of 10 cpm or less. Because alpha background levels were above 10 cpm, the beta ratemeter scan MDC equation is used. 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)

Alpha scans were designed to achieve an MDC of 100 dpm/100cm^2. A typical alpha scanning MDC calculation for the Ludlum 43-37 gas flow proportional detector is shown below:

$$i = 13.3\,\text{cm} \cdot \frac{\text{inch}}{2.54\,\text{cm}} \cdot \frac{\text{sec}}{3.9\,\text{inch}} \cdot = 1.34\,\text{sec}$$

$$b_i = 1.34\,\text{sec} \cdot \frac{20\,\text{counts}}{\text{minute}} \cdot \frac{\text{minute}}{60\,\text{sec}} = 0.45\,\text{counts}$$

$$MDC_{SCAN} = \frac{1.38\sqrt{0.45}\left(\frac{60}{1.34}\right)}{\left(\sqrt{0.5}\right)(0.10)\left(\frac{582}{100}\right)} = 100\,\text{dpm/100cm}^2$$

7.3.3 Smear Counting

Smear counting Minimum Detectable Concentration at a 95% confidence level is calculated using the following equation, which is NUREG 1507, 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)

A typical alpha smear MDC calculation is shown below.

$$MDC_{SMEAR} = \frac{3 + 3.29\sqrt{(1)(1)\left(1+\frac{1}{10}\right)}}{(1)(0.34)} = 19\ \text{dpm}$$

7.4 Instrumentation Specifications

The instrumentation used for facility decommissioning surveys is summarized in the following tables. Table 7-1 lists the standard features of each instrument such as probe size and efficiency. Table 7-2 lists the typical operational parameters such as scan rate, count time, and the associated Minimum Detectable Concentrations (MDC).

Table 7-1 - Instrumentation Specifications

Detector Model	Detector Type	Detector Width	Detector Area	Meter Model	Window Thickness	Typical Total Efficiency
Ludlum 43-68	Gas Flow Proportional	8.8 cm	126 cm^2	Ludlum 2221	0.8 mg/cm^2	10% (Th-230) 20% (Tc-99)
Ludlum 43-37	Gas Flow Proportional	13.3 cm	582 cm^2	Ludlum 2221	0.8 mg/cm^2	10% (Th-230) 20% (Tc-99)
Ludlum 43-10-1	Phoswich	N/A	32 cm^2	Ludlum 2929	0.4 mg/cm^2	34% (Th-230) 20 % (Tc-99)
Ludlum 44-10	2" x 2" Sodium Iodide	N/A	N/A	Ludlum 2241	N/A	760 cpm per μR/hr (Ra-226) 830 cpm per μR/hr (Th-232) 3,990 cpm per μR/hr (U_{nat})
Bicron MicroRem	Tissue Equivalent Organic Scintillation	N/A	N/A	N/A	N/A	N/A

Table 7-2 Typical Instrument Operating Parameters and Sensitivities

Measurement Type	Detector Model	Scan Rate	Count Time	Bkg. Time	Bkg. (cpm)	MDC (dpm/100cm^2)
Gross Alpha Surface Scans	Ludlum 43-68	0.2 in./sec.	N/A	60 sec.	12	100
Gross Alpha Surface Scans	Ludlum 43-37	3.9 in./sec.	N/A	60 sec.	20	100
Gross Beta Surface Scans	Ludlum 43-68	0.5 in./sec.	N/A	60 sec.	500	1000
Gross Beta Surface Scans	Ludlum 43-37	5.2 in./sec.	N/A	60 sec.	1500	1000
Gross Alpha Total Surface Activity	Ludlum 43-68	N/A	120 sec.	600 sec.	12	82
Gross Alpha Total Surface Activity	Ludlum 43-37	N/A	60 sec.	60 sec.	20	41
Gross Beta Total Surface Activity	Ludlum 43-68	N/A	60 sec.	60 sec.	500	850
Gross Beta Total Surface Activity	Ludlum 43-37	N/A	60 sec.	60 sec.	1500	315
Gross Alpha Removable Activity	Ludlum 2929	N/A	60 sec.	600 sec.	1	19
Gross Beta Removable Activity	Ludlum 2929	N/A	60 sec.	600 sec.	70	159
Gamma Soil Scans	Ludlum 44-10	0.5 m/s	N/A	60 sec.	10,000	2.8 pCi/g (Ra-226) 1.8 pCi/g (Th-232) 80 pCi/g (U_{nat}) from NUREG 1507, Table 6.4[8]

[8] NUREG 1507 calculations make assumptions regarding the geometry of the contaminated area that may not be appropriate for the site. No attempt was made to estimate the detection sensitivity for indoor or outdoor gamma scans because they were used qualitatively.

