FINAL

FINAL STATUS SURVEY REPORT

RADIOLOGICAL CHARACTERIZATION/CLOSURE SURVEYS IN SUPPORT OF BRAC 2005 WALTER REED ARMY MEDICAL CENTER, MAIN POST WASHINGTON, DC

CONTRACT No. W912DR-08-D-0024

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EXECUTIVE SUMMARY

As of 15 September 2011, per Permanent Order 161-013 issued by Headquarters, US Army Medical Command, Fort Sam Houston, Texas, patient treatment and biomedical research with radioactive materials ceased at Walter Reed Army Medical Center (WRAMC), Washington, District of Columbia (DC) as part of the Defense Base Realignment and Closure (BRAC) (Public Law 101-510 as amended through FY05 Authorization Act) [Ref. 7.1 and 7.39]. BRAC is the process by which the nation reshapes its military installations to become more efficient and effective in supporting its forces.

Activities at WRAMC Main Post operated under WRAMC's Nuclear Regulatory Commission (NRC) license, which were terminated as a result of the closure of WRAMC. Therefore, WRAMC must ensure that all locations where NRC licensed materials were used are released for unrestricted use or transferred to a new permit/license. WRAMC, through the U.S. Army Corps of Engineers (USACE), contracted Tidewater, Inc. (TIDEWATER) to evaluate the impacted buildings at WRAMC Main Post to determine if the facilities are suitable for unrestricted release with respect to radiological conditions.

The purpose of this survey effort was to specifically address facilities and areas identified during the Historical Site Assessment (HSA) [Ref. 7.2] as being impacted by current or former operations involving radioactive materials regulated via U.S. Nuclear Regulatory Commission (NRC) licensing or Department of the Army Radiation Authorizations (ARA).

Release criteria was established with the NRC's dose criteria in 10 CFR Part 20, Subpart E, using a screening approach to dose analysis as presented in NUREG-1757, Vol. 2, [Ref. 7.5]. Radionuclides in sealed source form were conservatively considered as radionuclides of concern (ROC) even though no leakage was ever known at WRAMC. With two exceptions described below, the look-up screening levels selected are found in Table H.1 of NUREG-1757, Vol. 2.

- A screening value was not available in the look-up tables for Co-57 and its value was selected from NUREG/CR-5512, Vol. 3, [Ref. 7.32] Table 5.19, *Concentration (dpm/100 cm^2) equivalent to 25 mrem/y for the specified value of P_{crit}*. The value for Co-57 was selected at P_{crit} equal to 0.90 which is the same criteria as those from DandD, Version 2.1 and those published in the lookup table.
- A screening level was not available for Ba-133 in either NUREG-1757 or NUREG/CR-5512. A screening level was developed using the default values for RESRAD-Build Version 3.5 [Ref. 7.23]. For an input of 3.79E8 dpm/m^2 (3.79E6 dpm/100cm^2), the resultant dose was 25.0 mrem/year.

A radiological survey of Buildings 1, 2, 7, 38, 41, 54, 91, 92 and two storage bunkers was performed by TIDEWATER on November 7th through December 30th, 2011 and on February 3rd, 2012 in accordance with the approved Site Characterization Work Plan (SCWP), Vol. I: Sampling and Analysis Plan (SAP) and Vol. II: Accident Prevention Plan (APP) [Ref. 7.3]. All

surveys were designed and completed according to guidance in the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) [Ref. 7.4]. MARSSIM provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance with a dose- or risk-based regulation. The MARSSIM guidance focuses on the demonstration of compliance during the final status survey. This survey included (a) exposure rate measurements, (b) scans and static measurements taken on floors, walls, hoods, laboratory workbenches for residual contamination, (c) collection of smears for removable contamination on various surfaces and inside drains and vacuum lines with analysis of the smears for gross alpha and gross beta analysis by liquid scintillation at an offsite laboratory. The offsite laboratory was accredited by the DoD Environmental Laboratory Accreditation Program (ELAP).

This survey followed the MARSSIM graded approach to emphasize collection of data that provides the most benefit. This survey was also rigorous as a large effort was made to ensure appurtenant issues were investigated. This survey included the likelihood of hidden work surfaces which might have been covered during renovations, air discharge areas on roofs, all drains in sinks located in known impacted rooms, and vacuum lines in impacted laboratories. Numerous bias scans, directs and smears were made to ensure that all locations were evaluated where contamination is known to accumulate such as floor, wall interfaces, drains, inside hoods and air exhaust ducts, laboratory work benches, and visible cracks. Approximately 48,000 square feet of floor area and 3,800 square feet of walls, hood, and other work areas were scanned during this survey. The rigor of the survey is further illustrated in the following table.

Executive Table 1 - Summary of Number of Survey Measurements Performed

Survey Units	Tritium		Beta		Alpha		Exposure Rate	Smears	
	MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias		MARSSIM Required	Bias
69	921	311	934	312	934	312	1246	138	485

This survey also included an evaluation of three clinical linear accelerator rooms (CLINAC) and two CLINACS that were present at the time of survey (in Building 2). No residual surface contamination was identified in the rooms. However, a potentially activated volume was identified in the heads of both LINACs, but results were not conclusive. Disposition and control of the LINACs is beyond the scope of this survey. The Final Status of these rooms as reported herein is assumed to remain unaffected by these accelerators, as long as they were not operated prior to their removal from the site. The Army is currently planning removal of the accelerators from the building.

Results of the surveys indicate that no impacted areas exceed residual radioactivity screening levels as described from the use of radioactive materials at the WRAMC Main Post.

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ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
AFIP	Armed Forces Institute of Pathology
AL	Action Level
ALARA	As Low As Reasonably Achievable
APP	Accident Prevention Plan
ARA	Army Radiation Authorization
BRAC	Base Realignment and Closure
CENAB	US Army Corps of Engineers Baltimore District
CFR	Code of Federal Regulations
CHP	Certified by American Board of Health Physics
Ci	Curie, a unit of radioactivity, defined as equaling 3.7×10^{10} decays per second
CL	Confidence Level
cm2	square centimeter
COC	chain of custody
cpm	counts per minute
CQC	Contractor quality control
CRSO	Corporate Radiation Safety Officer
CSM	Conceptual Site Model
d	day
DandD	An NRC dose modeling computer software program
DC	District of Columbia
DCGL	Derived Concentration Guideline Level
DCI	Department of Clinical Investigation
DoD	Department of Defense
dpm	disintegrations per minute
DMC	Data Management Coordinator
DQCR	Daily Quality Contractor Report
DQO	Data Quality Objective
DU	Depleted Uranium
EMC	Elevated Measurement Comparison
EPA	Environmental Protection Agency
FIDLER	Field Instrument for Detection of Low Energy Radiation
FSM	Field Site Manger
FSS	Final status survey
ft2	square feet
g	gram
h	hour
HAZWOPER	Hazardous Waste Operations and Emergency Response
HPO	Health Physics Office
HSA	Historical Site Assessment
H_o	Null Hypothesis
IDW	Investigative Derived Waste
IL	Investigation Level
ISO	International Standards Organization
keV	one thousand electron volts (103 eV)
LBGR	Lower Bound of the Gray Region
m	meter
m2	square meter
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
mCi	millicurie

ACRONYMS AND ABBREVIATIONS (CONTINUED)

MDA	minimum detectable activity
MDC	minimum detectable count or concentration
MDCR	minimum detectable count rate
MDE	Maryland Department of the Environment
MeV	million electron volt; equal to 1.602 × 10-13 joules
mrem/yr	millirem per year
NaI	Sodium Iodide, a crystal
NARM	Natural and Accelerator Produced Radioactive Material
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
NUREG	NRC nuclear regulation document
OSHA	Occupational Safety and Health Administration
PDA	Personal Data Assistant
pCi	picocurie
PI	Principal Investigator
PM	Program or Project Manager
PPE	Personnel Protective Equipment
QAC	Quality Assurance Coordinator
QA/QC	Quality Assurance/Quality Control
QSM	Quality Systems Manual
RAM	Radioactive Material
ROC	Radionuclide Contaminants of Potential Concern
RSO	Radiation Safety Officer
R/h	Roentgen per hour
s	second
SAP	Site Analysis Plan
SCWP	Site Characterization Work Plan
SSHO	Site Safety Health Officer
STDEV	Standard Deviation
SU	survey unit
TEDE	Total Effective Dose Equivalent
UFP-QAPP	Uniform Federal Policy - Quality Assurance Project Plans
URSA	Universal Radiation Spectrum Analyzer
US	United States
USACE	US Army Corps of Engineers
U Nat	Natural uranium
WRAMC	Walter Reed Army Medical Center
y	year
µrem	microrem
µCi	microcurie
Δ/σ	Relative shift

ACRONYMS AND ABBREVIATIONS FOR RADIONUCLIDES

Am-241	Americium-241
Cr-51	Chromium-51
Ba-133	Barium-133
C-14	Carbon-14
Ca-45	Calcium-45
Cd-109	Cadmium-109
Cl-36	Chlorine-36
Ce-141,144	Cerium radioactive isotopes
Cr-51	Chromium-51
Cs-134, 137	Cesium radioactive isotopes
Co-57, 60	Cobalt radioactive isotopes
Eu-152, -154	Europium radioactive isotopes
Fe-59	Iron-59
Ga-67	Galium-67
Gd-153	Gadolinium-153
H-3	Tritium
I-123, 125, 129, 130, 131	Iodine radioactive isotopes
In-111	Indium-111
Ir-192	Iridium-192
K-42	Potassium-42
Na-22	Sodium-22
Nb-95	Niobium-95
Ni-63	Nickel-63
Mn-54	Manganese-54
Mo-99	molybdenum-99
P-32, 33	Phosphorus radioactive isotopes
Pd-103	Palladium-103
Pu-239	Plutonium-239
Ra-226	Radium-226
Rb-86	Rubidium-86
Ru-103	Ruthenium-183
S-35	Sulfur-35
Sc-46	Scandium-46
Sb-125	Antimony-125
Se-75	Selenium-75
Sr-85, 89, 90	Strontium radioactive isotopes
Ta-182	Tantalum-182
Tc-99, 99m	Technetium radioactive isotopes
Tl-201	Thallium-201
Yb-169	Ytterbium-169
Zn-65	Zinc-65

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FINAL STATUS SURVEY REPORT

1.0 INTRODUCTION

1.1 Purpose and Scope

This Final Status Survey Report (FSSR) is based on requirements set forth in the project SCWP, specifically in Volume I, the SAP and summarizes the survey details and analytical results to support termination of WRAMC's NRC license. It was prepared by TIDEWATER in support of Base Realignment and Closure (BRAC) 2005 at the former WRAMC-Main Post, Washington, DC. As of 15 September 2011, patient treatment and biomedical research with radioactive materials ceased at WRAMC.

The USACE is responsible for evaluating whether impacted areas and buildings at WRAMC Main Post are suitable for unrestricted release with respect to radiological conditions. This work was performed under contract to the USACE Baltimore District (CENAB), Contract No. W912DR-08-D-0024**,** Delivery Order 02. In accordance with contract direction, this survey effort was designed using the approach outlined in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) [Ref 7.4]. Specific references to all planning documents are provided as follows:

- USEPA, August 2000, 402-R-97-016, Rev. 1, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). [Ref. 7.4]
- USNRC, NUREG 1757 - Vol. 1 and 2, Consolidated NMSS Decommissioning Guidance. [Ref. 7.5]
- USACE, February 2001, EM 200-1-3, Requirements for Preparation of a Sampling and Analysis Plan. [Ref. 7.6]
- USACE, November 2008, EM 385-1-1, Safety and Health Requirements Manual. [Ref. 7.7]
- USACE, May 1997, EM 385-1-80, Radiation Protection Manual. [Ref. 7.8]
- USACE, May 2007, ER 385-1-92, Safety and Occupational Health Document Requirements for Hazardous, Toxic, and Radioactive Waste and Ordnance and Explosive Waste Activities. [Ref. 7.9]
- USACE, July 2005, EM 1110-35-1 Management Guidelines for Working With Radioactive and Mixed Waste. [Ref. 7-10]
- Department of Defense Quality Systems Manual (DoD QSM), Version 4.2 (Dec 2010); provides baseline requirements for the establishment and management of quality systems for environmental testing laboratories performing services for the Department of Defense. [Ref. 7.11]
- Recommendations for Phase II Environmental Condition of Property Investigation, Walter Reed Army Medical Center, Washington, D.C., USACE August 2006. [Ref. 7.12]
- USEPA, Guidance for the Data Quality Objective Process, 2000 [Ref. 7.13]

The field team closely followed the protocol presented in the SCWP and completed field activities on February 3, 2012.

1.2 Historical Site Assessment (HSA)

The use of radioactive material at WRAMC was conducted in accordance with a number of NRC licenses (now consolidated to NRC License Number 08-01738-02) [Ref. 7.14] and Army Radiation Authorization (ARA) [Ref. 7.15]. The HSA was performed for the Main Post of WRAMC in accordance with MARSSIM guidance and finalized in January 2007. As part of the HSA process, areas were classified as impacted or non-impacted. The complete HSA is found as Appendix H. The impacted areas were further classified by contamination potential. Specific uses of radioactive material documented in the HSA are summarized as follows:

- Medical treatment using sealed sources in milliCurie (mCi) quantities (e.g., brachytherapy and oncology seeds).
- Health physics support using sealed sources in microCurie (μCi) quantities (e.g., calibration sources).
- Medical treatment and research with various radionuclides in unsealed form.

During the HSA, documents gathered from various sources were reviewed and evaluated to extract information on the possession and use of radioactive material (RAM). These documents included licenses, permits, authorizations, inventory records, surveys, historical drawings, and floor plans. In addition, the HSA and work planning included a visual inspection of all buildings and areas where RAM was used or stored. The use of RAM at WRAMC was historically conducted in accordance with NRC licenses and Department of the Army Radiation Authorizations.

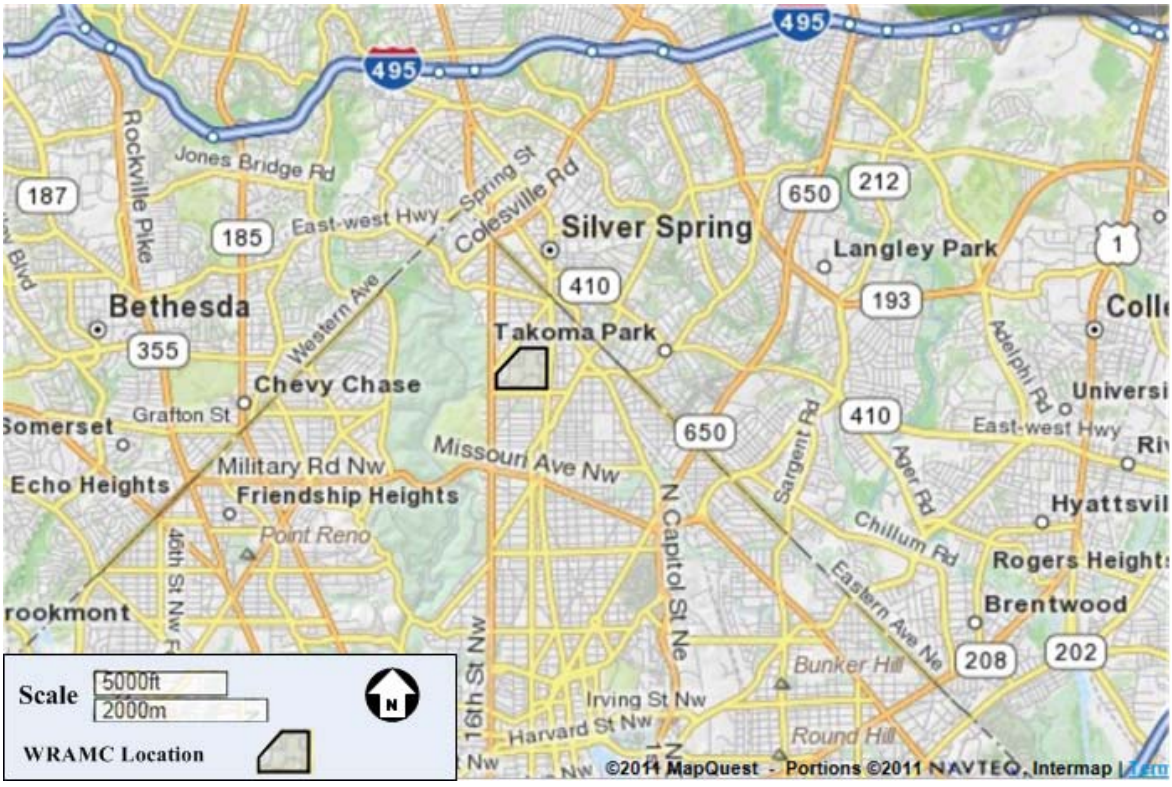
TIDEWATER thoroughly evaluated the HSA, performed additional interviews (contained in Appendix A) with prior WRAMC Health Physics Office staff, reviewed subsequent operations post the HSA and subsequently developed a Site Characterization Work Plan (SCWP) [Ref. 7.3]. The SCWP detailed a survey approach to be in compliance with MARSSIM. The intent of this survey was to evaluate the radiological status of this facility.

1.2.1 Site Location

The Property is located at 6900 Georgia Avenue N.W., Washington, DC, between Rock Creek Park and Georgia Avenue near the Maryland and DC boundary. The tract encompasses approximately 113 acres and is comprised of 48 buildings. The Main Post section, containing the main hospital complex, is bounded by 16th Street on the northwest and Alaska Avenue (U.S.

Route 29), Georgia Avenue, and Fern and Aspen Streets. A general location map showing the extents of the WRAMC Main Post is provided in Figure 1-1.

Figure 1-1 WRAMC Map Location



1.2.2 Site History

The WRAMC was operational for 101 years. In ten decades, the WRAMC grew to a vast medical complex, teaching medical professionals, medical research programs, and treating hundreds of thousands of patients. In addition to the main post, WRAMC also controlled two noncontiguous properties in Forest Glen, MD and Wheaton, MD (Glen Haven). The two noncontiguous properties are not addressed in this survey.

1.2.2 Licenses and Army Radiation Authorizations

Radioactive materials use was conducted under NRC Licenses and ARA issued to WRAMC. The following is a list of active and terminated licenses and permits issued to WRAMC:

- NRC License No. 08-01738-02, Expiration Date 30 April 2015 (original Atomic Energy Commission License dates to 1957). License 08-01738-02 allows possession and use of any byproduct radionuclide with mass number between 1 and 83 up to 400 mCi each, plus nuclide-specific possession and use limits pertaining to nuclear medicine and bio-medical research activities (H-3, P-32, Co-60, Sr-90, Mo-99, Tc-99m, I-131, Xe-133, Cs-137, Gd-153, Ir192, Pu-239 and Am-241). [Ref. 7.14]
- Terminated NRC License No. 08-01738-03, terminated on 17 August 2004 – NRC License 08-01738-03 allowed for possession and use of gamma cell irradiators. Upon termination of the license, gamma cell irradiator possession was transferred to NRC License No. 08-01738-02. [Ref. 7.16]
- NRC License No. 08-01738-02 10-year renewal application (Form 313 with attachments dated 7 January 2005) requested the deletion of several items including thorium as WRAMC had no records to support the use of thorium in licensed activities. WRAMC did indicate possession of microcurie amounts of thorium in check sources. [Ref.7.14]
- ARA No. 08-01-15, Amendment No. 1, Expiration Date 30 November 2015. This ARA allows for the use of linear accelerators in medical therapy. [Ref. 7.15]
- NRC License No. SUB-603 was amended on May 28, 1968 and authorized 50 pounds of natural uranium, 50 pounds of depleted uranium and 5 pounds of thorium. One of its purposes was for Uranyl solution for microscopic slides. In the application dated July 5, 1973, the purpose of the material was for staining histological specimens; analytical chemical procedure and preparation of standards; and preparation of comparison standards for use in monitoring radioactive contamination in food and water. Amendment #3 was issued on July 31, 1973 authorizing 260 kilogram of uranium and 5 kilograms of thorium. On February 7, 1979 this license was terminated by incorporating the material and its uses into license 08-01738-02. At that time, materials to be used were stated as 50 kg natural uranium as uranyl sulfate, uranyl nitrate, uranyl acetate and uranyl zinc acetate; 280 kg depleted uranium in any form and as shielding; and 5 kg thorium as thorium chloranilate, thorium oxide, and thorium nitrate. The renewal application for license 08-01738-02 in 2005 requested removal of thorium as WRAMC had no records of use. [Ref. 7.17]

WRAMC used linear electron accelerators (LINACs) for medical treatment of cancer. According to the ARA issued to WRAMC, the linear accelerators and use energy as listed in Table 1-1 were authorized [Ref. 7.15]. Quality control records indicated that the 2100C was tested at 20 MeV for quality control purposes which should have none to minimal impact on causing activation of building surfaces.

Table 1-1 Authorized LINAC Use At WRAMC

Manufacturer	Model	Serial No.	Maximum Photon Energy
Varian	Clinac 600C	613	6 MV
Varian	2100C-SC	149	6 MV
Varian	2100IX	24236	15 MV (20 MeV electrons)

Correspondence from the NRC was provided in the HSA to document that certain buildings formerly used for radioactive materials use under NRC License No. 08-01738-02, at WRAMC Main Post are now "released for unrestricted use." These include:

- Decommissioned Building 40, Main Post (NRC Letter dated 26 May 2004)
- Decommissioned Building T-2, Main Post (NRC Letter dated 10 March 2005)
- The research reactor that was located in the basement of Building 40 at the WRAMC Main Post was operated under U.S. Atomic Energy Commission (AEC) License Number AEC SUB 603 and AEC SNM 472. The Building 40 Research Reactor was de-fueled in 1971 and partially decontaminated in 1972. The AEC license was terminated at this time. Complete decommissioning of the sub-basement and basement levels of Building 40 was completed in 2001.

1.3 Summary of Impacted Areas at WRAMC Main Post

Based on the HSA findings and subsequent review work, nine buildings on the WRAMC Main Post were considered impacted from the historical use of radioactive material (see Table 1-2). The locations of the impacted buildings are shown in Figure 1-2. Within the nine identified buildings and areas, 200 rooms or laboratories were considered as "Impacted." Since the HSA, two storage areas were established in concrete bunkers immediately south of Building 40 for short-lived radioactive waste and small (microcurie quantities) check sources. The specific rooms known to have contained RAM are identified in Table 1-3. Few radiologically impacted outdoor areas or release points were identified for the Main Post; however, three areas were selected for investigation: (1) the road way in front of and immediately adjacent to the waste storage bunkers was deemed to be a Class 3 area to provide a buffer zone from the Class 2 bunkers; (2) the air exhaust from nuclear medicine near the roof of Building 2; and (3) air exhaust areas on the south wing of Building 54.

It is common to find that buildings being surveyed have undergone some degree of renovation; that was the case at all buildings considered in this survey. Renovations included removal/replacement of flooring (new tile, carpet and/or epoxy), wall removal or addition to create new rooms or expand existing areas, painting of surfaces, removal/replacement of legacy laboratory hoods, ventilation and plumbing renovation, and removal/replacement of cabinetry. Where renovation took place, the survey team used professional judgment and took a conservative approach to the survey methodology. For example, Building 38 had been totally renovated and was subjected to a MARSSIM Class 3 survey. In all impacted buildings, efforts were made to identify and survey original work surfaces beneath carpets, floor tiles, and new wall structures, e.g., floor tiles were removed to permit measurements if suspected as being a second layer of tile, carpeting was removed for integrated measurements at all locations, and thirty-five (35) wall sections were drilled through (4 inch diameter holes) to provide access for visual inspections. One covered wall was identified in Building 91 and was subsequently investigated. The entrance to a RAM storage closet in Building 92 was discovered and removed for survey. A sufficient number of measurement locations were investigated in all areas to meet MARSSIM requirements; in addition, survey technicians provided multiple bias measurements including sinks, drain, exhaust ducts, and hoods in each survey unit.

Table 1-3 was also developed based on information from (1) additional follow-up interviews, (2) the HSA Building Fact Sheets, (3) inventory reports, and (4) Fireman Notification list.