7.5 Efficiency Determination

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 alpha emissions and beta emissions with maximum energies less than 400 KeV is conservatively set at 0.25, resulting in a total efficiency of approximately one half of the 4π efficiency. For smear counting, 4π efficiencies are used. Due to cleanliness of smears, no correction was made for alpha shielding from dust loading.

8.0 Survey Units

Each building elevation was surveyed as an independent survey unit for convenience of data management. Outside grounds were treated as a single survey unit.

9.0 Design and Performance of Characterization Surveys

Characterization surveys were performed using the Data Quality Objective (DQO) process to ensure data were of a sufficient quality to be useful for intended purposes. The goal of characterization is to define the extent and magnitude of residual radioactivity at the facility within the constraints of current operational limitations, personnel safety, and access restrictions. Chase surveyed accessible portions of the entire facility including all elevations, the attic, the roof, and outside grounds.

Characterization consisted of the following types of measurements:

- Indoor surface scans for alpha and beta emissions using gas flow proportional detectors (100% of accessible surfaces < 2m height)
- Indoor surface scans for gamma emissions using a 2" x 2" sodium iodide detector at a distance of 10 cm (100% of accessible surfaces < 2m height)
- Large area wipes for alpha and beta removable activity (100% of accessible floor surfaces)
- At locations of elevated activity:
    - Static measurements for alpha and beta total surface activity
    - Static measurements for gamma emissions at a distance of 10 cm
    - External dose rates at a 1 meter distance
    - Disc smears for alpha and beta removable activity
- Solid samples of concrete surfaces for gamma spectroscopy analysis (a subset of samples was also analyzed by alpha spectroscopy analysis)
- Solid samples of contaminated brick and wood floor in the attic.
- Surface soil gamma scans
- Surface soil samples for gamma spectroscopy analysis (a subset of samples was also analyzed by alpha spectroscopy analysis)
- Sampling for airborne radioactivity

All surveys were performed according to survey package instructions. Survey data were documented on survey maps and associated data information sheets.

9.1 Background Determination

For direct measurements, an ambient background level was determined for each survey, was subtracted from gross measurements, and was used to calculate the actual survey MDCs. Material-specific background determinations were not performed.

For indoor gamma measurements, background was determined by calculating the mean of ten one-minute timed counts in the basement and ten one-minute timed counts on the third floor of Switzler Hall at a distance of 10 cm above floor surfaces. Switzler Hall (Building 152 in Figure 1) was built at the same time as Pickard Hall and is of similar construction.

For outdoor gamma scans, background was determined by calculating the mean of ten one-minute timed counts in the quadrangle near Switzler Hall at a distance of 10 cm from the ground surface.

For indoor dose rate measurements, background was determined by calculating the mean of ten instantaneous measurements at the same locations in Switzler Hall as for indoor gamma scans, but at a distance of 1m from the surface.

Gamma and dose rate background measurements are presented in Appendix E.

Three background concrete samples were collected in the basement of Switzler Hall and six background surface soil samples were collected in the quadrangle. Background sample results are provided with soil and concrete sample results.

9.2 Surface Scans

The purpose of scanning was to identify locations of elevated activity. Where elevated activity was identified, the surveyor stopped and re-scanned the suspect area at a slower rate to determine if the elevated activity was sustained. Where a sustained increase in the audible response was identified, the boundary of the elevated area was recorded for locating the area for additional measurements. 100% accessible surfaces less than a 2-meter height were scanned for alpha, beta and gamma emissions.

9.2.1 Alpha/Beta Scans

Alpha and beta scans were performed by moving a gas flow proportional detector over surfaces at a distance of less than one centimeter and at a rate less than the maximum allowable scan rate necessary to achieve DQOs.