Phase I Initial Assessments [Ref. 7.18, 7.19, and 7.20] conducted in 2011 for Buildings 2, 7, and 54 were reviewed to identify locations of electron microscopes which are routinely associated with uranyl solutions for slide staining. Uranyl solutions contain natural uranium or depleted uranium and purchases were made under an NRC general license; packages were received without inventory by WRAMC HPO. None were identified in Building 2. One room was identified in Building 7 and ten rooms were identified with staining or scope activities in Building 54. Other rooms identified with RAM in these Phase I Initial Assessments were verified to be on or added to the impacted room listing shown in Table 1-3. The Phase I Initial Assessment for Building 54 listed the rooms of the firing range located in the basement. Additionally, a 1975 general survey indicated electron microscopes in four rooms in Building 54 [Ref. 7.21].

When possible, the physical properties, e.g., half-life, emitted particles, and energies, of the various radionuclides presented in this document are primarily from *The Health Physics and Radiological Handbook,* Revised Edition, Scinta, Inc., (RHH) [Ref. 7.22]. When data was not available from RHH, data bases from the RESRAD or DandD modeling codes were used [Ref. 7.23 and 7.24].

Figure 1-2 Locations of Impacted Buildings/Areas

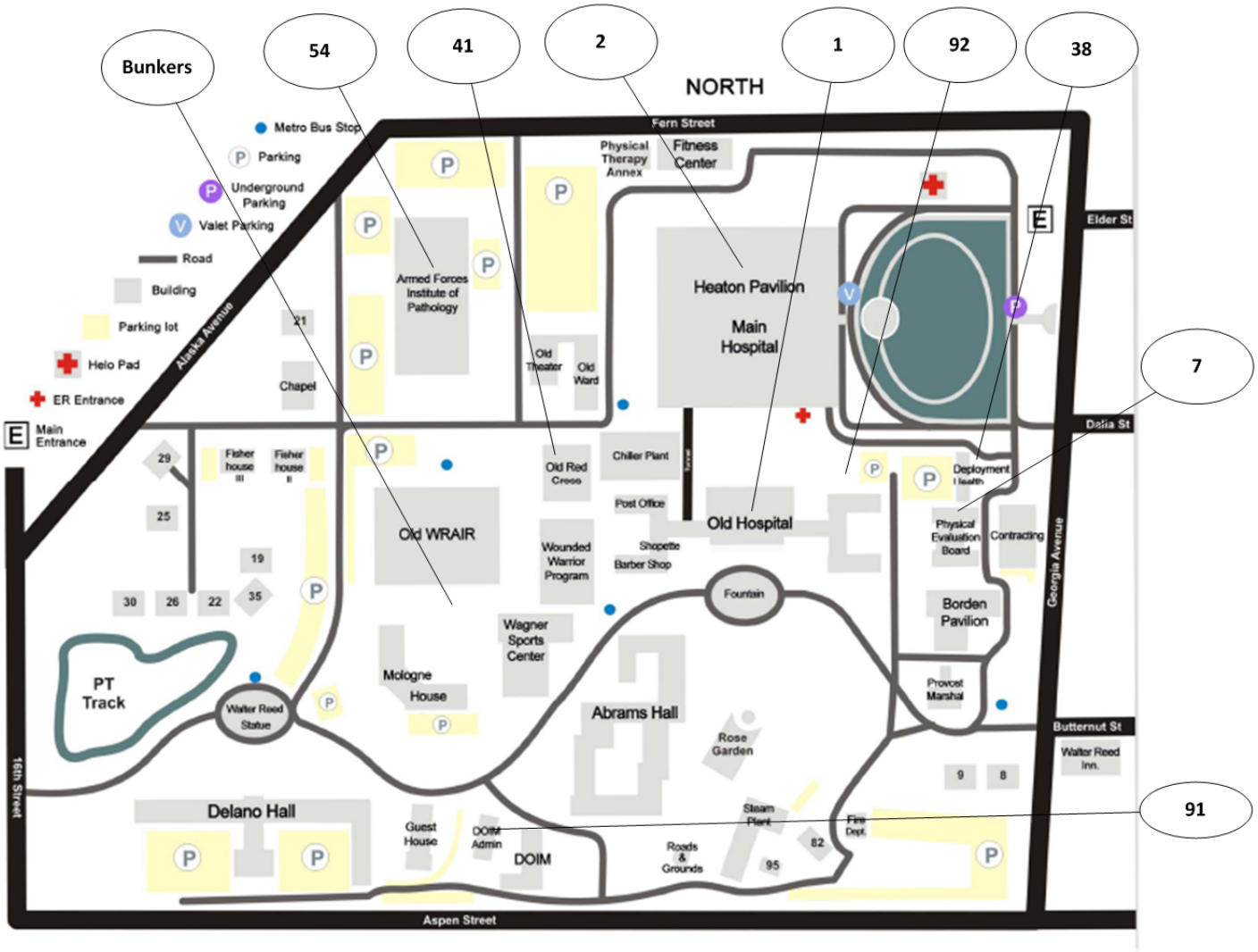


Table 1-2 WRAMC Main Post Impacted Buildings

Building Number	Original Structure	Department(s)/ RAM Use(s)	Current Tenant and Conditions	Total Building Gross (Square Feet)	Total Number of Rooms	Rooms Impacted
1	Walter Reed General Hospital	Original Hospital Building – Nuclear Medicine, Oncology, Others	WRAMC Administration and post support	336,302	491	9
2	Heaton Pavilion	Current Hospital Building - Nuclear Medicine, Radiation Oncology, Department of Clinical Investigation (DCI) Research Labs	WRAMC Administration and post support	2,584,477	3295	98
7	Barracks	DCI - Research Labs	Building extensively renovated over its history. DCI still active in one lab.	50,379	108	26
38	Guard House	Medical Outpatient Clinic	Building totally renovated.	9,641	43	43
Bunkers	Storage, near Building 40	Storage	HPO radioactive waste storage.	400	2	2
41	Red Cross Building	Health Physics Office (HPO) – Radioactive Waste Storage and calibration sources	WRAMC Administration and post support	50,023	84	3
54	Armed Forces Institute of Pathology (AFIP)	AFIP - Research Labs	WRAMC Administration and post support. Several floors extensively renovated. RAM usage continues in several labs.	359,743	582	582
91	Former Regional Dental Lab	U.S. Army Institute of Dental Research – Research Labs	Directorate of Information Management / Industrial Hygiene	8,581	19	16
92	Nuclear Medicine Clinic	Nuclear medicine and imaging	Photo laboratory	5,534	15	15

Table 1-3 Identity of Impacted Rooms*

Building	Floor	Rooms/Areas
1	Basement	B-019 (now F001-F008)
2	1	1H23-1H25, 1H28A, 1H33 (LINAC Room), 1J33, 1J39, 1J39A, 1J43
	2	2B26, 2B51, 2B53, 2B54, 2B56, 2B59, 2B62, 2B81D, 2F209
	4	4726, 4742, 4743, 4744, 4746, 4747, 4748, 4750, 4750C, 4751, 4752, 4754, 4760, 4942, 4954
	5	5Z60, 5Z68, 5Z70
	6	6Z60, 6Z70, 6562
	7	7A03, 7A05, 7A07, 7A09, 7A14, 7A16, 7A18, 7A20, 7B02, 7B03, 7C01, 7C05, 7C06, 7C07, 7C07A, 7C07B, 7C08, 7E10A, 7F15, 7F59, 7Z11, 7Z60, 7Z68, 7Z70, 7438, 7544, 7545
7	Basement	001, 009, 011, 018, 019, 022, 025, 025A, 025H, 026, 026A, 027, 031, 034, 035, 040, 046, 053
	1	108, 109
	2	209, 216, 217, 218, 221, 222
38	All	All three floors (221, 223, and 224)
Bunkers	Ground	Two bunkers
41	Ground	39, 42
54	Basement	B032, B042A, B045, B063, B065, B066, B067, B088, B092
	Ground	G014, G075
	Museum	M093A, M093B, M093F, M109, M111, M124A
	1	1028, 1032, 1034-1036, 1040, 1046, 1050
	2	2008, 2012, 2014, S2028, S2030, S2050, 2072
	3	3002, 3004, 3006, 3008, 3010, 3012, 3014, 3028, 3032, 3034, 3060, 3067, 3068, 3099, 3061B, 3100, 3102, 3106, 3112, 3118
	4	4004, 4004A, 4006, 4008, 4008A, 4008B, 4032, 4064, 4066, 4086, 4100, 4106, N4202, 4205/4209, 4509, 4603, N4608, 4609, 4613
	5	5003, 5005, 5042, 5047, 5051
91	Ground &1	2, 22, all of 1st floor
92	Ground	1, 1A, through 18

*Based upon professional judgment, other rooms were considered impacted and surveyed.

1.3.1 Building 1

Building 1 was the primary patient care facility and Post Library at WRAMC from 1909 until construction of the new hospital, Building 2 in 1977. This was the location of the former Nuclear Medicine Clinic and Radiation Oncology departments. No authorization or permit was found for Building 1. However, a previous employee from the WRAMC HPO prior to the completion of the new hospital confirmed that the only impacted room was B-19 (now designated as rooms F001-F008) in Building 1B (East Pavilion); see Appendix A for interview summary. After 34 years of decay, only Ba-133, Ra-226, Cs-137, H-3, and C-14 would be detectable, if present today, as the routine short-lived radionuclides have decayed to insignificant activities. See Table 1-4 for a listing of radionuclides used in nuclear medicine; the MARSSIM Classification was 3.

1.3.2 Building 2

Building 2 was the Main Hospital for the WRAMC Complex. The building consists of 8 levels: the basement and seven floors. Each floor has an interstitial mechanical level above it for piping, wiring, A/C ducts, and other infrastructure. During the HSA, Building 2 had an active Nuclear Medicine clinic, Radiation Oncology and Radiology units, and several research laboratories that use radioactive materials. Rooms 7544 and 7545 were used by the HPO for temporary short-lived radioactive waste storage. The WRAMC Nuclear Medicine Receipt Logs and the WRAMC HPO RAM Shipments Report for shipments received from 1/1/1990 through 11/01/2011indicate the various receipts and activity which are shown I Table 1-4. The list of impacted rooms is presented in Table 1-3. No work with radioactive materials was ongoing during this survey.

The MARSSIM Classification for routine use rooms was Class 3; the radiopharmaceutical preparation areas are Class 2. The waste storage rooms (7544 and 7545) were Class 2. Note no long-lived radionuclides were known to be stored as waste.

Building 2 had housed three medical linear accelerators (LINAC) of which two were present during the FSS. All three rooms were surveyed to see if any residual activation above background could be identified. Induced radioactivity depends on many factors, such as type and energy of accelerated particles and material irradiated by the primary beam and secondary radiation [Ref. 7-25]. One study indicated a LINAC which produced 20 MeV electrons, 18 MV photons and was in operation for 15 years did not produce significant activation above background level. However, activated machine parts could be a radiation safety issue if any remains [Ref. 7.26]. As there were no previous radiation surveys for these rooms, the LINAC room (1H33) was surveyed as a Class 1 as the 2100IX unit had multiple beams. The LINAC

rooms (1H23 and1H27) were combined in to a single Class two survey unit. If produced, the activation products in concrete would be H-3, Na-22, Mn-54, Co-60, Cs-134, Eu-152, and Eu-154 coming from (n,γ) reactions in trace amounts (a few parts per million or less by weight) of stable nuclides [Ref. 7-25 and 7.26].

Table 1-4 Nuclear Medicine Purchases (mCi Quantities) of Radionuclides for the Years 2002 -2011

Isotope	$T_{1/2}$	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002
C-14	5700 y	0.01	0.008					0.02			
Co-57	270.9 d						0.004			0.022	0.03
Cr-51	27.7 d		0.035	0.5	0.75	0.85	0.75	1.5	1.75	2.5	1
F-18	110 m	6900	13,470	17,930	25,450	19,760	19,520	19,610	19,730	5,200	499
Ga-67	3.3 d	20	34		3		22	22	23	134	144
Pd-103	13.6 h	376	385	2,186							
I-123	13.3 h	149	62,710	567	448	2,246	301	1662	99	140	34
I-125	59.4 d				40		1	0.2		0.7	
I-131	8.02 d	4252	4,297	4,704	6,777	7,444	5,757	8,891	8,110	7,729	6,118
In-111	2.83 d	74	157	82	167	336	312	288	314		292
Mo-99	66 h	215000	173,500	248,000	500,000	507,000	510,000	552,500	532,500	550,000	550,000
Ra-223	11.4 d		0.16								
Sm-153	46.3 h	47		150	100	200	250	450	150	1050	1,300
Sr-89	50.5 d										
Tc99m	6.02 h	452800	394	649,360	1,102,024	973,470	1,031,966				
Tl-201	73.1 h	1218	2,862	2,403	2,765	2,735	3,244	3,002	4,162	4,602	4,236
Xe-133	5.2 d	3097	5,200	4,980	5,300	5,060	4,760	5,360	6,320	6,800	4,500
Y-90	64 h		27		24			52	222		

1.3.3 Building 7

During the conduct of the HSA, the Pathology Laboratories, Department of Clinical Investigation (DCI) were the only group using RAM in Building 7. The building consisted of 4 levels; First Floor to Third Floor plus a Basement and was renovated in 2000. The list of impacted rooms is presented in Table 1-3.

During the HSA, Room 026 was reported as the only remaining laboratory with RAM usage. All other former research labs with RAM were closed out by HPO prior to extensive building renovation. However, records of the HPO surveys were not available but knowledge of the results of no positive findings support the MARSSIM Classification of 3 for all rooms. The WRAMC HPO RAM Shipments Report for shipments received from 1/1/1990 through 11/01/2011indicate the following radionuclides with their last receipts:

- Co-57 on 9/25/2002 (decay >10 half-lives through 2011)
- Eu-152 on1/9/1995
- H-3 on 5/29.2002
- I-125 on 9/3/2009 (decay >10 half-lives through 2011)
- P-32 on 7/3/2003 (decay >10 half-lives through 2011)

Carbon-14 was listed as a potential source in the HSA. Additionally, there were records of electron microscope usage in Room B019. Uranyl solutions were typically used as a staining agent for these purposes. No work with radioactive materials was ongoing during this survey.

1.3.4 Building 38

During the HSA, Building 38 was undergoing an extensive renovation and was renamed to "Vacarro Hall" in 2007. Radionuclides identified for us in the HSA were C-14, Ca-45, Cl-36, Cr-51, H-3, I-125, I-131, Na-22, P-32, Rb-86, and Tc-99m. No work with radioactive materials was ongoing during this survey. The building was considered as Class 3 even though none of the original surfaces remain. HPO close-out survey results from October 2005 for Rooms 221, 223, and 224 support a Class 3 determination.

1.3.5 Waste Bunkers

Two concrete bunkers immediately south of Building 40 were placed in service after the HSA for the storage of short-live radioactive waste from nuclear medicine and research and also for the storage of small (μCi quantities) sealed check sources. The origin of the waste was only from Building 2 and Building 54. The WRAMC HPO close-out survey after the removal of the material indicated no contamination; however, the two areas were classified as MARSSIM Class 2 with a buffer zone Class 3 area on the adjoining lot area.

1.3.6 Building 41

The original tenant was the Red Cross; however, during the HSA, the building was used for instructional purposes, an Outpatient Clinic, and the Health Physics Offices. The building consists of three levels: Ground Level, First Floor, and Second Floor. Table 1-5 provides a listing of the various radionuclides received by the HPO for their use; all material was in a sealed form or standard.

Table 1-5 Last Receipts by Radionuclide for HPO Use

Isotope	T 1/2	Activity (mCi)	Receipt Date	Isotope	T 1/2	Activity (mCi)	Receipt
H-3	12.3 y	63	3/18/99	Zn-65	244 d	0.011	12/2/99
C-14	5700 y	0.5	1/14/10	Pd-103	13.6 h	36	2/4/11
P-32	14.2 d	0.25	5/16/07	Cd-109	462.6 d	0.001	7/30/01
S-35	87.3 d	0.12	12/2/99	I-125	59.4 d	0.011	12/2/99
Cl-36	3.01E5 y	0.0001	12/2/09	Sb-125	2.75 y	0.26	3/27/95
Ca-45	162.2 d	1	2/13/04	Ba-133	10.51 y	0.02	11/14/05
Cr-51	27.7 d	0.14	12/4/99	Cs-137	30.1 y	0.01	5/16/03
Mn-54	312.5 d	0.011	12/2/99	Eu-152	13.3 y	0.02	2/15/90
Co-57	270.9 d	0.05	2/25/08	Gd-153	241.6 d	522	4/16/10
Co-60	5.27 y	0.007	9/14/07	Ir-192	73.8 d	106	3/27/98
Ga-67	3.26 d	0.006	7/6/98	Pu-239	2.41 E+4 y	0.00002	3/7/05
Ni-63	100 y	9.3	11/2/07	Am-241	432.2 y	954	9/9/03

Room 39 was the HPO counting lab and was the only location at WRAMC authorized to use Am-241 and Pu-239. Room 42 was used for source storage, temporary radioactive waste storage, and instrumentation. This was the only WRAMC authorized location for Cd-109. No work with radioactive materials was ongoing during this survey. The MARSSIM Classification was 2 for both rooms.

1.3.7 Building 54

The tenant of Building 54 was the Armed Forces Institute of Pathology (AFIP). This institution was concerned with diagnostic consultation, education, and research in the medical specialty of pathology. The AFIP Medical Museum, officially known as National Museum of Health and Medicine (from 1989), was located on the southern side of Building 54, on the street level. The building consists of 8 levels: First Floor through Fifth Floor, with Ground level, Basement level,

and Sub-Basement level. Several floors of Building 54 have undergone significant renovation. New room configuration and numbering schemes do not match rooms as listed in some authorizations. The Fourth and Fifth floors had been renovated as of the HSA site visit. HPO closeout survey records are available for the following rooms: 1028, 1030, 2008, 3012, 5007, 5044, and 5050; however, these room were also considered impacted. Authorized radionuclide use included Ba-133 and Sr-90 as sealed sources and unsealed material as H-3, C-14, I-125, and P-32. The WRAMC HPO RAM Shipments Report for shipments received from 1/1/1990 through 11/01/2011indicate the last receipt for C-14 was 10.6 mCi in 2004 and the last receipt for H-3 was in 1999. Sealed sources containing Ba-133 and Ni-63 were received in 2004 and 2006, respectively.

A reference to an abandoned firing range in the basement of Bldg 54 was made in the HSA. The tour guide mentioned potential for depleted uranium from firing of 50-caliber rounds. The location of the range was B018, B019, B028, B030, B030A, B030B, and B031.

There are records of electron microscope usage in Building 54. Therefore, uranium was added to the ROC list since uranyl solutions are typically used as a staining agent for these purposes. The impacted rooms are B045, B063, B067, M093B, 3002-3008, 3010/3012, 3078, 3108, 3118, and 3061B, and N4202.

No work with radioactive materials was ongoing during this survey. The MARSSIM Class for all impacted areas in Building 54 was Class 3.

1.3.8 Building 91

During the HSA, the tenant of Building 91 was Directorate of Information Management (DOIM)/ Industrial Hygiene; however, the former occupant was the US Army Institute of Dental Research (USAIDR). Building 91 consists of 2 levels, ground level and a first floor. RAM use was documented in Room 2, but terminated in Oct. 1991. HPO closeout surveys were not available and the building was completely renovated after closeout. It now houses administrative departments.

The unsealed radionuclides involved included H-3 and C-14. However, there are records of electron microscope usage by the Dental Activity Command [Ref. 7.27]. Therefore, uranium was added to the ROC list since uranyl solutions were typically used as a staining agent for these purposes. Room 2 was completely renovated but without closeout survey documentation, it was classified as Class 3. As no specific rooms were identified for electron microscope use, additionally impacted Class 3 areas were those remaining rooms on the ground level and the first floor.

During prior remodeling, one of the original walls was covered with drywall which was required to be removed for this radiological survey. No work with radioactive materials was ongoing during this survey.

1.3.9 Building 92

Building 92 was a single story, brick building added to the northeast wing of Building 1 in 1954 as the Nuclear Medicine Clinic. It had a direct entrance into the basement level of Building 1. The HPO had no records of RAM use in Building 92 but RAM use likely ceased over 34 years ago in 1977 (year Building 2 opened). Therefore, nuclides typically used in nuclear medicine and imaging, which have gone through ten half-lives were not considered as potentially detectable. After the ten half-life period, the potentially remaining unsealed radionuclide sources include H-3 and C-14. The MARSSIM Classification was 3.

One RAM storage area which contained a shielded Lazy Susan was covered over with dry wall which was removed and surveyed as a Class 1.

1.4 Summary of Radionuclide Use at WRAMC

1.4.1 Significant Historical Accounts

1.4.1.1 No Use of Thorium

One notable licensed radionuclide which was not used was thorium as WRAMC officially declared no record of use in the reapplication for the NRC license in 2005. Subsequent interviews with WRAMC HPO and prior employees indicate no use or possession of thorium. A detailed investigation of historical documents was conducted which also did not indicate use of thorium. Ultimately, not a single interview or historical research suggested that thorium was ever present at the site in a form other than exempt microcurie check sources.

1.4.1.2 Non-Leaking Sealed Sources

The HSA and subsequent investigation indicates there were never any accounts of leaking sources; maintenance of records of leak testing beyond 5 years was not required (License Condition 17.I.). As no leaking sealed sources were ever identified, all sealed sources could be dismissed from consideration. A discussion of sealed sources was included in this section as release criteria and survey design was conservatively based upon screening levels for certain of them. Leak test records are provided in Appendix A for generally licensed Chemical Agent Monitors (CAM) containing Ni-63; the storage locations of the CAMS in Buildings 12 and 14 were considered as non-impacted.

1.4.1.3 Uranium

Uranium as uranyl solutions was used in certain laboratories containing electron microscopes. Uranyl solutions are water-soluble depleted uranium or natural uranium compounds and these were often used as stains in electron microscopy. Use was limited to Buildings 2, 54, and 91.

There were anecdotal accounts of depleted uranium being potentially used as ammunition in a firing range in the basement of Building 54.

Per NUREG-1717 [Ref. 7.28], the isotopes of DU are U-238, U-235, and U-234 with activity abundance of 90.1%, 1.5%, and 8.4% and for natural uranium are 48.83%, 2.34%, and 48.83%.

1.4.2 Clinical Applications

Unsealed radionuclides purchased for use at WRAMC from 2002 through 2011 for clinical diagnosis and treatments are shown in Table 1.4. Of those listed only two C-14 and Co-57 have half-lives sufficiently long enough to be considered as Radiological Contaminants of Concern (ROC). Medical use of sealed sources included Co-60, Ni-63, Sr-90, Cs-137, Eu-152, and Ra-226. Sealed sources used for calibration and quality control of equipment typically include Na-22, Mn-54, Co-57, Co-60, Cs-137, Cd-109, I-129, Ba-133, Am-241. Point sources and anatomical markers are listed as Co-57, Au-195.

1.4.3 Biomedical Research

Radionuclides used at WRAMC for biomedical research consisted of both sealed and unsealed radioactive material. Radionuclides used and possessed were identified from the HSA Building Fact Sheets and various receipt inventories, see Appendix A for copies of these documents. The identified radionuclides are a typical suite of unsealed radionuclides for biomedical applications and research and are listed with the respective half-lives in descending order in Table 1.6.

Table 1-6 Radionuclides Authorized in Unsealed Form for Biomedical Research

ROC	Half-life	ROC	Half-life
DU	4.47E+9 y	I-125	59.4 d
U Nat	4.47E+9 y	Sr-89	50.5 d
Cl-36	3.01E5 y	Fe-59	44.5 d
C-14	5700 y	Ru-103	39.28 d
H-3	12.3 y	Ce-141	32.5 d
Eu-154	8.8 y	Yb-169	32 d
Sb-125	2.77 y	Nb-95	31.2 d
Na-22	2.6 y	Cr-51	27.7 d
Cs-134	2.062 y	P-33	25.3 d
Mn-54	312.5 d	Rb-86	18.7 d
Ce-144	284.3 d	P-32	14.2 d
Se-75	120 d	I-131	8.02 d
Ta-182	114.4 d	Ga-67	3.3 d
S-35	87.3 d	Tl-201	3.05 d
Sc-46	83.8 d	In-111	2.83 d
Co-56	78.8 d	Mo-99	66 h
Ir-192	74 d	Pd-103	13.6 h
Co-58	70.8 d	I-123	13.3 h
Sr-85	64.8 d	Tc-99m	6.02 h

1.4.4 ROC in Unsealed Form by Building

Table 1-7 shows the various ROCs with their respective half-lives which were used in a particular impacted building. For this calculation, radionuclide use ceased in Buildings 1, 2, 38, 91 and 92 in 1977, 2011, 2005, 1991, and 1972; respectively, as indicated in the sections above. Short term storage of unsealed RAM in the bunkers ceased in October 2011 and decay was assumed for the remainder of 2011. For this study, ROCs decaying through more than 10 half-lives were deemed as most probably non-detectable with today's instrumentation. No long lived material (>120 days) was stored in the bunkers in an unsealed form.