9.2.2 Gamma Scans

Indoor and outdoor gamma scans were performed by moving a 2" x 2" sodium iodide detector over surfaces at a distance of 10 cm and at a rate of 0.5 meters per second. Indoor gamma scans included accessible ventilation ducts and drain piping. Outdoor gamma scans included roof drain downspouts. Initial outdoor gamma scans identified elevated activity, and surface soil samples were collected at those locations. Subsequently, and after removal of two areas of surface soil with elevated activity, outdoor gamma scans were performed using GPS mapping to provide visualization of surface gamma radiation levels. Several areas of elevated activity were identified on the GPS Map. All of the locations of elevated activity were attributed to granite markers and brick pavers except for in the northwest corner where elevated activity had previously been identified. It should be noted that, even though elevated radiation levels were identified, all of the more than 13,000 measurements were less than twice the background rate.

The results of indoor gamma scans are presented in Appendix F. The initial results of outdoor gamma scans are provided in Appendix G. The report of GPS-mapped outdoor gamma scans is provided in Appendix H.

9.3 Static Measurements

Direct surveys (static measurements) for total surface activity and gamma emissions were taken on accessible building surfaces where elevated activity was identified. Additionally, a small set of measurements were performed by randomly selecting locations in areas without elevated activity as identified during scans. The results of static measurements are provided in Appendix I. Maps showing the locations of measurements are provided in Appendix J.

9.3.1 Alpha/Beta Static Measurements

Alpha and beta static measurements were performed by holding the probe at a distance of less than one centimeter and performing a one-minute timed count. Field measurements were converted to activity concentrations using the following equation:

$$\text{Activity}\,(\text{dpm}/100\text{cm}^2) = \frac{cpm_{sample} - cpm_{background}}{E_{total} \cdot \dfrac{A}{100cm^2}}$$

Where:

cpm_{sample}	=	sample count rate in counts per minute
$cpm_{background}$	=	background count rate in counts per minute
E_{tot}	=	total detector efficiency for radionuclide emission of interest (includes combination of instrument efficiency and surface efficiency of 0.25)
A	=	active area of the detector in cm^2

9.3.2 Gamma Static Measurements

Indoor gamma static measurements were performed by holding the probe at a distance of ten centimeters and performing a one-minute timed count. The results of gamma static measurements are provided in Appendix K. Maps showing the locations of measurements are provided in Appendix J.

9.4 Removable Contamination Measurements

9.4.1 Large Area Wipes

Large Area Wipes (LAWs) of 100% of accessible floor surfaces were performed by wiping a Masslinn cloth over an area of 400 ft^2 or more per wipe and then performing alpha and beta static measurements on the cloth. LAWs are more sensitive and have wider coverage than disc smears (LAWs cover surface areas thousands of times larger than disc smears), but cannot be accurately quantified in $dpm/100cm^2$. LAWs were used as qualitative measures of removable surface contamination. The locations and results of large area wipe samples are provided in Appendix L. LAW locations are provided by room number on the results data sheet (there is not a map for sample locations).

9.4.2 Disc smears

Removable contamination measurements were performed by wiping an area of approximately 100 cm^2 on surfaces with a cloth disc smear and then counting the smear for beta and alpha emissions in a portable smear counter. Disc smears were collected at each static measurement location and at additional locations where geometry prohibited static measurements, such as drains. Disc smear results are provided in Appendix I. Maps showing the locations of smears are provided in Appendix J.

9.5 Dose Rates

Dose rate measurements were performed with a tissue equivalent Bicron MicroRem meter. This instrument was selected due to its flat energy response. Because the Bicron is a ratemeter, an average of ten instantaneous rates was determined at each location by covering the meter and recording the measurement observed when it is uncovered (this is a relatively unbiased method to obtain an average dose rate). Dose rates were performed at each static measurement location at a distance of one meter from the source (midpoint

of a receptor). The results of dose rate measurements are provided in Appendix K. Additionally, the occupancy required at each location to achieve external doses of 25 mrem/yr and 100 mrem/yr were calculated. A background rate of 6.7 μR/hr (based on the mean of dose rate measurements performed in the basement of Switzler Hall) was used to correct the results for occupancy calculations. Maps showing the locations of dose rate measurements are provided in Appendix J.