Table 1-7 illustrates which radionuclides were important for DCGL development per building or area. Blank cells reflect the non-use of the radionuclide in that building or the radionuclide has decayed through ten or more half-lives.

Table 1-7 does not imply that each radionuclide listed for a particular building was used in all rooms and areas of that building. Survey design requires that when actual use by building room

or area was known, only those particular radionuclides of use or potentially detectable were considered.

Table 1-7 ROC In Unsealed Form by Building

ROC	Half-life	Impacted Buildings							
		1	2	7	38	Bunkers	54	91	92
H-3	12.3 y	X	X	X	X		X	X	X
C-14	5700 y	X	X	X	X		X	X	X
Na-22	2.6 y				X				
Cl-36	3.01E5 y				X				
Ca-45	162.2 d				X				
Co-57	270.9 d		X						
Uranium	4.47E+9 y			X			X	X	

1.4.5 Use of Sealed Sources by Building

Table 1-8 illustrates which sealed sources were considered for DCGL development per building or area. Blank cells reflect the non-use of the radionuclide in that building.

Table 1-8 does not imply that each radionuclide listed for a particular building was used in all rooms and areas of that building, e.g., Pu-239 and Am-241 were only authorized in one room of Building 41.

Survey design requires that when actual use by building room or area was known, only those particular radionuclides of use or potentially detectable were considered.

Table 1-8 Use and Storage of Sealed Sources

ROC	Half-life	Impacted Buildings								
		1	2	7	38	41	Bunkers	54	91	92
Ca-45	5700 y					X				X
Cl-36	3.01E5 y					X				
Ca-45	162.2 d		X							X
Co-57	270.9 d		X			X				X
Co-60	5.27 y		X							X
Ni-63	100 y		X			X		X		X
Zn-65	244 d		X							X
Sr-90	29.12 y		X					X		X
Cd-109	462.6 d					X				
Sb-125	2.77 y					X				
I-129	1.57E+7 y		X							X
Ba-133	10.51 y	X	X			X		X		
Cs-137	30.1 y	X	X			X	X			X
Eu-152	13.3 y		X	X		X				
Gd-153	241.6 d		X			X				
Ra-226	1.12E+03 y	X	X				X		X	X
Pu-239	2.41E+04 y					X				
Am-241	432.2 y					X				

1.5 Physical Characteristics of Radionuclides of Concern (ROC)

1.5.1 ROC Principal Beta and Alpha Emissions

Table 1-9 lists the ROCs for (1) routine medical and research uses and (2) potential activation products along with their respective half-lives, principle emitted particle and maximum energy. Their respective principal beta or alpha emissions are listed and rounded to two decimal places. The beta and alpha energies indicated play a significant role during data interpretations and determining which radionuclides can be measured with hand held detectors and which must be sampled for analysis. ISO-7503-1 [Ref. 7.29] makes recommendations for default source efficiencies. A source efficiency of 0.5 is recommended for beta emitters with maximum energies above 0.4 MeV. Alpha emitters and beta emitters with maximum beta energies between 0.15 and 0.4 MeV have a recommended source efficiency of 0.25. Source efficiencies for some common surface materials and overlaying material are provided in NUREG-1507 [Ref. 7.30].

Table 1-9 ROC Half-lives, Decay Type, and Principal Energy

ROC	Half-life	Principal Emission	Energy (MeV)	ROC	Half-life	Principal Emission	Energy (MeV)
H-3[a]	12.3 y	Beta [b]	0.02	I-129	1.57E+7 y	Beta [c]	0.15
C-14[a]	5700 y	Beta [c]	0.16	Ba-133	10.51 y	Beta [c,f]	0.32
Na-22	2.6 y	Positron	0.55	Cs-134	2.05 y	Beta [d]	0.658
Cl-36	3.01E5 y	Beta	0.71	Cs-137	30.1 y	Beta	0.51
Ca-45	162.2 d	Beta [c]	0.26	Eu-152 [a]	13.6 y	Beta	1.47
Co-57	270.9 d	Electron [b]	0.13	Eu-154 [a,d]	8.8 y	Beta	0.84
Co-60[a]	5.27 y	Beta [c]	0.32	Gd-153	241.6 d	Beta [c]	0.39
Ni-63	100 y	Beta [b]	0.07	Ra-226	1600 y	Alpha	4.78
Zn-65	244 d	Positron	0.33	Uranium [e]	4.47E+9 y	Alpha	1.20
Sr/Y-90	29.12 y	Beta	2.28	Pu-239	24065 y	Alpha	5.16
Cd-109	462.6 d	Beta [b]	0.13	Am-241	432.2 y	Alpha	5.49
Sb-125	2.77 y	Beta	0.30				

[a] Also part of ROCs for activated concrete
[b] Considered very low energy (<0.15 MeV) and requires windowless detector .
[c] Considered a low energy beta (0.15 MeV < $E_{\beta max}$ <0.4 MeV) and has low efficiencies with hand held instrumentation.
[d] If present, associated only with LINAC operation.
[e] Based on U-238.
[f] Percent abundance is very low at 1.5%; primarily a gamma emitter.

1.5.2 Gamma Emitting ROCs

Table 1-10 lists the ROCs and the principal gamma energies emitted and the percent probability of occurrence.

Table 1-10 Gamma Emitters and Principal Energies

Isotope	Principal Gamma Energies (MV) (%)
Na-22	1.82 (100%)
Mn-54	0.835 (100%)
Co-57	0.122 (85.5%), 0.16 (10.6%)
Co-58	0.811 (99%), 0.511 (30%)
Co-60 [a]	1.17 (100%), 1.33 (100%)
Zn-65	1.116 (51%)
Se-75	0.121 (17%), 0.136 (59%) 0.265 (60%), 0.280 (25%) 0.40 (11%)
Sb-125	0.176 (7%), 0.428 (29%) 0.463 (10%), 0.601 (18%) 0.606 (5%), 0.636 (11%)
Cs-134 [b]	0.57 (23%), 0.605 (98%) 0.796 (99%)
Cs-137	0.662 (90%)
Ce-144	0.134 (11%)
Eu-152 [a]	0.122 (37%), 0.344 (27%)
	0.779 (14%), 0.96 (15%)
	1.087 (12%), 1.11 (14%)
	1.408 (22%)
Eu-154 [b]	0.12 (38%), 0.72 (21%)
	1.00 (31%), 1.278 (37%)
Gd-153	0.103 (21%, 0.097 (29%)
Ir-192	0.296 (29%), 0.308 (30%) 0.317 (83%), 0.468,(48%) 0.604 (8%)

[a] Also part of ROCs for activated concrete
[b] Associated only with LINAC operation.

2.0 DERIVED CONCENTRATION GUIDELINE LEVELS

Survey planning was conducted in accordance with guidance presented in NUREG-1757, *Consolidated NMSS Decommissioning Guidance, Volumes 1 and 2* [Ref. 7.5]. This section describes the establishment of derived concentration guideline levels (DCGLs) that were used to guide site decommissioning activities. DCGLs, expressed for surface activity in disintegrations per minute per 100 square centimeters (dpm/100cm^2), represent the residual radioactivity concentrations (above background) on surfaces that correspond to the allowable radiation dose limit, considering the collective risks to human health associated with anticipated potential exposure scenarios and pathways to a potential future site population. Demonstrating that residual radioactivity remaining at the site was statistically within site-specific DCGLs maintains compliance with acceptable risk to a potential future site population.

The NRC has established a radiation dose limit of 25 millirem per year (mrem/yr) above background as the allowable annual dose to the public contributed by residual radioactivity at a site released for unrestricted use. In 10 CFR 20, Subpart E, *Radiological Criteria for License Termination*, [Ref. 7.31] the following release criteria are specified:

1. Residual radioactivity that is distinguishable from background and results in a total effective dose equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem/yr, including that from groundwater sources of drinking water; and

2. Residual radioactivity that has been reduced to as low as reasonably achievable (ALARA) levels.

The NRC's discussion regarding demonstration of compliance with the dose criteria in 10 CFR Part 20, Subpart E, using a screening approach to dose analysis is presented in NUREG-1757, Vol. 2, [Ref. 7.5]. The look-up screening levels were found in Table H.1 of NUREG-1757, Vol. 2. However, a screening value was not available in the look-up tables for Co-57 and its value was selected from NUREG/CR-5512, Vol. 3, [Ref. 7.32] Table 5.19, *Concentration (dpm/100 cm^2) equivalent to 25 mrem/y for the specified value of P_{crit}*. The value for Co-57 was selected at P_{crit} equal to 0.90 which is the same criteria as those from DandD, Version 2.1 and those published in the lookup table. The technique for development of a screening level for uranium is described in Section 2.1.1.

The screening values for unsealed sources identified in Section 1.4.4 are shown in Table 2-1.

Table 2-1 Screening Levels (Unsealed Radioactive Material) for Building Surfaces [a]

ROC	Isotopic DCGL (dpm/100cm^2)
H-3	1.20E+08
C-14	3.70E+06
Na-22	9.54E+03
Cl-36	5.00E+05
Ca-45	2.80E+06
Co-57	2.11E+05
Uranium	96

[a] Removable fractions were expected to average less than 10% of the DCGL.

2.1 Calculation of Screening Level for Uranium

NRC License No. SUB-603 was amended on May 28, 1968 and authorized 50 pounds of natural uranium, 50 pounds of depleted uranium and 5 pounds of thorium. One of its purposes was for Uranyl solution for microscopic slides. In the application dated July 5, 1973, the purpose of the material was for staining histological specimens; analytical chemical procedure and preparation of standards; and preparation of comparison standards for use in monitoring radioactive contamination in food and water. Amendment #3 was issued on July 31, 1973 authorizing 260 kilogram of uranium and 5 kilograms of thorium. On February 7, 1979 this license was terminated by incorporating the material and its uses into license 08-01738-02. At that time, materials to be used were stated as 50 kg natural uranium as uranyl sulfate, uranyl nitrate, uranyl acetate and uranyl zinc acetate; 280 kg depleted uranium in any form and as shielding; and 5 kg thorium as thorium chloranilate, thorium oxide, and thorium nitrate. The renewal application for license 08-01738-02 in 2005 requested removal of thorium as WRAMC had no records of use. Subsequent interviews with prior WRAMC HPO employees indicate no use of thorium; see interviews in Appendix A.

The DCGL for DU was calculated to be 100 dpm/100cm^2. The following methodologies were utilized during the derivation of the DCGL for DU and the process is illustrated in Table 2-2.

- NUREG-1717 lists the isotopes of DU as U-238, U-235, and U-234 with activity abundance of 90.1%, 1.5%, and 8.4%; respectively. [Ref. 7.28]
- The number of alpha and beta particles: U-238 has one alpha and two beta emitters (Th-234 and Pa-234m), U-235 has one alpha and one beta (Th-231), and U-234 has one alpha

and no beta particles. Each of those alpha and beta emitters was assumed to be in secular equilibrium with their uranium parent. [Ref. 7.28]

- The isotopic DCGL is the surface screening criteria referenced from Table 5.19 of NUREG/CR-5512, Vol. 3, for each uranium isotope. [Ref. 7.32]
- Determination of the DU DCGL was made by multiplying the percentage of activity fraction and individual DCGL, the activity-specific DCGL were calculated for each uranium isotope. The activity-specific DCGL for each isotope was summed to determine the DU Building Surface DCGL.

Table 2-2 Determination of Screening Level for Depleted Uranium

Uranium Isotope	Activity Fraction (AF)	Abundance (Alpha Particles/ disintegration)	Isotopic DCGL (dpm/100cm^2)	Activity Specific DCGL for Alpha (dpm/100cm^2)
U-234	0.084	1	90.6	7.6
U-235	0.015	1	97.6	1.5
U-238	0.901	1	101	91.0
DU			Total:	100

Similarly, natural uranium (U-nat) has been separated from its longer half-life decay products by extraction of the uranium from the naturally occurring ore state. So U-nat is composed of uranium-238, uranium-235, and uranium-234 at relative natural activity percentages per NRC NUREG-1717 [Ref. 7.28] of 48.83%, 2.34%, and 48.83%; respectively. The DCGL for U-nat was calculated to be 95.8 dpm/100cm^2. The results from the process are illustrated in Table 2-3.

Table 2-3 Determination of Screening Level for Natural Uranium

Uranium Isotope	Activity Fraction (AF)	Abundance (Alpha Particles/ disintegration)	Isotopic DCGL (dpm/100cm^2)	Activity Specific DCGL for Alpha (dpm/100cm^2)
U-234	0.4883	1	90.6	44.2
U-235	0.0234	1	97.6	2.3
U-238	0.4883	1	101	49.3
U-nat			Total:	95.8

2.2 Look-up Screening Levels for Sealed Sources

The radionuclides in sealed source or calibration standard forms were identified in Section 1.4.5. As stated in Section 1.4.1.2, the HSA and subsequent investigation indicates there were never any accounts of leaking sources. Screening levels for sealed sources were generally more restrictive than those for unsealed sources and were applied as a conservative factor in instrumentation selection and use and also in survey design.

NUREG-1757 describes the screening analysis for building surfaces using one or both of the currently available screening tools:

- a look-up table for common beta- and gamma-emitting radionuclides for building surface residual radioactivity (63 FR 64132, November 18, 1998); and
- screening levels derived using DandD, Version 2.1 [Ref. 7.24], or the most current version for the specific radionuclide(s) that use the code's default parameters.

The screening levels were from the sources listed above except for Ba-133. The screening level for Ba-133 was developed using the default values for RESRAD-Build Version 3.5 [Ref. 7.23]. For an input of 3.79E8 dpm/m^2 (3.79E6 dpm/100cm^2), the resultant dose was 25.0 mrem/year. A copy of the computer results is found in Appendix B.

As no leaking sealed sources were identified, all sealed sources could be dismissed from consideration. However, the screening levels shown in Table 2-4 were applied when they were more restrictive than those from unsealed radioactive material shown in Table 2-1.

Table 2-4 Screening Levels (Sealed Sources) for Building Surfaces

ROC	Screening Level (dpm/100cm^2)
H-3	1.20E+08
C-14	3.70E+06
Cl-36	4.99E+05
Ca-45	2.80E+06
Co-57	2.11E+05
Co-60	7.10E+03
Ni-63	1.80E+06
Zn-65	4.81E+04
Sr-90	8.71E+03
Cd-109	1. 14E+05
Sb-125	4.43E+04
I-129	3.50E+04
Ba-133	3.78E+06
Cs-137	2.80E+04
Eu-152	1.27E+04
Gd-153	2.02E+05
Ra-226	1.12E+03
Pu-239	27.9
Am-241	27

2.3 Look-up Screening Levels for Activation Products

As indicated in Section 1.3.10, the activation products in concrete, if any, would be H-3, Na-22, Mn-54, Co-60, Cs-134, Eu-152, and Eu-154 coming from (n,γ) reactions in trace amounts (a few parts per million or less by weight) of stable nuclides. The screening levels shown in Table 2-5 were obtained from NUREG-1757 or the DandD code. These screening levels are presented for hazard comparison purposes as building surface and measurements should be indistinguishable from background for consideration for release. Screening for volumetric activation was performed with gamma scans and in situ gamma spectroscopy.

Table 2-5 Screening Levels (Activation Products) for Building Surfaces

ROC	Screening Level (dpm/100cm^2)
H-3	1.20E+08
Na-22	9.54E+03
Mn-54	3.15E+04
Co-60	7.10E+03
Cs-134	1.27E+04
Eu-152	1.27E+04
Eu-154	1.15E+04

2.4 Transferable (Removable) Radioactivity Fractions

As the primary ROC target for removable contamination ROC was H-3, wet smears were collected for gross alpha and gross beta removable activity as wetted smears collect H-3 better than dry. These smears were analyzed via liquid scintillation processes. The results of these smears was compared to fixed measurement results to determine the fraction of transferable radioactivity which was not to exceed an average of 10% of the respective screening guideline level (more discussion on this topic is found in Section 4.2). ISO-7503 also suggests repetitive testing at the same location to derive a total removable fraction; this process was impractical with the very low activity anticipated in both WRAMC Class 2 and Class 3 survey units. See Section 4.2 regarding tests for removable fractions for low and high energy beta emissions.

3.0 SURVEY DESIGN AND METHODOLOGY

Field activities at the Site were performed by the TIDEWATER team on November 7 through December 30, 2011 and February 3, 2012. The field activities included radiological characterization surveys. The characterization survey efforts consisted of static (fixed) and smear (removable) radiological contamination surveys. Additionally, floor and wall scanning occurred, and exposure rate surveys were conducted.

3.1 Data Quality Objectives

Data Quality Objectives (DQOs) are qualitative and quantitative statements that establish a systematic procedure for defining the criteria by which data collection design was satisfied in order to make determinations regarding impacted properties. The DQOs for this survey include:

- Identifying the project problem;
- Defining the data necessary for achieving the end use decisions;
- Determining the appropriate method of data collection; and
- Specifying the level of decision errors acceptable for establishing the quantity and quality of data needed to support the project decisions.

3.1.1 Step 1 – State the Problem

3.1.1.1 Problem Description -Human use applications and research in existing and former hospital facilities at WRAMC, Main Post involved a significant listing and quantities of radioactive material. The problem was the potential presence of residual radioactive contamination in the impacted buildings. The question was "Do the concentrations of the radionuclide contaminants of potential concern (ROC) in the building exceed applicable levels for unrestricted release?"

3.1.1.2 Planning Team Members-Planning team members included BRAC-WRAMC, WRAMC-HPO, USACE-Baltimore, and TIDEWATER.

3.1.1.3 Primary Decision Maker-The ultimate decision regarding facility disposition will rest with the NRC.

3.1.1.4 Conceptual Site Model-The HSA presented critical elements of the conceptual site model for the facility. The ROCs were incorporated into a model which served as the basis for subsequent inputs and decisions.

3.1.1.5 Available Resources -The survey team had sufficient resources to perform and complete work required to achieve characterization objectives. Notwithstanding the full use of personnel identified in Section 2, the survey team had access to subcontractors that were available to

provide equipment and personnel required to conduct the surveying and sampling activities identified.

3.1.2 Step 2 – Identify the Decision

3.1.2.1 Principal Study Question-Are there any areas or materials with ROC residual concentrations in the facility which exceed background levels by more than the release criteria (NRC Surface Screening Levels)?

3.1.2.2 Decision Statement-The null hypothesis was that the residual radioactivity in the survey unit exceeded the NRC Screening Levels. The nature and extent of ROC concentrations in the facility was to be determined as to how much they exceeded background concentrations.

Impacted areas were classified based on contamination potential as per guidance in MARSSIM Sections 2.2, 4.4, 5.5.2, and 5.5.3.

- Class 1: Areas that have a potential for radioactive contamination (based on site operating history) or known contamination. The area may have been contaminated above the release criteria, and it is possible to find radioactivity above the release criteria;
- Class 2: The area had radioactive material use, but it is unlikely to have radioactivity above the release criteria;
- Class 3: The area had some use of radioactive material, but it is very unlikely to have radioactivity above a small fraction of the release criteria.

The Survey Unit Classifications given in Section 3.3 were based on MARSSIM guidance on classifying areas per the potential level of residual radioactive material contamination relative to the established release criteria. Material contained in the HSA was used to determine the Classification of the areas at WRAMC, Main Post.

3.1.3 Step 3 – Identify Inputs to the Decision

In order to resolve the decision statements listed in the previous section, a variety of data was required. This section lists data needs, describes the sources of that data, and discusses the means of obtaining the required data. Concentrations of residual radioactive material in the survey units were determined by means of:

- Direct and scan surface radioactivity measurements
- Removable radioactivity measurements (gross beta and alpha - liquid scintillation counter (LSC) results)
- Exposure rate surveys
- In-situ gamma identification

3.1.4 Step 4 – Define the Study Boundaries

As recommended in MARSSIM, the spatial and temporal extent of the subject facility must be defined. The following defines the characterization study boundaries.

3.1.4.1 Population of Interest Defining Characteristics-The population of interest was the concentration of ROCs on building material/surfaces and in building systems in the impacted buildings. This population were subdivided and examined by floors/rooms into survey units.

3.1.4.2 Spatial Boundaries of the Decision Statement-Based on the HSA and subsequent interviews with prior employees, as well as a physical inspection of the facility, surrounding areas and structures, the physical boundaries were (1) the interior surfaces of the eight buildings (1, 2, 7, 38, Waste Bunkers, 41, 54, 91, and 92), (2) potential roof discharge areas, (3) exterior roadway adjacent to the waste bunkers, and (4) the mechanical system components in the RAM use areas.

3.1.4.3 Temporal Boundaries of the Decision Statement

- Time frame to which the decision applies:
  The lower temporal bound for this investigation was 1957, when radioactive materials were used pursuant to an Atomic Energy Commission license. The upper temporal bound was December 2011 following termination of facility operations and all known licensed material was removed.
- Time frame for data collection:
  Data collection and analyses were performed to meet project schedules, goals, and objectives and completed on February 3, 2012.

3.1.4.4 Scale of Decision Making-Decisions were made for areas or materials that may exhibit elevated levels of radioactivity. Decisions were made on a survey unit basis.

3.1.4.5 Constraints on Data Collection-

- Constraints on data collection included renovations made based on prior surveys for which records may or may not exist. Decisions were made in the field as to whether or not a surface was present during RAM operations. If surfaces were found to have been covered, it was removed in sufficient quantity and area to survey original surfaces. Specifically, decisions were made regarding new or replaced tile versus covered; in which case, certain tiles was removed to get to the original surface. The same approach was made regarding new wall construction and replacement versus covering over the old wall. Assessments were needed at locations as to the necessity of removing carpet to perform measurements on the old laboratory floor.

- Constraints on data collection included the continued occupancy and use of the various hospital and laboratory spaces during execution of the characterization surveys, i.e., the bunker radioactive waste storage areas and the Health Physics Office. In cases where access was denied, disposition was delayed until the areas were abandoned.
- Constraints on data collection included inaccessible areas, such as pipe runs between drains and cleanout traps. In these instances, decisions were made based on data collected from the areas where radioactive material may have entered the system.

3.1.5 Step 5 – Develop the Decision Rules

3.1.5.1 Surface Radioactivity Scan Surveys

If areas of elevated radioactivity were identified during scan surveys, identified areas were further characterized. Smear samples were also collected and analyzed. An in-situ gamma isotopic analysis was made if gamma emitters were suspect, e.g., the LINAC room.

3.1.5.2 Residual Radioactivity

If residual radioactivity was found and multiple radionuclides were involved, the unity rule, also called the "sum of fractions" rule, was used to ensure that the total dose is within the decommissioning guidance of 25 mrem/y. Within a survey unit, radiological conditions were evaluated using the sum of fractions which must not exceed "1" (i.e., "unity"). The concentrations were limited as follows:

$$\frac{C_1}{DCGL_1} + \frac{C_2}{DCGL_2} + \frac{C_3}{DCGL_3} + \ldots \leq 1$$

Where: $C_{1,2,3..}$ = Concentration of Radionuclides
$DCGL_{1,2,3..}$ = DCGL for that Radionuclide

- **MARSSIM Required Locations (Random or Systematic)**

The use of radionuclides in each survey unit was established to determine the most restrictive DCGL (surrogate) for alpha and beta emitting radionuclides.

For compliance testing, there were three direct measurements collected at each survey point: one for low energy (hard-to-detect) betas with the Ludlum 44-110 windowless gas flow proportional detector and two with the Ludlum 43-68 detector for higher beta energies and alphas.