9.6 Solid Samples

9.6.1 Concrete

MU removed floor coverings at basement floor locations of highest activity identified by scans to accommodate concrete sample collection by Chase. Chase selected six locations with highest alpha surface activity to collect solid samples. A map showing the locations of concrete samples is provided in Appendix M. Chase performed alpha and beta static measurements and smears at each location before and after collection of concrete samples. The results of these measurements are provided in Appendix N. Results indicate that scarification is an effective decontamination method for surface activity. All samples were analyzed by the contract laboratory for gamma spectroscopy. Gamma spectroscopy results were then used to select a subset of three samples for alpha spectroscopy analysis. Concrete sample analytical reports are provided in Appendix O.

9.6.2 Surface Soils

Initially, surface soil samples were collected at four locations of elevated activity detected by gamma scans of outside grounds surrounding the building. Additionally, a soil sample was collected at the location of highest activity in the steam tunnel feeder adjacent to mechanical Room 15. Six background soil samples were collected in the Quadrangle. A map showing the locations of samples is provided in Appendix G[9]. All samples were analyzed by gamma spectroscopy at the contract laboratory. Gamma spectroscopy results were used to select a subset of three background samples and three soil samples for alpha spectroscopy analysis.

After remediation of two discreet areas of surface soil contamination, GPS gamma scans were conducted of outside grounds surrounding Pickard Hall to provide better visualization of surface radiation levels. The information provided by the GPS survey provided input to the design of additional surface soil sampling locations. Nineteen additional samples were collected (two of the samples were a composite of four locations in the Quadrangle). The locations of surface soil samples are provided in Appendix G. Analytical results of soil samples are provided in Appendix O.

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[9] Sample numbers 5-10 are assigned to concrete samples. The locations of the concrete samples are presented in Appendix M.

9.6.3 Attic Brick and Wood Samples

Solid samples of contaminated materials in the attic were collected and sent to the contract laboratory for gamma spectroscopy analysis. Two samples were collected from brick ducts and one sample was collected of wood from the floor. Analytical results of these solid samples are provided in Appendix O.

9.7 Laboratory Analyses

Solid samples were sent to Teledyne Brown Engineering in Knoxville, TN for analysis. All solid samples (concrete and soils) were analyzed by gamma spectroscopy. The results of gamma spectroscopy were used to select a subset of samples to receive alpha spectroscopy analysis.

9.8 Sample Chain-of-Custody

Samples sent off-site for analysis used an approved Chain of Custody Procedure. The sample chain-of-custody maintains the integrity of the sample; that is, there is an accurate record of sample collection, transport, analysis, and disposal. This ensures that samples are neither lost nor tampered with, and that the sample analyzed in the laboratory is actually and verifiably the sample taken from a specific location in the field.

9.9 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

10.0 Soil Removal

Chase removed surface soils in outside grounds and in the steam tunnel feeder. The two elevated areas of surface soil activity identified during Phase 1 were remediated by hand to a depth of approximately one foot. Each excavation was surveyed after remediation, covered with a geotextile fabric to provide a clear interface, and then backfilled with soils provided by MU. The purpose of this remediation was to ensure normal landscaping activities such as thatching and aerating do not disturb soils with residual radioactivity. The steam tunnel feeder soil was removed in an area of 4’ x 10’ and a depth of approximately one foot. After soil removal, the area was covered with a geotextile fabric and pavers to provide a barrier from radioactive materials.

11.0 Encapsulation of Mechanical Rooms

During the initial characterization surveys, low levels of removable activity were identified on bare concrete floors in mechanical rooms 13 and 15. Subsequently, Chase scarified the concrete floors (for encapsulant adhesion) in these mechanical rooms, and then encapsulated floor and wall surfaces. The purpose of encapsulation was to provide a protective barrier from radioactive materials and eliminate removable contamination.