Net results of the direct measurements were compared to the most restrictive DCGLs for the survey unit for each data point evaluation. These comparisons or fractions were summed and the Sum of Ratios (SOR) determined from the following equation:

$$SOR = \frac{Gross\ Low\ Energy\ Beta_{44-110}}{DCGL_{Most\ Restrictive(H-3,Ni-63\ or\ Cd-109)}} + \frac{Gross\ Beta_{43-68}}{DCGL_{\ Beta\ Most\ Restrictive}} + \frac{Gross\ Alpha_{43-68}}{DCGL_{Alpha\ Most\ Restrictive}}$$

It should be noted that any stated "Low Energy Beta Residual Activity" was conservatively assumed to be entirely due to low energy betas but a portion (or even all) of the gross residual count rate was attributable to other radionuclides of concern. However, for the sake of evaluating potential contamination, this assumption was deemed appropriate.

Two smears wetted with distilled water were collected in each survey unit as a performance check of the direct measurement technique. The two smears were collected at non-adjacent locations.

For verification that removable activity was less than 10% of total activity, smear results for gross beta and gross alpha activity, which include removable activity from all ROCs, were compared to the integrated direct results for gross beta and alpha.

- **Bias Locations**

When the 43-68 and the 44-110 detectors were used, compliance testing was the same as that for the routine MARSSIM required locations.

There were locations such as drains and air exhaust vents where the detectors were too large to fit or the surface was inaccessible (e.g., curved or not flat or a proper seal cannot be made). In these situations, a wet smear were collected for LSC results comparison to the most restrictive DCGL of all radionuclides formerly used in the survey unit. To assure a graded approach and good use of resources, bias smears were performed in drains and air exhaust vents in known impacted rooms shown in Table 1-3. Several survey unit areas were developed based upon professional judgment and a potential lack of historical data; professional judgment was used in determining where to obtain smear samples in those survey units. These comparisons or fractions were summed and the Sum of Ratios (SOR) determined:

$$SOR = \frac{Gross\ Beta_{wet\ smear}}{10\%DCGL_{Beta\ Most\ Restrictive}} + \frac{Gross\ Alpha_{wet\ smear}}{10\%\ DCGL_{Alpha\ Most\ Restrictive}}$$

In this determination, results of wet smears need to be approximately equal or larger than dry smears results to be meaningful. The SOR becomes a three fraction formula; one for the net difference for lower energy beta, one for higher energy beta, and one for the higher of the gross alphas (either wet or dry).

$$SOR = \frac{Gross\ Beta_{Net\ (wet-dry)}}{10\%DCGL_{\substack{Low\ Energy \\ Most\ Restrictive}}} + \frac{Gross\ Beta_{dry}}{10\%DCGL_{\substack{High\ Energy \\ Most\ Restrictive}}} + \frac{Gross\ Alpha_{wet\ or\ dry}}{DCGL_{Alpha\ Most\ Restrictive}}$$

3.1.6 Step 6 – Specify Limits on Decision Errors

Appendix D in MARSSIM provides a discussion regarding decision errors. This discussion includes the concept that acceptable error rates must be balanced between the need to make appropriate decisions and the financial costs of achieving high degrees of certainty.

Errors can be made when making site remediation decisions. The use of statistical methods allows for controlling the probability of making decision errors. When designing a statistical test, acceptable error rates for incorrectly determining that a site meets or does not meet the applicable decommissioning criteria must be specified. In determining these error rates, consideration was given to the number of sample data points that are necessary to achieve them. Lower error rates require more measurements, but result in statistical tests of greater power and higher levels of confidence in the decisions. In setting error rates, it was important to balance the consequences of making a decision error against the cost of achieving greater certainty.

Acceptability decisions are often made based on acceptance criteria. If the mean and median concentrations of a contaminant are less than the associated acceptance criteria, for example, the results can usually be accepted; this was the case for this survey. In cases where data results are not so clear, statistically based decisions are necessary and this FSS was established to make such decisions. Statistical acceptability decisions, however, are always subject to error. Two possible error types are associated with such decisions.

The first type of decision error, called a Type I error, occurs when the null hypothesis is rejected when it is actually true. The probability of a Type I error is usually denoted by alpha (α). The maximum Type I error rate is 0.05.

The second type of decision error, called a Type II error, occurs when the null hypothesis is not rejected when it is actually false. The probability of a Type II error is usually denoted by beta (β). The power of a statistical test is defined as the probability of rejecting the null hypothesis when it is false. It is numerically equal to 1-β where β is the Type II error rate. Potential consequences of Type II errors include unnecessary remediation expense and project delays.

For the purposes of this survey, the acceptable error rate for both Type I and Type II errors was five percent (i.e., $\alpha = \beta = 0.05$).

3.1.7 Step 7 – Optimize the Design for Obtaining Data

To the extent practical, the design for collecting data was optimized to achieve the stated DQOs. The scope of work and data collection process has been designed to provide near real-time data during implementation of field activities. These data were used to modify and expand the scope of field activities, as needed, to ensure the DQOs were met. The following sequence of events was specifically related to optimization of data collection for this project.

- Gamma scoping/scanning survey
- Gross alpha and beta scans
- In-situ gamma analysis, as required
- Direct measurements
- Smear collection

3.2 Survey Design

A final status survey is performed to demonstrate that residual radioactivity in each survey unit satisfies the predetermined criteria for release for unrestricted use. The survey provides data to demonstrate that all radiological parameters do not exceed the established DCGLs. For the final status survey, survey units represent the fundamental elements for compliance demonstration using the statistical tests. As with any site operating for 100 years, there is always the potential, however small, for missing historical accounts of RAM use and scoping surveys were performed in areas nearby known impacted areas to provide a safety basis for the survey technicians and also a reasonable assurance that no areas were overlooked. As MARSSIM's Figure 2-4 leads any survey (even those considered as scoping) into at least a Class 3, these nearby areas were incorporated into established survey units or made into additional survey units. More details are provided below but the extent of the Class 3 scoping surveys were based upon professional judgment.

The design of this radiological characterization survey incorporates the methods and locations for the performance of direct radioactivity scan surveys and integrated direct radioactivity measurements in order to assess the nature and extent of ROCs. Due to a very low energy beta emission, tritium, Ni-63, and Cd-109 were problematic in that they cannot be scanned for. Carbon-14 was also problematic in that the emitted beta is also of low energy and the detection efficiency is low. To make up for scanning weaknesses of these radionuclides, the sample density per survey unit were much higher than that required by MARSSIM. [The area of individual survey units was considerably less than MARSSIM recommendations and with the same number of required measurements in each, the sample density increases.] As most surveys

units were Class 3 with no limit on area, professional judgment was applied to assure a sufficient sample density.

In accordance with MARSSIM, the null hypothesis (H_o) tested for this plan is that residual contamination exceeds the release criteria. The alternative hypothesis (H_a) is that residual contamination meets the release criteria. The statistical tests used attempt to reject the null hypothesis.

The radionuclide contaminants of concern vary from building to building. Section 1 provides a listing of ROCs with their respective building or storage area. The release limits are presented in Section 2 and these were the DCGLs that were tested in the hypothesis testing. The suite of radionuclides with the most restrictive DCGLs is summarized in Table 3.2 and was determined from the specific WRAMC use authorizations which were documented in the HSA and subsequent review of records or receipt and inventories. Noting that the hospital was established over 100 years ago and that recorded history cannot be 100% complete, prudence indicated a need to survey certain buffer zone areas beyond those described in the HSA: (1) buffer zones near MARSSIM Class 2 areas, and (2) possible areas not described but associated near RAM areas. For example:

- The rooms and area of investigation of Building 54 was expanded from those identified in the HSA as radioactive material use was widespread dating perhaps from 1953. As were shown in the survey unit diagrams, the specific rooms on a floor designated in Table 3-2 below were grouped into contiguous survey units and the remaining floor areas were surveyed as a separate survey unit.
- In Building 92, the former Nuclear Medicine Clinic, the adjacent hallway to the impacted rooms was included as an area to be surveyed. This building also has a small storage closet (approximately dimensions were 4 feet by 5 feet by 5 feet) for historical storage of radioactive materials that extends from the building. The drywall was removed to gain entrance to the closet.
- Table 3-1 provides a breakdown of the type and number of survey units by floor.

Table 3-1 Class and Number of Survey Units by Floor

Building	Floor	Number of Survey Units		
		Class 1	Class 2	Class 3
1	Basement			1
2	1	1[a]		2
	2			3
	4			2
	5			1
	6			1
	7		2	3
7	Basement			6
	1			1
	2			4
38	All			1
Bunkers	Ground		2	1
41	Ground		2	1
54	Basement			3
	Museum			2
	Ground			3
	1			3
	2	1[b]		3
	3			6
	4			4
	5			3
91	1			2
	2			1
92	Ground	1[c]		3

[a] LINAC room 1H33 was a Class 1 due to the higher MeV energy use.
[b] Room 2094 identified with residual alpha contamination during characterization.
[c] The small storage closet with the Lazy Susan; walled up for >20 years.

Integrated direct measurements for the hard-to-detect radionuclides were surveyed with the Ludlum-44-110 detector while the other readily detectable beta and alpha emissions were surveyed with the Ludlum 43-68 detector. Table 3-2 shows the applicable ROC with the

respective buildings and areas. Characteristics of selected instrumentation are provided in Section 4 but the integrated count times, MDCs, and fraction of DCGL achieved with the stated count times are provided in Table 3-3; alpha detection MDCs appear as the most critical and require longer count times.

- All H-3 count times in all impacted areas for static measurements were 0.5 min. An evaluation of detection of the very low energy levels such as that from H-3 and Ni-63 is presented in Appendix B.
- Radium-226 has the most restrictive alpha DCGL in Buildings 1, 2, 38, the waste bunkers, and 92. The associated count time was two minutes.
- Uranium has the most restrictive alpha DCGL in Buildings 7, 54, 91, and Room 39 of Building 41. The associated count time was four minutes.
- Americium-241 has the most restrictive alpha DCGL in Room 42 and the associated hallway of Building 41. The associated count time per measurement was thirty minutes.

The survey plan consisted of systematic processes and procedures that have been deemed acceptable by industry practices and the NRC. MARSSIM methodology and its graded approach were afforded particular attention. Activities (organized units of work needed to complete a function) have been defined and tasks (specific work assignments within a specific activity) have been delegated to the appropriate team members. Appendix C provides drawings showing each of the survey units. Table 3-3 provides a breakdown of activities and tasks.

Table 3-2 Restrictive ROCs Per Building and Area By Type

Building	Areas	Hard-To-Detect	Beta	Alpha
1	All	H-3	Cs-137	Ra-226
2	Routine Use	Co-57	Co-60	Ra-226
	Waste	Ni-63	Co-60	Ra-226
	LINAC	H-3	Cs-134	Ra-226
7	Routine Use	Ni-63	Eu-152	Uranium
	Electron Microscope	Ni-63	Eu-152	Uranium
38	All	H-3	Co-60	Ra-226
Bunkers	All	H-3	Co-60	Ra-226
41	Room 39	Ni-63	Co-60	Am-241
	Room 42	Cd-109	Co-60	Uranium
54	Routine Use	Ni-63	Co-60	Uranium
	Firing Range	Ni-63	Co-60	DU
91	All	H-3	C-14	Uranium
92	All	Ni-63	Co-60	Ra-226

3.2.1 Determining the Number of Survey Points

Determining the number of samples required per survey unit is a MARSSIM graded approach. The following technique was used to determine the number of samples required.

Permitted by NUREG-1557, Vol. 2, A.3.3, the Sign test was selected for determining the number of measurement locations per survey unit. Measured backgrounds for different materials were applied and the Sign test was to be applied on the difference between the paired measurements from the survey unit and from the appropriate reference material. Chapter 2 of NUREG-1505 [Ref. 7.33] is quoted: "When a specific background can be established for individual samples, the results of the survey unit measurements can be compared directly to the DCGL, since each is a measurement of the residual radioactivity alone." For building and structure surfaces, the Sign test were applied after a material specific background was subtracted from each measurement taken in a survey unit.

Section 5.5.2.2 of MARSSIM describes the process for determining the number of survey measurements necessary to ensure a data set sufficient for statistical analysis. The method for determining the combined number of data points (N) for the survey unit and reference area was based on the expected contaminant variability and the predetermined acceptable Type I and Type II error rates. The project data quality objectives (DQO) established the Type I and Type II error rates (α and β respectively) at 0.05.

The "relative shift" (Δ/σ) is the ratio involving the concentration to be measured (Δ) relative to the expected variability in that concentration sigma (σ), and can be thought of as an expression of the resolution of the measurements. The sigma (σ) is selected from the larger of that found in the survey unit or the reference area. The shift (Δ) is the width of the statistical gray region or difference in the release criterion and the lower bound of the gray region (LBGR). The gray region is the area where the impact of making an incorrect error decision (Type I or Type II error) is small. The Lower Bound of the Gray Region (LBGR) represents average concentrations that one expects to find.

From the review of records of licensing, inventory, operations, and radiological safety at WRAMC, Main Post, it was evident that any significant contamination identified through routine operational radiological safety surveys was decontaminated at that time. Common good laboratory practices were used to remove and dispose of contamination as it was generated or discovered.

As indicated, the WRAMC decontamination requirements [Ref. 7.34] show that by 1974, restricted areas required decontamination below 1000 dpm/100cm^2 for beta emitters and,

although permitted, there was no tolerance for alpha. For this analysis as no measurements had been taken, an assumption was made that 10 dpm as alpha would be unacceptable to WRAMC; this number was reviewed during actual measurements. The unrestricted areas required even more decontamination but these areas cannot be readily discerned from historical documents.

The standard deviations in the contaminant level were not available from previous survey data. As they were not available, MARSSIM suggests to 1) perform some limited preliminary measurements (about 5 to 20) to estimate the distributions, or 2) to make a reasonable estimate based on available site knowledge. Both approaches described were used and certain preliminary measurements were used to estimate the standard deviation.

For beta emitters, the LBGR for Class 2 areas was selected as the WRAMC restricted area contamination limit for betas of 1000 dpm/100cm^2. For Class 3 areas, the LBGR was assumed to be 20% of the WRAMC restricted area contamination limit of 1000 dpm/100cm^2 or DCGL; any larger values would imply Class 2. For the single Class 1 area, the LBGR were established at time of survey. Reasonable estimates of sigma were initially set as 80% of the LBGRs described.

Based on prior experiences, a reasonable estimate of sigma for alpha emitters in Class 2 and Class 3 areas was selected initially at 80% of WRAMC's permissible contamination levels.

The value for sigma for both alpha and beta were confirmed by review of the MARSSIM suggested minimum 5 measurements in each of the survey units. The following formula is provided by MARSSIM to determine the relative shift.

$$\frac{\Delta}{\sigma} = \frac{DCGL - LBGR}{\sigma}$$

Table 3-4 shows the initial calculated results for Δ/σ for this project. Regardless, the required number of samples were adjusted accordingly per any detected change in the relative shift.

The relative shift values are very large and exceed those listed in MARSSIM Table 5.3. As suggested by MARSSIM, when Δ/σ >3, the Sign P =1. For this survey at α=β=0.05, the number of data points, N, to be obtained for the Sign test was next calculated using the following formula:

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(Sign\ p - 0.5)^2}$$

Where the decision error percentiles, $Z_{1-\alpha}$ and $Z_{1-\beta}$, represented by the selected error levels, α and β, respectively from MARSSIM Table 5.2. As Δ/σ was greater than 3, the *Sign p* was set equal to 1.

$$N = \frac{(1.645 + 1.645)^2}{4(1 - 0.5)^2}$$

And the number of anticipated points was increased by 20% to ensure sufficient power of the tests and to allow for possible data losses at 13. With reasonable estimates of LBGR and Δ/σ, the maximum number of points will not increase as long as Δ/σ remains greater than 3 which was clearly the case for both beta and alpha emitters prior to scoping exercises; see Table 3-3.

Table 3-3 Sampling Statistics

ROC	ROC	DCGLs for Building Surfaces (dpm/100 cm^2)	Class 2 Survey Units			Class 3 Survey Units		
			LBGR (dpm/100cm^2)	σ	Δ/σ	LBGR (dpm/100cm^2)	σ	Δ/σ
Most Restrictive Beta Emitter	Co-60	7.10E+03	1000	800	8	200	60	115
Restrictive Alpha Emitters [a]	Ra-226	1,120	10	8	139	10	8	139
	DU	100	10	8	11	10	8	11
	U Nat	95.8	10	8	11	10	8	11
	Am-241	27	10	8	2	Not Applicable		

[a] The ROCs listed are not the same in each survey unit, e.g., Am-241 was only authorized in one survey unit.

3.2.2 Reference Area and Reference Materials

Measurements were made on the various reference materials for quantifying radioactivity in "background," non-impacted conditions. Attempts were made to establish the background reference materials with similar physical, chemical, and radiological characteristics to the impacted area being surveyed, but which were not contaminated by site activities [Ref. 7.4]. The distribution of measurements for reference material were similar to the distribution of measurements in the survey units. Locations of the reference material were chosen on-site based on field observations and professional judgment.

Ten background measurements were performed and recorded for each survey instrument to establish "background radioactivity" for each different type of surface material being surveyed (e.g., concrete, floor tile, wood, etc.) and for each separate survey area (i.e., as general background radioactivity changes from area to area).

The following sets of measurements were performed within the reference area to establish the necessary comparison criteria for decision rule implementation:

- Direct alpha radioactivity scan surveys performed within buildings/indoor areas
- Direct beta radioactivity scan surveys performed within buildings/indoor areas
- Integrated direct surface alpha radioactivity measurements to be performed within indoor areas
- Integrated direct surface beta radioactivity measurements performed within indoor areas
- General area dose rate measurements in each area

3.2.3 Determination of Survey Point Locations

Before the surveys were conducted within a survey unit, a fixed reproducible starting point was selected, such as the southwestern corner of the survey unit at ground level. The survey unit points were based on an X-Y reference-coordinate system that is provided with the work maps. Equipment such as tape and laser measurers were used in the measurement of the survey units for the survey. SAE units (feet and inches) were used for measuring the survey units. Visual aids such as paint and/or removable tape can be used to mark survey point locations within the survey unit, other methods can be used when applicable.

Lower walls up to 2 meters above the floor were surveyed as part of a survey unit.

For Class 2 survey units, the location of starting grid node within each survey unit was determined using a random number generator to generate an X and Y coordinate in meters from a reference point (0, 0). Locations of the remaining survey points were gridded from that location. The initial grid nodes are located on the survey maps. The maps show the random start survey points on a square grid with their (X, Y) coordinates for the Class 2 survey units. The distance between each survey point "L" were indicated on the Class 2 survey unit drawings and was different for each survey unit.

All locations of Class 3 survey points were a random selection via a random number generator to generate an X and Y coordinate in meters from a reference point (0, 0). A working map with coordinates for all required locations was available prior to the start of a survey unit.

The (0, 0) point was generally taken as the left corner of the entrance to the survey unit or survey area at ground level. The referenced points are clearly identified on each survey unit map. For an X or Y coordinate to be valid, it must fall on the survey map within the survey unit.

Reference material measurements were randomly selected and recorded in a similar fashion to measurements taken in the survey units. Reference area material measurements were taken in

non-impacted buildings or areas of similar construction and age, if possible. The number of reference material measurements was at least ten for each material of group of materials.

3.2.4 Selection of Area Size for Survey Units

Suggested survey unit sizes from MARSSIM are given in Table 3-4. These areas were suggested in MARSSIM because they give a reasonable sampling density and they are consistent with most commonly used dose modeling codes. The limitation on survey unit size for Class 2 areas ensures that each area was assigned an adequate number of data points. To facilitate survey design and ensure that the number of survey data points was relatively uniformly distributed among areas of similar contamination potential, the buildings were divided into survey units that share a common history or other characteristics, or were naturally distinguishable from other portions of the building. However, the size and shape of a particular survey unit was adjusted to conform to the existing features of the floor area. MARSSIM suggests that a survey unit have a minimum floor area of 10 m^2 (108 ft^2) so smaller rooms were combined with similar nearby areas. Areas and rooms in close proximity were combined to form survey units while maintaining MARSSIM suggested area limits. The largest permissible Class 2 survey unit can be approximated by a square 100 feet long on each edge. MARSSIM does not place an area size limit on Class 3 survey units but for this survey they were limited to areas no larger than a single floor. Class 3 areas represent the greater majority of this work effort, see Table 1-2.

Table 3-4 MARSSIM Suggested Area Limits for Survey Units

Class	Structures (Floor Area)
1	Up to 100 m^2 (1,076 ft^2)
2	100 to 1000 m^2 (1,076 to 10,763 ft^2)
3	No limit

3.2.5 Surface Scan Requirements

Scanning was used to identify locations within the survey unit that exceed the investigational level. These locations were marked and receive additional investigations to determine the concentration, area, and extent of the contamination.

The required area covered by scan measurement was based on the survey unit classification as derived from MARSSIM Table 5.9. For the Class 1 Survey Units, a 100% scan was required of the floor and lower walls. For Class 2 Survey Units, a scan area from 10% to 100% of the accessible area was required. For Class 3 Survey Units, scanning were performed on likely areas of contamination based on the likelihood of contamination and the judgment of the radiation

survey staff; there was no set percentage. Class 2 area scans were both systematic and judgmental while Class 3 area scans were judgmental only.

Each survey unit was subjected to a surface scan using appropriate survey instruments. Scanning for H-3 was not technically feasible with available technology and very low yields for the low energy beta emitters such as C-14.

For each survey unit, all integrated measurements were data logged.

For both Class 2 and 3 survey units, judgmental scans were performed in areas of highest potential (*e.g.*, corners, seams between concrete pours, or base of support poles) based on professional judgment. This provided a qualitative level of confidence that no areas of elevated activity were missed by the random measurements and that there were no errors made in area classification.

Sensitivity for scanning techniques used in Class 2 and 3 areas was not tied to the area between measurement locations, as they are in a Class 1 area. The scanning techniques selected represent the best reasonable effort based on the survey objectives.

The surface scans described above were for alpha and beta contamination. The LINAC room was the only Class 1 survey unit scheduled to receive a 100% gamma scan due to potential volumetric gamma emitters.

A comparison of DCGLs and MDCs is presented in Section 4.1.

3.2.6 Interpretation of Results

Data of a specific quality and quantity were needed to test the null hypothesis. The sampling plan was designed to provide these data.

3.2.6.1 Basic Statistics and Range

Following a determination of SOR, basic statistical quantities were calculated first from the data set, these include:

- Maximum
- Minimum
- Mean
- Standard deviation
- Number of samples

If all results were less than the $DCGL_w$ SOR of 1, then no additional statistical testing is required.

3.2.6.2 Data Reduction and Review

The data reduction and review process ensures that all procedures pertaining to sample preparation and handling, proper identification of analysis output (charts, graphs, etc), correctness and completeness of all data, adherence to documented procedures, documentation of abnormalities and the proper format has been used to report all data. The processing of data, either by manual computation, input of data for computer processing or by direct computer output, were performed. All documentation required for data processing was provided. Data were reported in hard copy and was electronically provided on a compact disc format. Information for an FSS survey unit included in the data package provides sufficient detail to substantiate conclusions.

3.2.6.3 Reporting Activity and Confidence Intervals

The term "measurement uncertainty" is used interchangeably with the term standard deviation. The uncertainty is qualified as numerically identical to the standard deviation associated with a normally distributed range of values. When reporting a confidence interval for a value, the range of values that represent a pre-determined level of confidence (*i. e.*, 95%) was made. To make this calculation, the final standard deviation, or total uncertainty σ_u as shown in MARSSIM Equation 6-16, was multiplied by a constant factor k representing the area under a normal curve as a function of the standard deviation. The values of k selected for this report was 1.96 representing a 95% confidence level.

The basic formula for calculating the dpm per 100 cm^2 is presented here:

$$\frac{dpm}{100cm^2} = \frac{\frac{C_s}{t_s} - \frac{C_B}{t_b}}{(\varepsilon_s)(\varepsilon_i)\left(\frac{a}{100}\right)}$$

where: C_s = Integrated counts recorded by the instrument

C_b = Background counts recorded by the instrument

t_S = Sample counting time

t_B = Background counting time

ε_i = Intrinsic instrument efficiency

ε_s = Surface efficiency

Total efficiency is the product of ε_i and ε_s.

Note that the numerator has an uncertainty associated with the count rates and the denominator has two efficiency terms and each of them has an uncertainty also. The standard deviation of the count rate was determined by MARSSIM equation 6-15; the uncertainty of the source efficiency is stated in Table 5.5 of NUREG-1507 as +/- 0.054 at the 95% CL; and the uncertainty of the calibration sources are presented above. The percentage uncertainty related to the instrument efficiency was assumed to be equal to the uncertainty percentage values reported for the calibration sources. The total efficiency uncertainty was determined through propagation of the uncertainties related to ε_s and ε_i. The uncertainty of the measurement was then determined through propagation of the uncertainties related to ε_{total} and the uncertainty of the count rate. Handling only two at a time of the various uncertainties permitted the use of the uncertainty propagation techniques described in paragraph 6.8.3 of MARSSIM.

The equation used for calculating the standard deviation of a net count rate over a time t with consideration given to background is found as MARSSIM formula (6-15):

$$s_r = \sqrt{\frac{R_c}{t_s} + \frac{R_B}{t_B}}$$

Where:

R_c = Sample count rate (cpm)

R_B = Background count rate (cpm)

For this work, t_B is the total number of one minute counts used to establish the background count rate was 10. This value is used for reference area counts for static/scan measurements and a laboratory blank is used for smears.

The MARSSIM equation for error propagation for division or multiplication was used to calculate total uncertainty:

$$\sigma_u = u * \sqrt{\left(\frac{\sigma_x}{x}\right)^2 + \left(\frac{\sigma_y}{y}\right)^2}$$

where u = x / y or x * y

The following example of a typical determination of the measurement result for a smear and its related uncertainty at the 95% confidence level is provided. The following are given:

- C_s = 60 cpm
- R_B = 55.6 cpm
- t_S = 1 min
- t_B = 20 min
- ε_i = 0.552 cpm/dpm
- ε_s = 0.25 cpm/dpm
- a = 100 cm^2

1) The total number of disintegrations is:

$$\frac{dpm}{100cm^2} = \frac{\frac{C_s}{t_s} - \frac{C_b}{t_b}}{(\varepsilon_s)(\varepsilon_i)\left(\frac{a}{100}\right)}$$

$$\frac{dpm}{100cm^2} = \frac{\frac{60cpm}{1\min} - \frac{55.6cpm}{20\min}}{(0.25cpm/dpm)(0.552cpm/dpm)\left(\frac{100cm^2}{100}\right)}$$

$$\frac{dpm}{100cm^2} = \frac{60 - 2.78}{0.138 * \frac{100cm^2}{100}} = 415\ dpm/100\ cm^2$$

2) The equation used for calculating the standard deviation of a count rate over a time *t* with consideration given to background is MARSSIM formula (6-15) modified here considering that the background sigma was determined for a sequence of background counts:

$$s_r = \sqrt{\frac{R_c}{t_c} + \sigma_B^2}$$

$$s_r = \sqrt{\frac{60\ cpm}{1\min} + (2.78\ cpm)^2}$$

$$s_r = 8.2\ cpm$$

3) The uncertainty for the instrument efficiency was estimated at one standard deviation for the set of 20 measurements of the check source and corresponding 20 measurements of the instrument background using the following approach.

$$\varepsilon_{total} = \frac{Average\ Count\ Rate - Average\ Background\ Rate}{4\pi\ Emission\ Rate}$$

The standard deviation of the instrument total efficiency was about 0.013 cpm/dpm.

4) The total uncertainty in the measurement activity related to the efficiencies and the net count rate was determined using MARSSIM's equation for error propagation for division:

$$\sigma_u = \frac{C_{net}}{\varepsilon_{total}} * \sqrt{\left(\frac{\sigma_{eff}}{\varepsilon_{total}}\right)^2 + \left(\frac{\sigma_r}{C_{net}}\right)^2}$$

Where $C_{net} = \frac{60cpm}{1\min} - \frac{55.6cpm}{20\min} = 57.2$ cpm

$$\sigma_u = \frac{57.2}{(0.25*0.552)} * \sqrt{\left(\frac{0.013}{0.138}\right)^2 + \left(\frac{8.2}{57.2}\right)^2}\ \text{dpm}$$

$$\sigma_u = 414 * \sqrt{(0.0942)^2 + (0.1434)^2} = 414 * \sqrt{0.0294}$$

$$\sigma_u = 71 \text{ dpm}$$

5) The activity is 415 dpm/100 cm^2 and the total uncertainty for this one sigma formula were about 71 dpm/100 cm^2. (Note that the count time was considered to have trivial variance and was assumed to be a constant.)

Referring to MARSSIM Table 6.9, a k value of +/-1.96 represents a confidence interval equal to 95% about the mean of a normal distribution. Therefore, the 95% confidence interval would be 1.96 x 71 dpm/100 cm^2 = 139 dpm/100 cm^2. The final result is 415 +/- 139 dpm/100 cm^2. These values were presented for each measurement in the results with any adjustment required for the physical size of the detector. Similar equations and techniques were used for static and scanning measurements.

3.2.7 Action Levels

Decisions on whether to perform additional investigations were made during performance of onsite field work based on the evaluation of scan data, direct measurement data, and smear data. For Class 3 survey units the fraction is not defined by MARSSIM but for this survey it was considered as 20% of DCGL which is an industry standard published by Oak Ridge Associated Universities (ORAU) [Ref. 7.35]. Table 3-5 lists the action levels (AL) and was derived from MARSSIM Table 5.8.

Table 3-5 Project Action Levels[a]

Survey Unit Classification	Flag Direct Measurement or Sample Result When:	Flag Scanning Measurement Result When:
Class 1	>DCGL	>DCGL or >MDCR[b]
Class 2	> DCGL	>DCGL or >MDCR
Class 3	> fraction (20%) of DCGL	> 20% DCGL or >MDCR

[a]ALs were for residual radioactivity greater than background. ALs for smears were 10% of any direct measurement DCGL.

[b]The use of NRC Screening Levels as DCGLs prohibit the use of the EMC in Class 1 area which is normally a flag value. Area factors were not developed and were not necessary for this survey.

4.0 SAMPLING APPARATUS AND FIELD INSTRUMENTATION

The purpose of this section is to describe survey instruments and methodologies that were used for surveys implemented during site radiological investigations. The field investigation is a MARSSIM graded approach requiring a combination of field screening methods and onsite/offsite smear evaluations.

Instrumentation or measurement techniques were selected based on detection sensitivity to provide technically defensible results that meet the objectives of the survey. When radionuclide contaminants cannot be detected at desired levels by direct measurement, the portion of the survey dealing with measurements at discrete locations was designed to rely primarily on smear or sampling and laboratory analysis. Survey instrumentation selected for this project is shown below in Table 4-1. The project was able to quantify alpha, beta and gamma radiation.

For building surfaces, scanning, direct measurements and surface smears were performed to measure surface radioactivity concentrations of site ROCs. These measurements were based on gamma, alpha or beta emissions, depending upon the ROC of interest.

- Wet smears collected for low energy betas were submitted for gross alpha and gross beta analysis off site. Dry smears were analyzed on-site, and then a designated fraction of them were submitted to an accredited laboratory for additional radiological analyses.
- Bias smears were collected for each sink/floor drain and other inaccessible areas that detectors cannot enter.

Ludlum detectors Model 43-68, 43-37, and 44-110, or similar type of equipment, were used with Ludlum data loggers utilizing P-10 counting gas (10% methane, 90% argon). The 43-68 detectors were calibrated with C-14, Tc-99, and Th-230. The 44-110 detector was calibrated with a H-3 source and the overall or total efficiency was provided by the manufacturer as 0.319 cpm/dpm; ISO-7503-2 does not provide recommendations regarding surface efficiency for H-3. The results summary section shows that tritium measurements were very low such they could not exceed the DCGL even if a surface efficiency was applied as low as 8.5E-6. This value for surface efficiency was obtained by dividing the highest measured ncpm result by the instrument efficiency of 0.639 and then by the DCGL of 1.2E8 dpm/100cm^2. A review of detection techniques and requirements for betas at the H-3 low energy level is presented in Appendix B. Certificates of calibration are provided in Appendix E.

Table 4-1 Selected Instrumentation

Measurement Type	Detector Type	Detector Area	Instrument Model	Detector Model
Gamma Scan/Static	NaI gamma scintillator	N/A	Ludlum 2221	Ludlum 44-10
Gamma Isotopic	NaI	N/A	URSA-II	Ludlum 44-20
Alpha/Beta Scan	P-10 gas proportional	582 cm^2	Ludlum 2360	Ludlum 43-37
Alpha/Beta Scan & Directs	P-10 gas proportional	126 cm^2	Ludlum 2360	Ludlum 43-68
Low Energy Beta Directs	Windowless P-10 Gas proportional	126 cm^2	Ludlum 2360	Ludlum 44-110
Smears/filters	ZnS (Ag) scintillator	2 inch samples	Ludlum 2929	Ludlum 43-10-1
Gamma	NaI scintillator	N/A	Ludlum 19	Internal

* N/A - not applicable

4.1 Direct and Scan Radiation Measurements

Building surfaces were measured for alpha and beta radioactivity using direct scan survey and direct measurement techniques. Gamma scans were performed in the LINAC room and other areas based on professional judgment. These components of radiological scoping/scanning surveys were performed in accordance with operational procedures listed in Appendix D.

Gamma scans were performed for the LINAC room 1H27 with a Ludlum 44-10 detector. Selected areas were followed up with an URSA-II isotopic evaluation.

Alpha and beta radioactivity direct scan surveys and integrated direct measurements were performed on floors and lower walls as possible using a Ludlum Model 43-37 gas flow proportional detector floor monitor (active area of 582 cm^2) or equivalent detector. In certain instances where accessibility was an issue, such as stairwells, the floor monitor was replaced with a Ludlum 43-68 (active area of 126 cm^2) handheld alpha/beta radioactivity gas flow proportional detector, or equivalent detector. Surveys performed on upper walls, ceilings, and potentially lower walls were also made with the Ludlum Model 43-68 gas proportional detector, or equivalent detector. Both the 43-37 and 43-68 detectors were coupled to a Ludlum 2360 Alpha-Beta Data Logger, or equivalent data logger. The 43-37 and the 43-68 were calibrated to measure both alpha and beta surface activity (i.e., dual channel analysis). The Ludlum 2360 data

logger allows for recording of both alpha and beta channels simultaneously at a one-second interval, allowing for a high density of data points. Alpha and beta measurement results were recorded separately.

The 43-37 and 43-68 detectors are not sensitive to relatively low-energy alpha/beta radioactivity due to the presence of their Mylar ® entrance windows. H-3, Ni-63, and Cd-109 are considered low energy (hard-to-detect) beta emitters and were ROCs in many survey units (See Table 1-7). The Ludlum 44-110 detector was used for these low energy beta emissions. It should be noted that any stated "H-3 Residual Activity" was conservatively assumed to be entirely due to H-3. In actual fact, a portion (or even all) of the gross residual count rate was attributable to other radionuclides of concern. However, for the sake of evaluating potential H-3 contamination, this assumption was deemed appropriate. C-14 has a satisfactory but low efficiency of about 5% for the 43-37 and 43-68 detectors.

One procedure deviation for the 44-110 was required as background rates were noticeably lower in basements and subbasements of Buildings. Tidewater's procedure mimicked the Ludlum operational manual which anticipated P-10 gas purging until a background level of approximately 400 cpm was reached. The background level was routinely in the 200 cpm range and purging was required until the level visually approached an asymptote; performance checks were required to conform to this level also.

The concept of material specific background radioactivity measurements was introduced in Section 3.4.2. At least ten gross alpha and beta background measurements were performed and recorded for each detector for each different type of surface material being surveyed (e.g., concrete, tile, plastic) and in each separate survey area (i.e., as general background activity changes from area to area). The primary purpose of the background measurements was to correct the instrument for material specific beta/alpha emissions that can result in additional beta or alpha counts.

Analysis count times for integrated alpha/beta measurements were dependent upon the alpha DCGL applicable to the survey unit. As illustrated in Table 3-3, the count times were from 2 to 10 minutes in duration to adjust per MDC requirements.

Biased measurements of surface alpha and beta radioactivity were performed in the following types of locations:

- Cracks in floors or walls
- Corners of floors and walls
- Openings in floors, walls, or ceilings such as drains and ducts
- Horizontal structures with surfaces where airborne contamination may have settled (e.g., building joists, etc.)
- Additional areas where contamination would be expected to accumulate

The net count rate was determined as the difference between the measurement count rate and the material specific background count rate measured prior to use.

4.1.1 Alpha and Beta Static Minimum Detectable Concentrations

NUREG-1507 provides a rigorous derivation of the expression for instrument sensitivity, typically stated as the minimum detectable concentration (MDC). The MDC equations and example values for both static measurements and swipe analysis are presented in this section. The following was an *a priori* analysis. Per the MARSSIM "Roadmap" For direct measurements and sample analyses, minimum detectable concentrations (MDCs) less than 10% of the DCGL were preferable while MDCs up to 50% of the DCGL were acceptable.

For static measurements, background measurements were taken in accordance with Tidewater radiation safety procedures. The backgrounds were taken on similar material that had not been impacted by radioactive material for 10 counts. For example, the DCGL for DU was 100 dpm/100 cm^2 and to obtain an alpha MDC of 50% of the DCGL, the length of the count is typically one (1) minute or two (2) minutes. When DU was not potentially present, radium was the ROC and the count time was decreased to 30 seconds. The following equation for the MDC from NUREG-1507, (Equation 3-10), as modified for efficiency and detector area, applies:

$$StaticMDC = \frac{3 + 4.65 * \sqrt{C_b}}{(\varepsilon_s) * (\varepsilon_i) * T * \left(\frac{a}{100}\right)}$$

where: C_b = Background count in analysis time
ε_i = Intrinsic instrument efficiency
ε_s = Surface efficiency
T = Time of background analysis interval
a = detector area in cm^2

Determining the MDC in cpm requires knowledge of the survey instrument efficiency, the material source efficiency and the background rates. (These or instruments with similar capabilities were used.) NUREG-1507 permits a different formula to achieve required MDCs by varying the count time and the background count times. This formula was used with alpha emitters and is shown below:

$$MDC = \frac{3 + 3.29\sqrt{R_B t_S \left(1 + \frac{t_S}{t_B}\right)}}{(\varepsilon_s)(\varepsilon_i)(t_S)\left(\frac{a}{100cm^2}\right)}$$

Where: R_B = Background rate in cpm

t_S = Sample counting time

t_B = Background counting time

Table 4-2 illustrates the static MDCs of three detectors selected for the project. Integrated direct measurements for the hard-to-detect radionuclides were surveyed with the Ludlum-44-110 detector while the other readily detectable beta and alpha emissions were surveyed with the Ludlum 43-68 detector. The integrated count times, MDCs, and fraction of DCGL achieved with the stated count times are provided in Table 4-2; alpha detection MDCs were the most critical and the count times were adjusted accordingly:

- All H-3 count times in all impacted areas for static measurements were 0.5 min.
- Radium-226 has the most restrictive alpha DCGL in Buildings 1, 2, 38, the waste bunkers, and 92. The associated count time was two minutes.
- Uranium has the most restrictive alpha DCGL in Buildings 7, 54, 91, and Room 39 and Hallway of Building 41. The associated count time was four minutes.
- Americium-241 has the most restrictive alpha DCGL in Room 42 of Building 41. The associated count time was thirty minutes.

Table 4-2 Instrument Count Times, Static MDCs, and Fraction of DCGL Achieved

Type	ROC	Isotopic DCGL (dpm/100cm^2)	Back-ground (cpm)	Count Time (min)	$\varepsilon_{2\pi}$	ε Surface	MDC (cpm)	MDC (dpm/100cm^2)	DCGL Fraction
44-110 Hard-To-Detect[a]	H-3	1.20E+08	136	0.5	The manufacturer provided a 4π efficiency for H-3 of 0.319		83	206	2E-6
	Ni-63	1.80E+06		0.5			83	206	0.001
	Co-57	2.11E+05		0.5			83	206	0.001
	Cd-109	1.14E+05		0.5			83	206	0.002
43-68 Beta	C-14	3.70E+06	206	4	0.2	0.25	34	542	0.0001
	Co-60	7.10E+03		2	0.2	0.25	49	773	0.109
	Co-60			4	0.2	0.25	34	542	0.076
	Co-60			30	0.2	0.25	12	195	0.027
	Cs-134	1.27E+04		2	0.2	0.5	49	386	0.030
	Cs-137	2.80E+04		2	0.29	0.5	49	267	0.010
	Eu-152	1.27E+04		4	0.29	0.5	34	187	0.015
43-68 Alpha	Ra-226	1.12E+03	3	2	0.39	0.25	7	59	0.052
	Uranium	95.8		4	0.39	0.25	5	39	0.406
	Am-241	27		30	0.39	0.25	2	13	0.473

[a] Efficiency for all HTDs was considered as that for H-3 which should be conservative as H-3 emits the weakest beta energy.
[b] Am-241 was only authorized in a Class 2 survey unit (Room 42 of Building 41); per MARSSIM and NUREG-1757, an MDC of 50% of the DCGL was acceptable but achieving that level required both an analysis time of 30 minutes and a background count time of 30 minutes.

MARSSIM provides that default source efficiencies may be obtained from ISO-7503-1 (Ref. 7.29). Except for tritium, Table 4.2 follows those recommendations: (1) A source efficiency of 0.5 is recommended for beta emitters with maximum energies above 0.4 MeV; and (2) Alpha emitters and beta emitters with maximum beta energies between 0.15 and 0.4 MeV have a recommended source efficiency of 0.25. Source efficiencies for some common surface materials and overlaying material are provided in NUREG-1507 (Ref. 7. 30). As most of the survey units were Class 3 and the most restrictive DCGL of the ROCs in a survey unit was used, source efficiencies determined whether or not 20% of an SOR of 1 was exceeded. Source efficiencies from NUREG-1507 were applied (1) to assure no measurement in a Class 3 survey unit exceeded a small fraction of the $DCGL_w$ SOR of 1; and (2) to assure no measurement in a Class 1 or 2 survey units exceeded the DCGL. When source efficiencies from NUREG-1507 were used, an annotation was made on the applicable results page in Appendix C.

Initially and for conservatism, the instrument efficiency for C-14 betas was generally used and a SOR of less than 0.2 was achieved. If a SOR of less than 0.2 was not achievable at this conservative level, an approach was taken to select the most probable ROC and the corresponding higher efficiency to demonstrate that SOR results were less than 0.2. Conservatism was maintained as the most restrictive DCGL was used. Regardless of the efficiency selected (most conservative or probable), a SOR of 1 was never exceeded. All efficiencies used in calculations were presented in Appendix C.

4.1.2 Alpha and Beta Scan Minimum Detectable Concentrations (MDC)

Scanning is the process by which the operator uses portable radiation detection instruments to detect the presence of radionuclides on a specific surface (*i.e.*, wall, floor, equipment). The term scanning survey is used to describe the process of moving portable radiation detectors across a suspect surface with the intent of locating radionuclide contamination. Investigation levels for scanning surveys were determined during survey planning to identify areas of elevated activity. Scanning surveys were performed to locate radiation anomalies indicating residual gross activity that may require further investigation or action. Because of the uncertainty associated with interpreting scanning results, the detection sensitivity of the selected instruments should be below the DCGL if possible. However, no particular MDC fraction (or minimum multiple) of a DCGL was required for survey units classified as Class 2 and Class 3.

4.1.2.1 Beta Scan MDC

For beta scanning, the time interval over an area was typically one to two seconds. The following equation was developed from above and NUREG-1507.

$$ScanMDC = \frac{1.38 * \sqrt{b_i} * \frac{60}{i}}{\sqrt{0.5} * (\varepsilon_s) * (\varepsilon_i) * \left(\frac{a}{100}\right)}$$

where: 1.38 = a desired performance proportions level of 0.95 for true positive results and a level 0.4 false positives;

b_i = Background counts during the observation interval;

i = Observation interval in seconds; and

$\sqrt{0.5}$ = MARSSIM determined level of performance for the surveyor.

There was no scanning capability for low energy (hard-to-detect) beta emissions. Results for detectable betas are tabulated in Table 4-4.

4.1.2.2 Alpha Scan MDC

Scanning MDCs for alpha emitters with low background detectors must be derived differently than scanning for beta emitters. MARSSIM has formulas and probability concepts for scanning alpha contamination when the background is less than 3 cpm. Abelquist [Ref. 7.36] has developed scan MDCs on structure surfaces for alpha radiation by use of Poisson summation statistics. Appendix J in MARSSIM provides a complete derivation of the formula used to determine the probability of observing a single count:

$$P(n \geq 1) = 1 - e^{-\left(\frac{G \varepsilon t}{60}\right)}$$

Where:
- $P(n \geq 1)$ = the probability of observing a single count;
- G = the elevated area activity (dpm);
- ε = the detector efficiency (4π); and
- t = the residence time of the detector over the activity (sec).

The scan process must be in two stages: continuous monitoring and stationary sampling (pausing). During the continuous monitoring, the surveyor listens to the number of clicks. Because the instrument background is low (<3 cpm), a single count gives the surveyor cause to

stop and investigate further by pausing for an additional number of seconds. The scan MDC for alpha contamination must be based on the continuous monitoring stage which is illustrated as follows.

Per Abelquist's example pages193-197: setting the P(n $\geq$ 1) at the 90% level and solving for G which is now defined as the alpha scan MDC.

$$scanMDC_{alpha} = \frac{[-\ln(1 - P(n \geq 1))]60}{\varepsilon_i \varepsilon_s t}$$

where: ε_i = Intrinsic instrument efficiency
ε_s = Surface efficiency
t = residence time (sec), calculated from scan rate

Some approximate MDCs for alpha and also for beta (C-14 and Tc-99) for the three detectors are presented in Table 4-3. The time interval for scanning was 2 seconds equivalent to a scan speed of one-half a detector width per second. Note that the scan MDC for the 43-37 detector was determined by the formula used for beta as the background was appreciably higher; the 43-37 detector were used the greater majority of scans.

Table 4-3 Scan MDCs of Various Detectors (2 sec interval)

Detector Model	Alpha		Beta		
	Back-ground (cpm)	MDC (dpm/100cm^2)	Back-ground (cpm)	C-14 MDC (dpm/100cm^2)	Tc-99 MDC (dpm/100cm^2)
43-68	0.7	691	255	1936	521
43-37	12	349	830	N/A	176

Table 4-4 provides a comparison of the DCGLs for the various ROCs and the direct and scan capabilities for the Ludlum 43-68 detector. Only H-3, Ni-63, and Cd-109 cannot be directly monitored and these radionuclides are addressed in the smear discussion in Section 4.2.

Table 4-4 Selected ROC's DCGLs and Ludlum Detector 43-68 Detection Capabilities

ROC	DCGLs for Building Surfaces (dpm/100 cm^2)	Static MDC (dpm/100cm^2)	Scan MDC(dpm/100cm^2)
H-3	1.20E+08	--	--
C-14	3.70E+06	612	1936
Na-22	9.54E+03	165	521
S-35	1.27E+07	612	1936
Cl-36	4.99E+05	165	521
Ca-45	2.80E+06	612	1936
Sc-46	2.87E+04	612	1936
Co-60	7.10E+03	612	1936
Ni-63	1.80E+06	--	--
I-129	3.50E+04	612	1936
Cs-137	2.80E+04	612	1936
Eu-152	1.27E+04	165	521
Ra-226	1,120	91	691
Uranium	95.8	34	691
Am-241	27	12	691

4.1.3 Gamma Exposure Rate Measurements

4.1.3.1 RAM Use Areas

General area gamma dose rate measurements were qualitatively performed during the survey activities to ensure worker health and safety and to identify elevated dose rate conditions. Measurements were performed using a Bicron® Microrem tissue-equivalent scintillation detector, or equivalent, and were performed in accordance with operational procedure RS-010.0, "Surveys". Measurements were performed using the "slow" response time constant setting. A scan evaluation was made of each survey unit to appraise the general gamma exposure rate. At any location greater than twice background rates, the detector were positioned over the area of interest and allowed to stabilize prior to recording the measurement. The technicians used their judgment to determine when the instrument has stabilized, it was estimated that this took at least 15 seconds. Such measurements were typically performed at 1 meter from and/or on contact with the surface being evaluated.