Chase used a shrouded floor scarifier for most areas and a shrouded hand-held scarifier for areas not accessible to the floor scarifier. HEPA-filtered vacuums were attached to the scarifiers to control loose radioactive materials and a HEPA-filtered ventilation unit was used to maintain work areas at a negative pressure. Air sampling for radioactive materials was performed during invasive activities. The highest result was 1.2E-13 µCi/ml (24% of the Th-232 W Class DAC, the most limiting nuclide).

Wall surfaces in mechanical rooms 13 and 15 were covered with an encapsulant using an airless sprayer. Floor surfaces were encapsulated with a rolled-on two-part epoxy floor coating that is commonly used for garage floors. All coatings are water-based and nontoxic. Radiological surveys were performed encapsulation. Post-encapsulation results are presented in Appendix P.

12.0 Interpretation of Survey Results

Characterization survey results indicate that the nuclides of concern are, as expected, U-238, Th-232 and their progeny (particularly Ra-226). This conclusion is based on what is known about the historical use of the site and on gamma spectroscopy and alpha spectroscopy of concrete and soil samples.

Residual radioactivity exists in the following locations:

- On basement concrete floor surfaces that are covered with paint or vinyl tiles (and are effectively encapsulated).
- In the steam tunnel feeder soils (following some remediation, remaining soils were covered with geotextile fabric and pavers).
- In buried drain lines under the basement floor and possibly in a sewer line from the building.
- In a small inaccessible area under the stage in Room 106 – this area is also detectable in the basement ceiling in Room 1B.
- In a small area inside a wall in Room 213.
- In the attic on the floor and in open joist areas under the elevated floor.
- Inside brick ducts (assumed to be fume hood exhaust ducts) that are open in the attic and likely extend to the basement.
- In surface soils immediately outside the northwest corner of the building and likely in subsurface soils around sewer lines.

Residual radioactivity in the building is contained primarily in two locations with limited occupancy – in the attic and in the basement storage and mechanical rooms. In the basement, there is likely distributed surface contamination on floor surfaces as well as buried drain lines with residual radioactivity, based on surface measurements and the linear geometry of elevated readings with a 2" x 2" sodium iodide detector. The attic has residual radioactivity on surfaces and in open brick ducts. These ducts are within walls and likely extend to the basement, and may be a source of slightly elevated dose rates on all elevations.

There were two small areas of residual radioactivity in surface soils of outside grounds that were remediated and the buried sewer discharge from the building appears to contain elevated activity. There may also be subsurface soil contamination under the basement floor.

Residual materials are effectively encapsulated based on removable contamination measurements. Low levels of removable contamination were detected in the attic and mechanical areas in the basement where there is low occupancy. Some areas of the building do not meet the decommissioning criteria for unrestricted use (based solely on external dose rates and the occupancy assumption of the building occupancy scenario of 2340 hrs). Occupied areas appear to meet the public dose limits based on removable contamination results, dose rates and conservative occupancy assumptions, except Room 27 (office) and Room 12 (storage). However, MU is controlling access to these areas and providing radon and external dosimetry monitoring sufficient to ensure public dose limits are met in unrestricted areas.

Characterization results indicate that the building does not meet current decommissioning criteria and further characterization to include inaccessible surfaces and subsurface investigations are required to fully characterize the site.

13.0 References

- NRC Regulations
- Chase Commonwealth of Kentucky radioactive materials license number 201-605-90
- NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM)
- NUREG-1505, "A Nonparametric Statistical Methodology for the Design and Analysis of Final Decommissioning Surveys"
- 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

- FC 83-23, "Guidelines for the Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Byproduct, Source, or Special Nuclear Material Licenses."
- ISO-7503-1, "Evaluation of Surface Contamination – Part 1: Beta Emitters and Alpha Emitters." 1988
- NUREG-1720 "Re-evaluation of the Indoor Resuspension Factor for the Screening Analysis of the Building Occupancy Scenario for NRC's License Termination Rule," 2002
- ANL/EAD/03-1 "User's Manual for RESRAD-BUILD Version 3," June 2003
- ICRP Publication 72, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides Part 5, Compilation of Ingestion and Inhalation Coefficients"
- Pickard Hall Characterization Work Plan, November 2009
- Pickard Hall Phase 2 Characterization Work Plan, March 2010
- Pickard Hall Scarification and Encapsulation Work Plan, June 2010