4.1.3.2 Accelerator Areas

The linear accelerators were located in 1H33, 1H27 and 1H25. The use of the 21 MV machine in Room 1H-33 in recent years has mostly been at the 6 MV setting because of the newer protocols. An estimated 3,000 min/year of beam on time at 15 MV for the last couple of years but progressively more in earlier years. Literature research indicated that concentrations of any activation by linear accelerators used at WRAMC would be too low to measure. This area survey included direct beta and gamma measurements as well as wet smears on a systematic grid in Room 1H33 which housed the linear accelerator with authorized use energies of 20 MeV.

For an office worker, the rate equivalent to 25 mrem per year is 12.5 μR/h (above background) for a 2000 hour work year. A dose comparison as follows was attempted at a distance of 1 meter above the floor surface. MARSSIM uses modeling (using Microshield™) of a small area of elevated activity (soil concentration) to determine the net exposure rate produced by radionuclide concentrations at a distance above the source. Factors used include—the areal dimension of a cylindrical area of elevated activity as 0.25 m^2 (radius of 28 cm), the depth of the area of elevated activity as 15 cm, the dose point at 10 cm above the surface, and the density as 1.6 g/cc. The objective is to determine the radionuclide concentration that is correlated to the net exposure rate. For this evaluation, two distances were considered, 10 cm and 100 cm. The concrete density used was 3.6 g/cc with barium as an additive (Ref. 7.36). An average mix of radionuclides from various densities of concrete of higher energy accelerators was selected (Ref. 7.36). Results of the Microshield® [Ref. 7.37] analysis are presented in Appendix B.

The modeling run indicates exposure rates for 1 pCi/g of the mix as 0.74 μR/h at 6 inches and 0.04 μR/h at 1 m distances above the floor surface. The required concentration to produce an exposure rate of 12.5 μR/h above background would be 312 pCi/g and the exposure rate at 6 inches would be about 230 μR/h.

Qualitative evaluations were attempted with the URSA-II to identify specific radionuclides and ratios of concentrations at locations where exposure rates exceed 2 sigma of background. Results are provided in Section 5 and Appendix G.

4.2 Smear Collection and MDCs

The following is quoted from MARSSIM, "…measurements of smears are very difficult to interpret quantitatively. Therefore the results of smear samples should not be used for determining compliance. Rather they should be used as a diagnostic tool to determine if further investigation is necessary." This advice was followed except for instances when a direct measurement cannot be made, i.e., irregular surfaces, cracks or very small areas where detectors cannot fit, which were considered with smear evaluations.

In the rooms identified in Table 1-3, bias smear/swab samples were collected for each sink/floor drain and other inaccessible areas that detectors cannot enter, to quantify transferable surface alpha and beta radioactivity. If possible, smear samples were collected over approximately 100 cm^2. For non-listed rooms in the expanded survey units, bias smear samples were collected. These samples were analyzed off-site for gross alpha and gross beta with MDCs below twenty-five percent of the restrictive alpha DCGL and about 1-thousanths of the restrictive beta DCGL listed in Table 4-5. Smear results and chain of custody forms are provided in Attachment D.

General Engineering Laboratories, LLC (GEL) was selected as the contract analytical laboratory. GEL is Depart of Defense (DoD) Environmental Laboratory Accreditation Program (ELAP) certified. As GEL's Laboratory Quality Assurance Plan (LQAP) was accepted in the ELAP, a copy is not provided or reviewed with this FSSR.

- Wipe tests were analyzed for gross alpha and beta activity using liquid scintillation counting. A Packard Tri-Carb 3100 liquid scintillation counter (or similar equipment) were used for the analysis.

- Each sample was combined with 15 mL of "Optiflour O" counting cocktail in a 20-mL glass vial and counted for an minimum of 5 minutes. The counting protocol spans the energy range from 0 -2000 keV for beta energies and 0-10 MeV for alpha energies.

- The gross alpha and gross beta efficiencies were determined for each analysis using a commercially available alpha and beta standards traceable to NIST. The counter was maintained under a routine service program and quench curves as appropriate established annually. Daily control charts (performance checks) were maintained of counts of background and unquenched NIST traceable beta standards.

- Results were transferred from the LSC data printout or file in units of cpm or counts, background was subtracted and the net count-rate was converted to activity using the determined efficiency. The activity was reported as gross alpha and gross beta activity per sample.

Instrumentation and techniques deployed at WRAMC for measurement tritium surface contamination utilized a windowless gas flow proportional detector (Ludlum 44-110) and wetted smears for analysis by liquid scintillation techniques. The full screening value was desired so the procedure included a technique for smear measurements to establish the fraction of removable radioactivity. The approach at WRAMC included direct surface measurement of tritium (low energy beta) with a gas flow windowless detector with intent of confirmation of removal fraction (smears) at locations with measurable contamination (proposed as spanning the useful range of results with a minimum of two smears per survey unit).

4.3 Portable Gamma Isotopic Measurements

Professional judgment and specific requirements in Section 4.1.3.2 were used to determine when a qualitative gamma isotopic analysis would assist in determining what ROCs were present. This information could potentially determine the most restrictive DCGLs for a survey unit. If deemed necessary, in-situ gamma isotopic measurements were performed with a *URSA II* - Universal Radiation Spectrum Analyzer, or equivalent. This device was configured up to 4096-channels and the detector selected for this project was a Ludlum model 44-20 (3"x3"). Software included:

- Full standard libraries include all 497 isotopes listed in "Kocher's Radioactive Decay Tables." Multi-channel scaling mode, peak search and identify, quantification based on ROIs or peaks search.
- Provisions were included for acquiring and saving spectra repeatedly and continuously while unattended. Spectra can be saved and reloaded to "live" for re-analysis or additional data accumulation, or loaded as a background spectrum. Saved spectra can be superimposed on the "active" spectrum for comparison. Spectrum format was easily accessible by a spreadsheet program. All reports can be previewed, printed, or saved as text or rich text files.
- "ASCII" mode allowed control of and data collection from the URSA-II with user's own software or hardware.

4.4 Vacuum Line Systems

The laboratory areas in buildings 54, 7 and 2 were furnished with vacuum ports at countertop work stations and in fume hoods. The inside diameter of the vacuum ports was approximately 0.25 inch internal diameter which were too small for standard hand-held detectors to enter. The vacuum system for each building was handled as a survey unit with the interior of 13 randomly chosen ports swiped and analyzed as a composite sample. Results can be found in Appendix F.

4.5 Laboratory Drain Lines

Laboratory sink drains and ventilation hood drains discharged into several waste streams, acid waste, bio-waste, and normal waste. Smears and direct measurements were taken in laboratory sinks and vent hood drains in all impacted areas and analyzed for gross Alpha and Beta. Locations of smear/direct measurements and results of the direct measurements can be found in Appendix C. Smear analysis results can be found in Appendix F.

5.0 DATA QUALITY ASSESSMENT

A quality assessment of the data collected during the Final Status Surveys at WRAMC Main Post was performed. The assessment included the following aspects of the data set:

- The completeness of the data set with respect to the requirements outlined in the SCWP.
- Basic (i.e. minimum, maximum, mean) Statistical Analysis of the data set
- QA/QC records for instrumentation

5.1 Data Completeness

All data that was specified in the SCWP was collected and analyzed successfully.

5.1.1 Statistical Analysis

Basic statistical analysis was performed on the characterization data that was collected during the performance of the sampling requirements of the SCWP. The analysis included quantities such as the minimum, maximum, and mean of static and smear sampling, as well as minimum, maximum, and mean of low energy beta analysis results. The values for this analysis are presented in the summary tables in section 6.

5.1.2 Instrument Quality Assurance / Quality Control

During the execution of Final Status Survey work, *qualitative* and *quantitative* instrumentation was used to collect measurements. *Qualitative* instruments (e.g., Ludlum Model 19) provide results that show that a parameter (e.g. radioactive contamination) was present or was not present with a lesser degree confidence in determining "how much" was present. Conversely, *quantitative* instruments [Alpha/beta detectors (e.g., Ludlum Models 43-68 and 43-37) were used to determine if a parameter was present and to estimate "how much" was present with a known degree of confidence. The QA/QC elements for these two instrument classes were similar, with the quantitative class being more rigorous. There were three QA/QC checks that were accomplished for each class:

General Instrument Conditions

During daily QA/QC checks, both classes of instruments were inspected for physical damage, battery voltage levels, current calibration, and erroneous readings, in accordance with TIDEWATER's standard operating procedures (SOPs)

Instrument Response Checks

Instruments used for qualitative measurements were response checked daily by comparing response to designated cesium-137 National Institute of Standards and Technology (NIST) traceable source and to ambient background. The acceptance criteria for these instrument response checks were +/- 20% of the mean response generated using ten initial source checks and ten measurements of ambient background

Instruments used for quantitative measurements were response checked daily by comparing response to designated ^{3}H, ^{230}Th and ^{99}Tc NIST-traceable sources and to ambient background. The acceptance criteria for these instrument response checks was two and three-sigma of the mean response generated using ten initial source checks and ten measurements of ambient background.

Background Checks

Background checks were performed daily for each qualitative instrument. These checks were performed to monitor fluctuations in ambient gamma background that could impact the interpretation of the measurements, not to monitor the performance of the instruments. The results of the background measurements were recorded and presented on a control chart. Background measurements were performed in an identical fashion for a 10-minute count, with no source. The acceptance criteria for these instrument response checks were two and three-sigma of the mean. The results of the background measurements were recorded

A response check outside the two-sigma range, but within the three-sigma range was considered cause for a recount prior to further evaluation. A response check outside the two-sigma range on the second count or three-sigma range on the initial count was considered cause for further evaluation prior to continued use. A response check outside these limits was cause for an evaluation of conditions (e.g., instrument operation, source/detector geometry) prior to further counts and/or removal of the instrument from service. Instruments must pass a response check prior to field use.

There were no QA/QC issues identified during the field activities at WRAMC-Main Post. The QA/QC data for this field effort is presented in Appendix G.

5.2 Off-Site Laboratory Sample Analysis

Gross alpha and gross beta liquid scintillation spectroscopy analysis of the composited swipe samples was performed by the off-site laboratory General Engineering Laboratories(GEL) in Charleston, SC, using the U.S. Environmental Protection Agency (USEPA) 900 method.

In January 2012, the laboratory analyzed 563 wipes and three composite smears for gross alpha and gross beta. As analytical QC, in January 2012, the laboratory analyzed 26 field blind blank samples, 53 method blanks (MBs), 53 laboratory control samples (LCS), and 53 laboratory control sample duplicates (LCSD) for gross alpha and gross beta.

The laboratory performed internal validation of all sample results and assigned qualifiers. The laboratory validation addressed sample chain of custody, instrument performance, ability to meet required detection limits, the results of the QC samples, and other factors that might affect data quality. The results of the validation were summarized in a case narrative provided for each shipment of samples received by the laboratory. As a part of its analytical data review,

TIDEWATER reviewed the case narratives and the results of the quality control samples. The following sections provide a summary of those reviews. All off-site laboratory Electronic Data Deliverables (EDD) are included in Appendix F.

5.2.1 Laboratory Duplicate Evaluation

Duplicate analyses of samples were performed by GEL to evaluate the precision of their results. Duplicate analyses were required for at least 5% of the total samples analyzed from all SUs. The duplicate results were compared to the initial sample results by calculating a z-score and comparing it against the performance criteria as follows. The z-score for each sample-duplicate pair was calculated using the equation in Section 7.2.4.

The calculated z-score results were compared to a performance criterion of less than or equal to 1.96, which represents the 95% confidence interval to the mean in a normal population. Calculated z-scores less than 1.96 would be considered acceptable, and values greater than 1.96 would be investigated for possible discrepancies in analytical precision, or for sources of disagreement with the assumption that the sample result and duplicate sample result were of the same normally distributed population.

A total of 51 laboratory duplicate samples were analyzed for gross alpha and beta, representing 9.1% of the 95 study samples obtained. Based on these results, it is expected that the original and duplicate results were part of the same population at the required confidence interval (95%). Therefore, it was concluded that these laboratory sample results meet the evaluation of precision without the need for qualification.

5.2.2 Method Blank

A MB is a sample, typically reagent grade water and known to be free of the analytes of interest. The MB was analyzed along with samples of an associated analytical batch and receives the same reagents, in the same quantities, and was carried through the same sample preparation (e.g., digestion/extraction) and analysis steps as all other samples. The MB provides assurances that an analyte of interest was not inadvertently added to the samples through a reagent or analytical operation. GEL analyzed one MB with each analytical batch of 20 or fewer samples, for a total of 102 MBs in January 2012.

Results were qualified as estimated (J) for all associated samples that have activity concentrations above the detection limit and less than 10 times the blank value. When results were qualified as estimated, it falls on the data user to determine data are acceptability. None of the samples were qualified because of MB activity.

5.2.3 Laboratory Control Sample / Laboratory Control Sample Duplicate

When sample volume was insufficient to allow preparation of a duplicate, laboratory control samples (LCS) and laboratory control sample duplicates (LCSD) were prepared in lieu of a field

duplicate sample. A LCS is a sample that is prepared by adding a known aliquot of the analyte of interest, or a surrogate analyte to a volume of laboratory certified reagent grade water. The LCS was analyzed with the associated sample batch using the same analytical procedures and instruments. The LCS results were used as a measure of the accuracy of the analytical methods. GEL analyzed one LCS with each batch of 20 or fewer samples, for a total of 51 LCS (with 51 LCSD). If the LCS results were unacceptable, samples in the analytical batch are typically reanalyzed. In cases where the samples were not reanalyzed, the results may be rejected (R-qualifier) or qualified as estimated (J-qualifier) during the data validation or review process. No radiochemical sample results were rejected but 24 were qualified as estimated on the basis of LCS results.

5.2.4 Detection Limits

MDC requirements were established during the development of project data quality objectives and represent the sensitivity required for the analytical procedures. The MDC is a statistical parameter that represents the uncertainty associated with the measured concentration of an analyte near background concentrations. When practical, MDCs were set well below project-specific action criteria such as regulatory limits or clean-up goals. The MDCs were set sufficiently low to provide assurances that the concentrations of analytes that were "undetectable" will not exceed action limits. Occasionally due to the amount of substance in the smear, MDC will increase. For this FSS, the MDCs were set at well below any project DCGL defined as 8 dpm alpha per smear and 20 dpm beta per smear. The laboratory met the MDCs for the RCOPCs for samples but three for which the highest MDCs were still very much below DCGLs at 51 dpm alpha per smear and 80 dpm beta per smear. No data were qualified because of a failure to meet the requested MDCs.

5.2.5 Field Blind Blanks

Tidewater submitted 29 blind blank field samples which were analyzed by GEL and all results were qualified by the laboratory as less than their minimum detection limit for which the highest MDLs were 2.1 dpm per smear as alpha and 6.3 dpm per smear as beta. These were the expected results for field blind blank samples.

5.2.6 Method Performance and Summary Assessment

Overall, the performance of the laboratory analyses was excellent. The samples were analyzed for all of the analytes as required by the contracts with the laboratories as part of the FSS. The data were subjected to data review and validation by GEL personnel and appropriate qualifiers applied to the data. In addition, TIDEWATER independently reviewed the data for the QC samples: duplicate samples, LCS, and MBs. The results of the QC samples were all acceptable and did not indicate any data quality problems. None of the data was rejected during the data validation and review process.

5.3 Duplicate Measurements

Guidance found in NRC Inspection Procedure 83502.03 [Ref. 7.38] was identified to determine data quality of duplicate measurements. However, due to results with negative values, very low values, and most below the MDC, this testing was not performed. The daily instrument performance checks were considered a valid alternative to duplicate measurements.

6.0 INTERPRETATION OF FINAL STATUS SURVEY RESULTS

Final status surveys and sampling of potentially impacted building structures at WRAMC-Main Post have been completed in accordance with the requirements specified in the SCWP. In accordance with MARSSIM actual sample results for direct alpha, direct beta and low energy beta removable were divided by their respective DCGLs. The resulting ratios were then added together using a sum of ratios (SOR) calculation.

6.1 ALARA

The DCGLs for this survey effort were developed using the NRC default screening limits, ALARA was taken into consideration in accordance with NUREG 1757 Vol. 2 Rev 1, Section 6.3. Given that a small fraction of the DCGLs were not exceeded at WRAMC-Main Post, confidence was achieved that any residual radioactivity was ALARA as well.

6.2 Reference Material Background

Site specific background values were determined. Ambient and material background rates were measured in the site reference areas and selected accordingly for the age and type of material. Reference area measurements were applied to multiple survey units as long as the material being surveyed was similar to that in the reference area.

For comparability of results, survey measurements were collected from the reference area background survey units using similar instruments and survey techniques employed in the survey unit areas. Each background reference material was surveyed using at least 10 random static alpha and beta measurements for each material. Table 6.1 and 6.2 list the various reference materials identified.

Table 6.1 Material Specific Backgrounds for Alpha/Beta Static Measurements

Material	2360#253237 w/43-68 #216834 Alpha Background		2360#253237 w/43-68 #216834 Beta Background	
	CPM	Std Dev	CPM	Std Dev
Asphalt	1.09	0.94	38.73	5.64
Brick	4.45	1.69	56.82	4.87
Red Ceramic	0.82	0.87	105.18	8.30
Green Ceramic	10.18	2.89	179.45	13.66
Building 91 Mastic	3.45	1.04	41.27	6.26
Building 41 Mastic	7.82	1.47	57.27	6.07
Ceiling Tile	4.18	1.60	81.27	9.38
Building 91 Waxed Tile	2.55	1.57	45.36	6.99
White Tile	0.64	0.92	45.18	4.77
Tan Tile	0.55	0.93	48.00	7.06
Painted Metal	0.27	0.47	33.64	4.30
Unpainted Metal	1.00	0.77	34.82	4.24
Drywall	1.27	1.27	54.00	6.86
Drywall/Granite	6.30	1.95	56.80	8.23
Wood	0.73	1.01	24.55	4.13
Composite	0.36	0.50	29.18	6.74
Black Hood Base	11.45	5.52	68.09	14.54
Carpet	0.73	1.27	30.09	5.07
Painted Concrete	0.82	1.17	38.64	11.07

Table 6.2 Material Specific Backgrounds for H-3 Measurements

Material	2360#141321 w/ 44-110 #258430 ^{3}H Background	
	CPM	Std Dev
Red Ceramic	205.27	15.55
Green Ceramic	299.36	14.28
Floor Tile	47.80	14.35
Metal	63.05	8.52
Drywall	85.18	10.86
Wood/Composite	77.20	10.11
Painted Concrete/Linoleum	99.47	12.73

6.3 Summary of Results

Scan, static and swipe surveys were done in the various survey units to determine if any residual radioactive material was above the release criteria. During scan surveys, biased static surveys and smear surveys, surveyors concentrated most of their efforts on the places most likely to contain residual radioactive material.

6.3.1 Vacuum Lines

The complete results of the vacuum lines smear surveys for Buildings 54, 7 and 2 are provided in Appendix F. However, all results of the alpha testing were below the laboratory Minimum Detection Limit (MDL) with the highest MDL at 7.6 dpm per filter. One beta result was positive at 6.6 dpm which was slightly above the MDL of 5.2 dpm. These results reflect that a very minimum quantity of residual contamination could be in the vacuum lines and should not constitute a radiological hazard. . For example, removal and deposition would be required from 18 feet of vacuum lines (0.25 inch diameter) to approach the lowest DCGL (7.1E3 dpm/100cm^2); or from about 180 thousand feet of vacuum line for a 100 m^2 survey unit. Only a few thousand feet were roughly estimated in each building which implies that such deposition is an impossible scenario.

6.3.2 Liquid Waste Streams

Laboratory sink drains and vent hood drains discharged into several waste streams, acid waste, bio-waste, and normal waste. Smears and direct measurements were taken in all laboratory sinks and vent hood drains and analyzed for gross alpha and gross beta. Locations of smear/direct measurements and results of the direct measurements can be found in Appendix C. Smear analysis results can be found in Appendix F. These results reflect a very minimum quantity of residual contamination in the drain lines which should not constitute a radiological hazard. Results for all identified residual contamination were a small fraction of the applicable DCGL for the survey unit.

6.3.3 Air Effluent Ducting

Numerous direct integrated measurements were made for tritium, gross alpha and gross beta contamination in all vent hoods and accessible air exhaust pipes in the impacted areas. Smears were collected and analyzed off-site also. These surveys were considered bias and are identified in Appendix C. Smear analysis results can be found in Appendix F. The results are discussed as

part of the MARSSIM survey unit results which follow but no measurement indicates that the exhaust ducting would constitute a radiological hazard.

6.3.4 Smoke Detectors and Exit Signs

The USACE contacted BFPE International (BFPE), headquartered in Hanover, MD, who was contracted to maintain the fire protection systems at WRAMC Main Post site. BFPE used an "intelligent" alarm system that can be queried by computers at their headquarters to identify specific components of the system, and can specifically discern whether an ion-type detector (containing Am-241) or a photoelectric (PE)- type detector is connected to the main system panels.

The results of the query yielded the following totals for ion-type detectors:

- Bldg 01- 0
- Bldg 02- 0
- Bldg 07- 0
- Bldg 38- 0
- Bldg 41- 0
- Bldg 54- 168 (see text below for potential additional ion-types)
- Bldg 91- 0
- Bldg 92- 0 (Bldg 92 is an annex to Bldg 1 and was queried as part of the Building 1 system)

As is presented in the query results above, only Building 54 contains known ion-type smoke detectors in the main system panels. In addition to the main panels, Building 54 has several subpanels which service labs on the fourth and fifth floors, as well as a sub-panel for the Operations room located on the Museum Level. The practice of using subpanels is common for system expansion during renovations, especially where the original capacity of the main panel may be exceeded. In the case of subpanels, the system cannot identify individual components as they are combined into one signal from the subpanel to the main panel; therefore, visual inspection of detector components was required to complete the inventory where subpanels were located.

The labs on the fourth and fifth floors were visually inspected and all detectors were reasonably accessible; no additional ion-type detectors were found connected to the subpanels in the labs.

The Operations room was inspected. Ten smoke detectors were found connected to the subpanel at that location. Of these ten detectors, only four were reasonably accessible due to location and obstructions. Inspection of the four accessible detectors revealed that two were PE-type and two were ion-type, bringing the total of confirmed Am-241 containing detectors to 170. The remaining six detectors which were not inspected may contain Am-241, creating a range of 170 to 176 ion-type detectors total for Building 54.

The USACE performed a site walkdown to determine whether tritium containing exit signs were present in the buildings assessed in this FSS. The visual inspection included the following locations: Buildings 1, 2, 7, 38, 41, 54, 91, and 92, as well as the Storage Bunkers. Visual inspection of all locations provided no evidence of the presence of tritium exit signs.

6.3.5 MARSSIM Survey Unit Results

Survey results indicate that all SUs were properly classified and that the survey and sampling techniques were adequate to meet the standards promulgated by MARSSIMs guidance.
No Class 3 measurement exceeded a small fraction of the $DCGL_w$ SOR of 1. No measurements in Class 1 and 2 survey units exceeded their respective DCGLs or the $DCGL_w$ SOR of 1.

The following narrative describes the highest average alpha, beta and tritium direct results, gamma exposure measurements, and the highest alpha and beta smear results. Table 6.3 presents the results of the highest SOR with the corresponding exposure rate within each survey unit.

- The highest average beta scan measurements in any survey unit was identified in SU 54-4-3 as 803 dpm/100cm^2 which was 11% of the most restrictive DCGL for that area of 7.1E3 dpm/100cm^2.

- The highest average alpha scan measurements in any survey unit was identified in SU 92-G-4 as 34 dpm/100cm^2 which was 3% of the most restrictive DCGL for that area of 1.12E3 dpm/100cm^2 for Ra-226.

- The highest average and maximum static surface measurements in the H-3 energy range in any survey unit were identified in SU54-B-1 as 537 and 1626 dpm/100cm^2. Considering Ni-63 as having the most restrictive DCGL for this area, these measurements were both less than 0.1% of the DCGL of 1.8E6 dpm/100cm^2. The highest bias measurement for this energy range was found in SU 54-M-1 as 1654 dpm/100cm^2 which was about 0.2% of the most restrictive DCGL.

- The highest average and maximum beta static surface measurements in any survey unit were identified in SU 2-2-3 as 310 and 1165 dpm/100cm^2; respectively. Considering Co-60 with the most restrictive DCGL for SU 2-2-3, the highest average represents 5% of the DCGL and the maximum value was 16% of the DCGL of 7.1E3 dpm/100cm^2.

- The highest average and maximum alpha static surface measurements in any survey unit were identified in SU 2-1-3 as 9 and in SU 2-2-2 as 44 dpm/100cm^2; respectively. Considering radium with the most restrictive DCGL for SU(s), the highest average represents 0.8% and the maximum value was 3.9% of the DCGL of 1.12E3 dpm/100cm^2.

- The lowest and highest exposure rate measurements were 2 and 14 μR/hour; respectively, which were indicative of background in the various buildings and survey units.

- The highest smear result was reported as 12 dpm per smear as alpha and 175 dpm per smear as beta activity.

Table 6.3 Highest SOR with Exposure Rate by Survey Unit

Survey Unit	MARSSIM Class	Location of High SOR (N)	Fraction of Most Restrictive DCGL				Exposure Rate (µR/h)
			Low Beta Energy Fraction	Beta Fraction	Alpha Fraction	SOR	
1-B-1	3	8	0.00	0.02	0.00	0.02	9
2-1-1	3	5	0.00	0.00	0.01	0.01	2
2-1-2	3	12	0.00	0.01	0.01	0.01	7
2-1-3	1	4	0.00	0.04	0.04	0.08	3
2-2-1	3	6	0.00	0.03	0.01	0.05	9
2-2-2	3	B4	0.00	0.06	0.04	0.10	7
2-2-3	3	9	0.00	0.16	0.01	0.18	8
2-4-1	3	5	0.00	0.08	0.00	0.08	9
2-4-2	3	11	0.00	0.02	0.01	0.03	9
2-5-1	3	10	0.00	0.03	0.00	0.03	10
2-6-1	3	3	0.00	0.02	0.02	0.05	9
2-7-1	2	B3	0.00	0.12	0.00	0.12	6
2-7-2	3	B2	0.00	0.20	0.00	0.20	6
2-7-3	3	B1	0.00	0.03	0.00	0.03	3
2-7-4	2	4	0.00	0.02	0.04	0.06	9
2-7-5	3	6	0.00	0.05	0.01	0.06	9
7-B-1	3	7	0.00	0.00	0.17	0.18	8
7-B-2	3	5	0.00	0.00	0.20	0.20	7
7-B-3	3	8	0.00	0.00	0.10	0.10	5
7-B-4	3	B3	0.00	0.02	0.09	0.11	9
7-B-5	3	10	0.00	0.00	0.18	0.18	5
7-B-6	3	7	0.00	0.01	0.14	0.15	6
7-1-1	3	B1	0.00	0.00	0.11	0.11	7
7-2-1	3	11	0.00	0.00	0.02	0.02	10
7-2-2	3	B3	0.00	0.00	0.10	0.10	10
7-2-3	3	13	0.00	0.00	0.20	0.20	10
7-2-4	3	12	0.00	0.00	0.12	0.12	8

Table 6.3 Highest SOR with Exposure Rate by Survey Unit (Continued)

Survey Unit	MARSSIM Class	Location of High SOR (N)	Fraction of Most Restrictive DCGL				Exposure Rate (µR/h)
			Low Beta Energy Fraction	Beta Fraction	Alpha Fraction	SOR	
54-B-1	3	B2	0.00	0.04	0.01	0.05	5
54-B-2	3	7	0.00	0.04	0.16	0.20	6
54-B-3	3	9	0.00	0.00	0.12	0.12	5
54-M-1	3	B12	0.00	0.06	0.14	0.20	5
54-M-2	3	11	0.00	0.02	0.02	0.04	6
54-G-1	3	1	0.00	0.00	0.03	0.03	7
54-G-2	3	5	0.00	0.04	0.01	0.06	10
54-G-3	3	B1	0.00	0.00	0.18	0.18	9
54-G-4	3	B8	0.00	0.00	0.16	0.16	6
54-1-1	3	10	0.00	0.00	0.14	0.14	4
54-1-2	3	9	0.00	0.03	0.06	0.09	7
54-1-3	3	B25	0.00	0.00	0.20	0.20	6
54-2-1	3	3	0.00	0.00	0.08	0.08	5
54-2-2	3	B1	0.00	0.00	0.11	0.11	5
54-2-3	3	B11	0.00	0.02	0.06	0.08	4
54-2-4	1	1	0.00	0.00	0.14	0.14	3
54-3-1	3	5	0.00	0.00	0.14	0.14	5
54-3-2	3	3	0.00	0.01	0.06	0.07	6
54-3-3	3	1	0.00	0.02	0.12	0.14	6
54-3-4	3	B8	0.00	0.00	0.14	0.14	5
54-3-5	3	B1	0.00	0.00	0.04	0.04	5
54-3-6	3	5	0.00	0.03	0.14	0.17	6
54-4-1	3	8	0.00	0.05	0.08	0.12	3
54-4-2	3	7	0.00	0.06	0.08	0.14	3
54-4-3	3	7	0.00	0.00	0.10	0.10	3
54-4-4	3	7	0.00	0.00	0.08	0.08	4
54-5-1	3	4	0.00	0.00	0.15	0.15	7
54-5-2	3	3	0.00	0.03	0.01	0.04	7
54-5-3	3	3	0.00	0.00	0.17	0.17	7

Table 6.3 Highest SOR with Exposure Rate by Survey Unit (Continued)

Survey Unit	MARSSIM Class	Location of High SOR (N)	Fraction of Most Restrictive DCGL				Exposure Rate (µR/h)
			Low Beta Energy Fraction	Beta Fraction	Alpha Fraction	SOR	
38-0-1	3	B1	0.00	0.00	0.04	0.04	4
B-1-1	2	12	0.00	0.02	0.02	0.04	2
B-1-2	3	2	0.00	0.02	0.01	0.03	2
41-G-1	2	2	0.00	0.02	0.70	0.71	7
41-G-2	2	6	0.00	0.01	0.20	0.22	5
41-G-3	3	2	0.00	0.00	0.06	0.06	9
91-G-1	3	B3	0.00	0.00	0.17	0.17	7
91-1-1	3	11	0.00	0.00	0.17	0.17	7
91-1-2	3	13	0.00	0.00	0.18	0.18	5
92-G-1	3	3	0.00	0.05	0.01	0.05	10
92-G-2	3	5	0.00	0.03	0.01	0.04	9
92-G-3	3	B1	0.00	0.09	0.03	0.12	8
92-G-4	1	5	0.00	0.11	0.02	0.13	12

The highest exposure rate, as anticipated due to NORM, was in 92-G-4 inside the brick enclosed closet.

6.4 Conclusions By Survey Unit

The following subsections and tables summarize the results of the exposure rate, static, scan, and smear measurements per individual survey unit. Details including uncertainty of measurement results for each individual location are provided in Appendix C and results of smears are found in Appendix F. Drawings for survey units are also provided in Appendix C.

All DQOs were met for each particular survey unit. Many of the results indicate negative values which are expected when residual radioactivity, if any, is close to background levels. Drawings indicating measurement locations and the results of data reviews including maximums, means and standard deviations are found in Appendix C.

The swipe results are given in dpm/swipe; routine static point smears were approximately 100 cm^2 while smaller areas were necessarily used in drains and vacuum lines.

6.4.1 Building 1: SU1-B-1

This was a Class 3 Survey Unit which consisted of eight rooms which were numbered by TIDEWATER as the original floor plans were not readable. The unit consisted of the basement of

one of the several building wings and opens to Building 92 on the North; a general location drawing is shown in Appendix C. In carpeted areas, measurements were performed on the floor following removal of carpet. As this area was remodeled, the work surfaces were reviewed for covered or hidden surfaces with negative results.

Table 6.4 shows the number of direct measurements performed for H-3, gross alpha, gross beta, and exposure rates for this building and the survey unit.

Table 6.4 Number of Measurements Per Survey Unit in Building 1

Survey Unit	Class	Tritium		Beta		Alpha		Exposure Rate
		MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias	
1-B-1	3	13	3	13	3	13	3	16

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 370 and 598 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 365 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 72 and 521 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 83 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 5 and 14 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 16 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 278 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 8 and 12 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0 dpm/100cm^2 for gross alpha and 1.1 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

6.4.2 Building 2

Building 2 was the Main Hospital for the WRAMC Complex. The building consisted of 8 levels, the basement and seven floors. General location drawings for the survey units are

shown in Appendix C.

Table 6.5 shows the number of direct measurements performed for H-3, gross alpha, gross beta, and exposure rates for this building and the survey unit.

Table 6.5 Number of Measurements Per Survey Unit in Building 2

Survey Unit	Class	Tritium		Beta		Alpha		Exposure Rate
		MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias	
2-1-1	3	13	5	13	3	13	3	16
2-1-2	3	13	4	13	3	13	3	16
2-1-3	1	20	2	20	2	20	2	22
2-2-1	3	13	2	13	2	13	2	15
2-2-2	3	13	4	13	4	13	4	17
2-2-3	3	13	3	13	3	13	3	16
2-4-1	3	13	3	13	3	13	3	16
2-4-2	3	13	1	13	1	13	1	14
2-5-1	3	13	1	13	1	13	1	14
2-6-1	3	13	1	13	1	13	1	14
2-7-1	2	21	10	21	10	21	10	31
2-7-2	3	13	6	13	6	13	6	16
2-7-3	3	13	1	13	1	13	1	22
2-7-4	2	22		22		22		22
2-7-5	3	13		13		13		13

Building 2 housed three medical linear accelerators (LINAC) which were surveyed to see if any residual activation above background could be identified. Induced radioactivity depends on many factors, such as type and energy of accelerated particles and material irradiated by the primary beam and secondary radiation (Ref. 7.21). One study indicated a LINAC which produced 20 MeV electrons, 18 MV photons and was in operation for 15 years did not produce significant activation above background level. However, activated machine parts could be a radiation safety issue if any remains (Ref. 7.22). As there were no previous radiation surveys for these rooms, the LINAC room (1H33) was surveyed as a Class 1 as the 2100IX unit had multiple beams. The LINAC rooms (1H25and1H27) were combined in to a single Class two survey unit.

The MARSSIM Classification for routine use rooms was Class 3; the radiopharmaceutical preparation areas were Class 2. The waste storage rooms (7544 and 7545) were Class 2. Note no long-lived radionuclides were stored as waste.

- **Building 2: SU2-1-1**

This was a Class 3 survey unit which consisted of rooms 1H23, 1H27, and because of their close proximity and signage as laboratories, Rooms 1H24 and 1H09. Neither 1H24 nor 1H09 were discussed in the HSA and the floor plans did not disclose use or storage of radioactive material; however, 1H24 was placarded with "Isotope Room", and for prudence both rooms were scanned. At the time of survey, both Varian devices were present in Rooms 1H23 and 1H27. . The results of a gamma spectroscopy survey provided in Appendix G indicate no activated products which can be distinguished from background. The shielding in the heads had been confirmed to not contain depleted uranium. However, potential activated radioactive material was detectable through the housing in the target areas but could not be quantified.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 113 and 118 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 224 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 4 and 109 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -16 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 0 and 12 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -1 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 71 and -1dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 2 and 9 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.8 dpm/100cm^2 for gross alpha and 0.6 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-1-2**

The survey unit included Rooms 1J43, 1J39, 1J35, 1J33 and the adjacent hallway. No LINAC operations were associated with this area but clinical treatment with short-lived radionuclides was assumed. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 295 and 394 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 254 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 3 and 108 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -19 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 2 and 16 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 3 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 66 and -1dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 6 and 9 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.5 dpm/100cm^2 for gross alpha and -2.4 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-1-3**

This survey unit was a Class 1 which consisted of Room 1H33 which previously housed the Varian 2100IX LINAC. At the time of the survey, the device had been removed. The results of a gamma spectroscopy survey provided in Appendix G indicate no activated products which can be distinguished from background.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 82 and 156 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 72 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 17 and 308 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -136 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 9 and 41 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 12 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 49 and -1dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was around 3 µR/hour which was indicative of background levels.

- The maximum results of smear measurements were 0.5 dpm/100cm^2 for gross alpha and -2.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-2-1**

This was a Class 3 survey unit for a previous laboratory which included Rooms 2B73, 2B77, 2B81D, 2B81, and 2B81C.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 368 and 463 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 249 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 167 and 310 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 22 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 3 and 16 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 8 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 174 and 0 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 13 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.4 dpm/100cm^2 for gross alpha and 0.8 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-2-2**

This was a Class 3 survey unit for a previous laboratory which included Rooms 2B51, 2B53, 2B55, 2B54, 2B56, 2B62 and the interior hallway.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 377 and 518 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 329 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 169 and 333 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 417 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 7 and 20 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 44 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 58 and 6 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 7 and 9 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 04 dpm/100cm^2 for gross alpha and 1.3 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-2-3**

This was a Class 3 survey unit for a previous laboratory which included Rooms 2F09A, 2F09A, 2F09B, 2F09C, and associated hallway.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 248 and 370 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 261 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 310 and 1165 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 160 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -2 and 14 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 3 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 85 and -2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 6 and 10 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were -0.1 dpm/100cm^2 for gross alpha and -2.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-4-1**

This was a Class 3 survey unit which encompassed Rooms 4709, 4711, 4731, 4743A, 4713, 4715, 4752, 4754, 4801, 4807, 4831, 4833, 4837, 4839, 4841, 4843, 4E01, 4E02, 4E03, and the interior hallway.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 348 and 598 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 276 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 201 and 581 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 378 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 3 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 3 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 158 and 1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 9 and 10 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.4 dpm/100cm^2 for gross alpha and -0.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-4-2**

This was a Class 3 survey unit which encompassed Rooms 4951, 4952, 4953, 4954A, 4943, 4942, 4941, and the interior hallway.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 342 and 478 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 216 dpm/100cm^2.

- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 16 and 146 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 134 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 8 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 4 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 126 and 0 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 8 and 10 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.0 dpm/100cm^2 for gross alpha and -0.1 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-5-1**

This was a Class 3 survey unit for a laboratory area now converted to offices which encompassed Rooms 5Z60, 5Z68, 5Z70, and the interior hallway.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 396 and 503 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 40 and 209 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 1 and 8 dpm/100cm^2; respectively.
- The average scan results for gross beta and gross alpha were 159 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 10 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.8 dpm/100cm^2 for gross alpha and 0.8 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-6-1**

This was a Class 3 survey unit for a laboratory area now converted to offices which encompassed Rooms 6Z60, 6Z68, 6Z70, and the interior hallway.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 268 and 394 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 341 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 7 and 178 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 4 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -2 and 24 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -5 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 141 and 0 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 7 and 10 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.3 dpm/100cm^2 for gross alpha and 0.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-7-1**

This was a Class 2 survey unit encompassing the nuclear pharmacy rooms 7A05, 7A07, and 7A09.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 321 and 558 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 415 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 4 and 263 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 860 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 0 and 12 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -1 dpm/100cm^2.

- The average scan results for gross beta and gross alpha were 268 and -3 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 6 and 10 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.4 dpm/100cm^2 for gross alpha and 175 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-7-2**

This was a Class 3 buffer zone surrounding the nuclear pharmacy and included the Rooms 7F59, 7A01, 7A03, 7B01, 7B02, 7C01, 7C03, 7A19, 7A17, 7A13, 7C07, 7C07A, 7C07B, 7C05, 7A18, 7A16, and certain interior hallways. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 346 and 548 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 326 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 9 and 162 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 222 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1and 12 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 3 dpm/100cm^2.
- The average scan results for gross beta and gross alpha were 116 and -2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 6 and 10 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.9 dpm/100cm^2 for gross alpha and 2.3 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-7-3**

This was a Class 3 survey unit for a laboratory area now converted to offices which encompassed Rooms 7Z60, 7Z68, 7Z70, and the interior hallway. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 393 and 518 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 306 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 4 and 61 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 222 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -2 and 8 dpm/100cm^2; respectively
- The average scan results for gross beta and gross alpha were 225 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 6 and 10 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.1 dpm/100cm^2 for gross alpha and 1.0 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: SU2-7-4**

This was a Class 2 area for the waste storage rooms identified as Rooms 7544 and 7545. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 352 and 523 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 67 and 347 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 1 and 43 dpm/100cm^2; respectively.
- The average scan results for gross beta and gross alpha were 144 and -3 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 8 and 9 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.6 dpm/100cm^2 for gross alpha and 1.3 dpm/100cm^2 for gross beta.

- **Building 2: SU2-7-5**

This was a buffer zone Class 3 for the hallway immediately adjacent to the waste storage identified as Rooms 7544 and 7545. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 498 and 657 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 230 and 341 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 5 and 20 dpm/100cm^2; respectively.
- The average scan results for gross beta and gross alpha were 117 and -2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 9 and 10 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.3 dpm/100cm^2 for gross alpha and 1.0 dpm/100cm^2 for gross beta.

The measurement results were less than the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 2: Roof**

This area was an extension of the nuclear medicine survey area and had the only exhaust ventilation from the seventh floor. All measurements performed here were considered bias measurements.

- The average and maximum integrated direct measurements for betas in the H-3 energy range were 168 and 221 dpm/100cm^2; respectively.
- The average and maximum integrated direct measurements for gross beta were 534 and 747 dpm/100cm^2; respectively.
- The average and maximum integrated direct measurements for gross alpha were 8 and 13 dpm/100cm^2; respectively.
- The average scan results for gross beta and gross alpha were 745 and 2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.

6.4.3 Building 7

During the HSA, the Pathology Laboratories, Department of Clinical Investigation (DCI) was the only group using RAM in Building 7. No work with radioactive materials was ongoing during this survey. The building consists of 4 levels; First Floor to Third Floor plus a Basement and was renovated in 2000. Impacted areas assure coverage of areas where uranyl solutions could have been used in electron microscope work was performed. During the HSA, Room 026 was reported as the only remaining laboratory with RAM usage. All other former research labs with RAM were closed out by HPO prior to extensive building renovation. In carpeted areas, measurements were performed on the floor following removal of carpet. As this area was remodeled, the work surfaces were reviewed for covered or hidden surfaces with negative results. General location drawings for the survey units are shown in Appendix C.

Table 6.6 shows the number of direct measurements performed for H-3, gross alpha, gross beta, and exposure rates for this building and the survey unit.

Table 6.6 Number of Measurements Per Survey Unit in Building 7

Survey Unit	Class	Tritium		Beta		Alpha		Exposure Rate
		MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias	
7-B-1	3	13	3	13	3	13	3	16
7-B-2	3	13	3	13	3	13	3	16
7-B-3	3	13	4	13	4	13	4	17
7-B-4	3	13	3	13	3	13	3	16
7-B-5	3	13	4	13	4	13	4	17
7-B-6	3	13	3	13	3	13	3	16
7-1-1	3	13	3	13	3	13	3	16
7-2-1	3	13	3	13	3	13	3	16
7-2-1	3	13	3	13	3	13	3	16
7-2-3	3	13	3	13	3	13	3	16
7-2-4	3	13	3	13	3	13	3	16

- **Building 7: SU7-B-1**

This Class 3 survey unit was the Laboratory B, room 42. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 383 and 598 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 420 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 21 and 62 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 183 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 4 and 17 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 10 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -19 and -1 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 662 and -2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 12 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.8 dpm/100cm^2 for gross alpha and 1.6 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-B-2**

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 170 and 415 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 296 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -11 and 33 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 83 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 3 and 20 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 17 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 177 and 4 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha

were 700 and 11 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 12 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.1 dpm/100cm^2 for gross alpha and 0.6 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-B-3**

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 282 and 475 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 370 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -23 and 147 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 62 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -19 and 10 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 5 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 251 and 5 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 235 and 19 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 12 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.1 dpm/100cm^2 for gross alpha and 1.9 dpm/100cm^2 for gross beta.

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The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-B-4**

This Class 3 survey unit included rooms 009 and 011 with the related hallways. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 267 and 350 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 325 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 53 and 134 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 277 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 6 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 17 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 171 and -2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 11 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.9 dpm/100cm^2 for gross alpha and 1.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-B-5**

This Class 3 survey unit was the Laboratory D, rooms D-1 and D-2.
The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 219 and 300 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 296 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 16 and 45 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 76 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 1 and 18 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 6 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 164 and 2 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 339 and 27 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 12 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.7 dpm/100cm^2 for gross alpha and 1.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-B-6**

This Class 3 survey unit was the Laboratory A, room 38. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 248 and 379 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 266 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 111 and 170 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 98 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 7 and 14 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 21 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 103 and 9 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 282 and 19 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 11 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.2 dpm/100cm^2 for gross alpha and 1.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-1-1**

This Class 3 survey unit had previously been a laboratory (rooms 108 and 109) but now converted to administrative offices. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 137 and 340 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 276 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 85 and 251 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 103 dpm/100cm^2.

- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 2 and 10 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 20 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 154 and 6 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 11 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.2 dpm/100cm^2 for gross alpha and 1.1 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-2-1**

This Class 3 survey unit had previously been a laboratory (rooms 221 and 222) but now converted to administrative offices. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 247 and 405 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 276 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 30 and 223 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 196 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 4 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -1 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 47 and 1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 10 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.9 dpm/100cm^2 for gross alpha and 1.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-2-2**

This Class 3 survey unit had previously been a laboratory (rooms 209, 218 and 216) but now converted to administrative offices. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 278 and 435 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 435 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 101 and 383 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 286 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 10 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 18 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 25 and 4 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 235 and 19 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 11 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.1 dpm/100cm^2 for gross alpha and -0.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-2-3**

This Class 3 survey unit had previously been Laboratory E. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 196 and 305 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 420 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -56 and 153 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 12 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 5 and 20 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 9 dpm/100cm^2.

- The average floor scan results for gross beta and gross alpha were 87 and 9 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 607 and 6 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 10 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.9 dpm/100cm^2 for gross alpha and 7.6 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 7: SU7-2-4**

This Class 3 survey unit had previously been Laboratory F. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 196 and 355 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 375 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 2 and 72 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 306 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 1 and 12 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 13 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 64 and 1 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 788 and 6 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 9 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.0 dpm/100cm^2 for gross alpha and 1.8 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

6.4.4 Building 38: SU38-0-1

During the HSA, Building 38 was undergoing an extensive renovation and was renamed to "Vacarro Hall" in 2007. In carpeted areas, measurements were performed on the floor following removal of carpet. As this area was remodeled, the work surfaces were reviewed for covered or hidden surfaces with negative results. The building was considered as Class 3 even though none of the original surfaces remain. A general location drawing for the rooms within the building is shown in Appendix C.

Table 6.7 shows the number of direct measurements performed for H-3, gross alpha, gross beta, and exposure rates for this building and the survey unit.

Table 6.7 Number of Measurements Per Survey Unit in Building 38

Survey Unit	Class	Tritium		Beta		Alpha		Exposure Rate
		MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias	
38-3-1	3	13	3	13	3	13	3	16

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 370 and 598 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 365 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -69 and 148 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -18 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 4 and 18 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 43 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 29 and 9 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 10 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.4 dpm/100cm^2 for gross alpha and 0.9 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

6.4.5 Waste Bunkers

Two concrete bunkers immediately south of Building 40 were placed in service after the HSA for storage of short-live radioactive waste from nuclear medicine and research and also for storage of small (µCi quantities) sealed check sources. The origin of the waste was only from Building 2 and Building 54. General location drawings for the survey units are shown in Appendix C.

Table 6.8 shows the number of direct measurements performed for H-3, gross alpha, gross beta, and exposure rates for this building and the survey unit.

Table 6.8 Number of Measurements Per Survey Unit in the Waste Bunkers

Survey Unit	Class	Tritium		Beta		Alpha		Exposure Rate
		MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias	
B-1-1	2	15	0	15		15	0	15
B-1-2	3	0	0	13		13	0	13

- **Waste Bunker: SUB-1-1**

This survey unit consisted of the two concrete bunkers for which the walls, floors and ceilings were made from poured concrete. There was no potential discharge to the environment as the exhaust vents were closed and the exhaust fans had no power during the storage period. The bunkers were classified as MARSSIM Class 2.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 296 and 892 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -56 and 231 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 2 and 18 dpm/100cm^2; respectively
- The average floor scan results for gross beta and gross alpha were 0 and 3 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 132 and 5 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 2 and 5 µR/hour which was indicative of background levels.

- The maximum results of smear measurements were 0.1 dpm/100cm^2 for gross alpha and 3.9 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Waste Bunker: SUB-1-2**

This survey unit consisted of the access road/parking lot immediately outside and adjacent to the Waste Bunkers. It was added as buffer zone Class 3 area to the Class 2 storage areas.

The following summary of measurement results for this survey unit is provided:

- Integrated direct measurements for H-3 betas could not be collected due to the uneven asphalt surface.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 2 and 177 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 0 and 16 dpm/100cm^2; respectively
- The average floor scan results for gross beta and gross alpha were 101 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 2 and 5 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were -0.3 dpm/100cm^2 for gross alpha and 1.6 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

6.4.6 Building 41

The original tenant was the Red Cross; however, during the HSA, the building was being used for instructional purposes, an Outpatient Clinic, and the Health Physics Offices. The building consists of three levels: Ground Level, First Floor, and Second Floor. In the carpeted area of the hallway, measurements were performed on the floor following removal of carpet. As this area was remodeled, the work surfaces were reviewed for covered or hidden surfaces with negative results. No work with radioactive materials was ongoing during this survey. General location drawings for the survey units are shown in Appendix C.

Table 6.9 shows the number of direct measurements performed for H-3, gross alpha, gross beta, and exposure rates for this building and the survey unit.

Table 6.9 Number of Measurements Per Survey Unit in Building 41

Survey Unit	Class	Tritium		Beta		Alpha		Exposure Rate
		MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias	
41-G-1	2	15	3	15	3	15	3	16
41-G-2	2	13	0	13	0	13	0	13
41-G-3	3	13	0	13	0	13	0	13

- **Building 41: SU41-G-1**

Room 39 was the HPO counting lab and was the only location at WRAMC authorized to use Am-241 and Pu-239. The MARSSIM Classification is 2.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 398 and 538 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 356 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -30 and 107 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 87 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 7 and 19 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 0 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 197 and 0 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 699 and 16 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 10 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.5 dpm/100cm^2 for gross alpha and 5.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 41: SU41-G-2**

Room 42 was used for receipt of RAM, source storage, temporary radioactive waste storage, and instrumentation. The MARSSIM Classification is 2. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 281 and 593 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 1 and 400 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 20 dpm/100cm^2; respectively.
- The average floor scan results for gross beta and gross alpha were 154 and 6 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 11 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were -0.1 dpm/100cm^2 for gross alpha and 3.4 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 41: SU41-G-3**

This was the hallway which would be the transport route to Room 42 for RAM receipt and inspection. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -55 and 82 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -3 and 7 dpm/100cm^2; respectively.
- The average floor scan results for gross beta and gross alpha were 69 and 16 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 11 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were -0.1 dpm/100cm^2 for gross alpha and 2.1 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release

by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

6.4.7 Building 54

The building consists of 8 levels: First Floor through Fifth Floor, with Ground level, Basement level, and Sub-Basement level. Several floors of Building 54 had undergone significant renovation. New room configuration and numbering schemes did not match rooms as listed in some authorizations. The Fourth and Fifth floors had been renovated as of the HSA site visit. General location drawings for the survey units are shown in Appendix C.

In carpeted areas, measurements were performed on the floor following removal of carpet. As this area was remodeled, the work surfaces were reviewed for covered or hidden surfaces with negative results.

HPO closeout survey records were available for the following rooms: 1028, 1030, 2008, 3012, 5007, 5044, and 5050; however, these room were also considered impacted.

There were records of electron microscope usage in Building 54. Therefore, uranium was added to the ROC list since uranyl solutions were typically used as a staining agent for these purposes. The listed impacted rooms are B045, B063, B067, M093B, 3002-3008, 3010/3012, 3078, 3108, 3118, and 3061B, and N4202:

Table 6.10 shows the number of direct measurements performed for H-3, gross alpha, gross beta, and exposure rates for this building and the survey unit.

Table 6.10 Number of Measurements Per Survey Unit in Building 54

Survey Unit	Class	Tritium		Beta		Alpha		Exposure Rate
		MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias	
54-B-1	3	13	2	13	2	13	2	15
54-B-2	3	13	40	13	40	13	40	53
54-B-3	3	13	15	13	15	13	15	28
54-M-1	3	13	16	13	15	13	15	28
54-M-2	3	13	2	13	2	13	2	15
54-G-1	3	13	2	13	2	13	2	15
54-G-2	3	13	2	13	2	13	2	15
54-G-3	3	13	2	13	2	13	2	15
54-G-4	3	13	9	13	9	13	9	21
54-1-1	3	13	1	13	1	13	1	14
54-1-2	3	13	2	13	2	13	2	15
54-1-3	3	13	27	13	27	13	27	40
54-2-1	3	13	1	13	1	13	1	14
54-2-2	3	13	11	13	11	13	11	24
54-2-3	3	13	12	13	12	13	12	25
54-2-4	1	22	0	22	0	22	0	23
54-3-1	3	13	13	13	13	13	13	26
54-3-2	3	13	5	13	5	13	5	18
54-3-3	3	13	3	13	3	13	3	16
54-3-4	3	13	31	13	31	13	31	44
54-3-5	3	13	4	13	4	13	4	17
54-3-6	3	13	6	13	6	13	6	19
54-4-1	3	13	1	13	1	13	1	14
54-4-2	3	13	10	13	10	13	10	23
54-4-3	3	13	17	13	17	13	17	30
54-4-4	3	13	10	13	10	13	10	23
54-5-1	3	13	8	13	8	13	8	21
54-5-2	3	13	8	13	8	13	8	21
54-5-3	3	13	5	13	5	13	5	18

- **Building 54: SU54-B-1**

This survey unit consisted of rooms B092, B098 and the hallway providing access to them. These rooms were reported to have RAM use. This survey unit was a Class 3.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 537 and 1626 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 368 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -117 and 173 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 266 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -5 and 6 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 1 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 4 and 1 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 735 and 5 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 11 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.7 dpm/100cm^2 for gross alpha and 3.6 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-B-2**

This survey unit included rooms B045, B063 which were reported to have RAM use. This survey unit was designed to investigate potential use of uranyl solutions with electron microscope or other undocumented RAM use. This survey unit was a Class 3.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 298 and 629 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 688 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 30 and 619 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 815 dpm/100cm^2.

- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 4 and 16 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 13 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 297 and 1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 11 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.2 dpm/100cm^2 for gross alpha and 4.0 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-B-3**

As a reference to an abandoned firing range with the potential for depleted uranium as ammunition was made in the HSA, a survey unit was made of the area. The survey unit included the rooms B018, B019, B028, B030, B030A, B030B, B031 and any related hallways.

This survey unit was a Class 3.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 201 and 314 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 281 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -186 and -68 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 212 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 0 and 12 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 12 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -3 and 1 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 107 and 5 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 6 and 11 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.3 dpm/100cm^2 for gross alpha and 2.3 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release

by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-M-1**

This survey unit covering the north wing on this floor of the building was a Class 3 and its perimeter was made large to investigate the potential use of uranyl solutions with electron microscope work or other undocumented RAM use. It included rooms M093A, M093B, M093F, M109, M111, and M124A which were known RAM use rooms.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 174 and 335 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 1654 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -196 and 122 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 408 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 0 and 10 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 16 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 6 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 9 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 8.0 dpm/100cm^2 for gross alpha and 6.6 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-M-2**

This survey unit covering the south wing on this floor of the building was a Class 3. The AFIP museum was located here and all areas of the south wing were included due to the potential movement of museum pieces which might contain RAM including uranyl solutions for electron microscope displays or other displays containing RAM.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 229 and 500 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 971 dpm/100cm^2.

- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -256 and 127 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -317 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 0 and 3 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -1 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 125 and 1 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 735 and 5 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 9 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.1 dpm/100cm^2 for gross alpha and -2.0 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-G-1**

This was a Class 3 survey unit in the north wing which included rooms G127, G135, G139, G128, G117, G134, G119, G115, G107, G1O4, G110 and the hallway (G116). None of these rooms were identified with RAM use but were made into a survey unit to investigate the potential use of uranyl solutions with electron microscope work or other undocumented RAM use.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 306 and 647 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 738 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -185 and -48 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -70 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 3 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -1 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 10and 1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 7 and 12 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.8 dpm/100cm^2 for gross alpha and 0.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-G-2**

This was a Class 3 survey unit in the north wing which included rooms G139, G140, G090, G083, G086A, G086B, G086C, G083, G081, and associated hallways. None of these rooms were identified with RAM use but were made into a survey unit to investigate the potential use of uranyl solutions with electron microscope work or other undocumented RAM use.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 206 and 629 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 644 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 109 and 848 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 464 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -3 and 8 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -6 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 27 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 12 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.8 dpm/100cm^2 for gross alpha and -1.7 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-G-3**

This was a Class 3 survey unit in the south wing which included the only rooms with documented RAM use on this floor. The rooms included were G014, G075, G075A and the Hall (G077). This survey unit was designed to investigate potential use of uranyl solutions with electron microscope work or other undocumented RAM use.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 215 and 688 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 310 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -176 and 6 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -140 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -3 and 12 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 18 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -8 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 6 and 12 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.9 dpm/100cm^2 for gross alpha and 2.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-G-4**

This was a Class 3 survey unit which covered the majority of the south wing. None of these rooms were identified with RAM use. This survey unit was designed to investigate potential use of uranyl solutions with electron microscope work or other undocumented RAM use. Rooms randomly selected for survey locations included GO23, G035c, G037, G051, G066F, G066C, G066, G055, G071 and G065. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 220 and 359 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 256 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -183 and 76 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 282 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 0 and 8 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 16 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 81 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 12 μR/hour which was indicative of background levels.

- The maximum results of smear measurements were 0.9 dpm/100cm^2 for gross alpha and -1.9 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-1-1**

This survey unit covered the northern half of the north wing of the floor. Survey measurement locations were selected randomly and were identified with rooms 1103, 1108, 1112, 1117, 1614, 1612, 1610, 1113, 1604, and 1609. This was a Class 3 survey unit which was designed to investigate potential use of uranyl solutions with electron microscope work or other undocumented RAM use.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 151 and 221 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 932 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -54 and 350 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 16 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 1 and 14 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -55 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 42 and -2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 7 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.5 dpm/100cm^2 for gross alpha and 2.1 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-1-2**

This survey unit covered the southern half of the north wing of the floor. Survey measurement locations were selected randomly and were identified with rooms 1503, 1506B, 1507, 1504, 1509, 1513, 1205, 1209, 1211, 1213, and 1214. This was a Class 3 survey unit which was

designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 77 and 181 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 877 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -178 and 208 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 401 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 1 and 8 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -28 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 10 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 7 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.7 dpm/100cm^2 for gross alpha and 1.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-1-3**

This survey unit covered the south wing of the floor. Survey measurement locations were selected randomly and were identified with rooms 1054, 1052, 1050, 1048, 1046, 1036, 1032, 1030, 1028, 1029, and 1057. This was a Class 3 survey unit which was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use.

- **Building 54: SU54-2-1**

This survey unit covered the northern half of the north wing of the floor. Survey measurement locations were selected randomly and were identified with rooms 2062, 2060, 2076, 2074, 2072A, 2106, 2096, 2094, 2061, and 2090. This was a Class 3 survey unit which was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 82 and 758 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 57 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -247 and -46 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -26 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 3 and 8 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 2 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 23 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 6 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.0 dpm/100cm^2 for gross alpha and 0.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-2-2**

This survey unit covered the southern half of the north wing of the floor. Survey measurement locations were selected randomly and were identified with rooms 2067, 2065, 2066, 2068, 2056, 2012, 2006, 2008, and 2014. This was a Class 3 survey unit which was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 41 and 219 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 52 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -234 and -103 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 119 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -4 and -1 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 11 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -28 and -2 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 166 and 1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 6 µR/hour which was indicative of background levels.

- The maximum results of smear measurements were 0.7 dpm/100cm^2 for gross alpha and 18.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-2-3**

This survey unit covered the south wing of the floor. Survey measurement locations were selected randomly and were identified with rooms 2050, 2048, 2044, 2042, 2026, 2028, 2030, and 2032. This was a Class 3 survey unit which was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were -19 and 123 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 162 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -207 and 138 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 123 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -3 and -1 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 6 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 83 and -1 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 418 and 1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 6 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.9 dpm/100cm^2 for gross alpha and 2.7 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-2-4**

Room 2094 was designated a Class 1 survey unit as it previously contained a small area (a floor tile) identified with alpha contamination of 360 dpm/100 cm^2 and beta contamination 15k dpm/100 cm^2. The elevated area was found under a sink during site characterization as part of the extended survey effort to identify residual contamination from potential use of uranyl solutions. Several tiles were removed in order to ensure no residual contamination remained below the tiles. WRAMC HP Office handled removal and disposal of the characterization IDW. No bias measurements were taken in this survey unit as results of the 100% scan survey did not indicate any potential need.
The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 109 and 224 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -138 and 158 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 3 and 14 dpm/100cm^2; respectively.
- The average floor scan results for gross beta and gross alpha were 125 and 1 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 735 and 5 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 6 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.4 dpm/100cm^2 for gross alpha and 1.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-3-1**

This was a Class 3 survey unit in the north wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 3099, 3100, 3104, 3110, 3112, 3112A, 3111, and 3115.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 220 and 360 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 206 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -152 and 122 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -2 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -8 and 4 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 14 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 31 and -3 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 379 and 0 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 7 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.7 dpm/100cm^2 for gross alpha and 2.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-3-2**

This was a Class 3 survey unit in the north wing of the floor which was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 3095, 3095A, 3075, 3083, 3080, 3086, and 3087. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 135 and 209 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 121 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -69 and 185 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -60 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 6 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 5 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -44 and -2 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 244 and -1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 7 µR/hour which was indicative of background levels.

- The maximum results of smear measurements were 0.5 dpm/100cm^2 for gross alpha and 7.9 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-3-3**

This was a Class 3 survey unit in the north wing of the floor which was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 3001, 3005, 3009, 3015, 3016, 3067, and 3071.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 183 and 300 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 23 and 163 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 72 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -12 and 12 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 9 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 78 and 0 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 254 and 1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 7 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.0 dpm/100cm^2 for gross alpha and 1.6 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-3-4**

This was a Class 3 survey unit in the north wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the

potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 3002, 3004, 3006, 3008, 3010, 3012, 3014, 3060, and 3068. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 70 and 155 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 157 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -264 and -66 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 33 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 2 and 12 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 14 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -24 and 3 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 551 and 13 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 7 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.1 dpm/100cm^2 for gross alpha and 2.9 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-3-5**

This was a Class 3 survey unit in the south wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 3030, 3032, and 3034.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 97 and 140 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 221 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -244 and -54 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 49 dpm/100cm^2.

- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -3 and 12 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 4 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 14 and -2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 7 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.6 dpm/100cm^2 for gross alpha and 2.4 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-3-6**

This was a Class 3 survey unit in the south wing of the floor which was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. It surrounded the area SU54-3-5 which was known to have RAM use. Survey measurement locations were selected randomly and were identified with rooms 3026, 3028, 3036, 3044, 3048, 3050, and 3052. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 89 and 160 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 186 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 244 and 552 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 256 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 5 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 14 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -9 and -1 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 365 and 2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 4 and 7 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.1 dpm/100cm^2 for gross alpha and 4.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release

by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-4-1**

This was a Class 3 survey unit in the south wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with room 4613 and the adjacent hallway.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 61 and 161 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 151 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 203 and 340 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 306 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -2 and 8 dpm/100cm^2; respectively. For bias measurements, the highest measurement was -2 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -97 and -2 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 127 and 5 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 4 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.6 dpm/100cm^2 for gross alpha and 1.1 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-4-2**

This was a Class 3 survey unit in the south wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 4604, 4606, 4608, 4612, 4614, 4616, and 4618. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 28 and 116 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 146 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 154 and 422 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 41 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 8 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 10 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -112 and 0 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 373 and 4 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 4 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 2.0 dpm/100cm^2 for gross alpha and 12.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-4-3**

This was a Class 3 survey unit in the south wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 4204, 4205, 4209, 4210, 4214, and 4504. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 142 and 494 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 594 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -224 and -6 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 594 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -1 and 10 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 12 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 85 and 0 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 805 and 13 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.

- The range of results of exposure rate measurements was between 3 and 4 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 2.2 dpm/100cm^2 for gross alpha and 9.8 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-4-4**

This was a Class 3 survey unit in the south wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 4312, 4314, 4404, and 4405. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 98 and 286 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 156 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -171 and 72 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 37 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -3 and 2 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 8 dpm/100cm^2.
- The average floor items scan results for gross beta and gross alpha were -70 and 0 dpm/100cm^2; respectively. The average non-floor items scan results for gross beta and gross alpha were 444 and 4 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 4 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.1 dpm/100cm^2 for gross alpha and 3.4 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-5-1**

This was a Class 3 survey unit in the south wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 5100, 5101, 5104, 5102, 5105, 5107, and 5112. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 81 and 220 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 221 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 7 and 663 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 6 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -3 and 6 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 15 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -36 and 2 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 505 and 21 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 9 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 1.1 dpm/100cm^2 for gross alpha and 6.3 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-5-2**

This was a Class 3 survey unit in the south wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 5206, 5201, 5208, 5205, 5209, and 5301. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 250 and 594 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 271 dpm/100cm^2.

- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 52 and 323 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 263 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -10 and 10 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 1 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 47 and -3 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 761 and -2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 9 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.7 dpm/100cm^2 for gross alpha and 2.7 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: SU54-5-3**

This was a Class 3 survey unit in the south wing of the floor. Even though documented use of RAM occurred in certain rooms within this survey unit, it was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. Survey measurement locations were selected randomly and were identified with rooms 5302, 5311, 5307, and 5309. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 100 and 266 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 236 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -134 and 531 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 138 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -3 and 6 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 17 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -49 and -2 dpm/100cm^2; respectively. The average scan results for non-floor items of gross beta and gross alpha were 383 and 6 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 3 and 8 μR/hour which was indicative of background levels.

- The maximum results of smear measurements were 1.1 dpm/100cm^2 for gross alpha and 3.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 54: Roof**

This area was located on the south section of the building and included an evaluation of the entire air exhaust system. All measurements performed here were considered bias measurements.

- The average and maximum integrated direct measurements for betas in the H-3 energy range were 154 and 221 dpm/100cm^2; respectively.
- The average and maximum integrated direct measurements for gross beta were 265 and 537 dpm/100cm^2; respectively.
- The average and maximum integrated direct measurements for gross alpha were 7 and 11 dpm/100cm^2; respectively.
- The average scan results for gross beta and gross alpha were 403 and 0 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.

6.4.8 Building 91

Building 91 consisted of 2 levels, ground level and a first floor. RAM use was only documented in Room 2 on the first floor but terminated in Oct. 1991. As this area was remodeled, the work surfaces were reviewed for covered or hidden surfaces with negative results. It now houses administrative departments. In carpeted areas, measurements were performed on the floor following removal of carpet. As this area was remodeled, the work surfaces were reviewed for covered or hidden surfaces with negative results. General location drawings for the survey units are shown in Appendix C.

Table 6.11shows the number of direct measurements performed for H-3, gross alpha, gross beta, and exposure rates for this building and the survey unit.

Table 6.11 Number of Measurements Per Survey Unit in Building 91

Survey Unit	Class	Tritium		Beta		Alpha		Exposure Rate
		MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias	
91-G-1	3	13		13	3	13	3	16
91-1-1	3	13		13	1	13	1	14
91-1-2	3	13		13	1	13	1	14

- **Building 91: SU91-G-1**

This survey unit was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use or other work with RAM. This survey unit was a Class 3 which encompassed area on the entire ground floor that could have been a lab before remodeling. One original wall was discovered under drywall and sections were removed for radiological survey. The room numbers were not legible on the original drawings but were numbered 1-10 for this survey.

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 390 and 598 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 250 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -16 and 408 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 268 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -4 and 13 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 1 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were 57 and -2 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 8 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were -0.5 dpm/100cm^2 for gross alpha and 0.9 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 91: SU91-1-1**

This Class 3 survey unit was the area designated as Room 2 with documented use of RAM. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 271 and 552 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 251 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -125 and 50 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -4 and 17 dpm/100cm^2; respectively.
- The average floor scan results for gross beta and gross alpha were 43 and 5 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 6 and 8 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were -0.5 dpm/100cm^2 for gross alpha and -0.8 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 91: SU91-1-2**

This Class 3 survey unit was designed to investigate the potential use of uranyl solutions from electron microscope work or undocumented RAM use. The room numbers were not legible on the original drawings but were numbered 1-9 for this survey. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 239 and 299 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 291 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -124 and 2 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were -5 and 18 dpm/100cm^2; respectively.
- The average floor scan results for gross beta and gross alpha were 45 and 0 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 8 μR/hour which was indicative of background levels.
- The maximum results of smear measurements were -0.8 dpm/100cm^2 for gross alpha and -0.3 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

6.4.9 Building 92

Building 92 was a single story, brick building added to the northeast wing of Building 1 in 1954 as the Nuclear Medicine Clinic. It had a direct entrance into the basement level of Building 1. As this area was remodeled for administrative services, the work surfaces were reviewed for covered or hidden surfaces with negative results. In carpeted areas, measurements were performed on the floor following removal of carpet. As this area was remodeled, the work surfaces were reviewed for covered or hidden surfaces with negative results. General location drawings for the survey units are shown in Appendix C.

One RAM storage area which contained a shielded Lazy Susan was covered over with dry wall which was removed and surveyed as a Class 1. The Lazy Susan itself was removed, cleared and disposed of by WRAMC HP Office.

Table 6.12 shows the number of direct measurements performed for H-3, gross alpha, gross beta, and exposure rates for this building and the survey unit.

Table 6.12 Number of Measurements Per Survey Unit in Building 92

Survey Unit	Class	Tritium		Beta		Alpha		Exposure Rate
		MARSSIM Required	Bias	MARSSIM Required	Bias	MARSSIM Required	Bias	
92-G-1	3	13		13	3	13	3	16
92-G-2	3	13		13	3	13	3	16
92-G-3	3	13		13	1	13	1	14
92-G-4	1	13		13		13		13

- **Building 92: SU92-G-1**

This Class 3 survey unit consisted of rooms 12, 16, 18 and the adjacent hallway. The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 261 and 335 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 320 dpm/100cm^2.

- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 48 and 332 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 21 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 5 and 14 dpm/100cm^2; respectively.
- The average floor scan results for gross beta and gross alpha were 90 and 1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 8 and 10 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were -0.2 dpm/100cm^2 for gross alpha and -0.4 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 92: SU92-G-2**

This Class 3 survey unit consisted of rooms 6, 7, 9, 10, 11, 13, 17 and the adjacent hallway.
The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 342 and 598 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 355 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 33 and 200 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 21 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 5 and 14 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 35 dpm/100cm^2.
- The average floor scan results for gross beta and gross alpha were -71 and 1 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 5 and 9 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were 0.1 dpm/100cm^2 for gross alpha and 1.2 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 92: SU92-G-3**

The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 319 and 488 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 261 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were -139 and 22 dpm/100cm^2; respectively. For bias measurements, the highest measurement was 661 dpm/100cm^2.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 5 and 10 dpm/100cm^2; respectively
- The average floor scan results for gross beta and gross alpha were -13 and 0 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 6 and 8 µR/hour which was indicative of background levels.
- The maximum results of smear measurements were -0.8 dpm/100cm^2 for gross alpha and 0.5 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

- **Building 92: SU92-G-4**

This was the Class 1 survey unit which was a hidden closet previously used for RAM storage.
The following summary of measurement results for this survey unit is provided:

- For MARSSIM required measurements, the average and maximum integrated direct measurements for betas in the H-3 energy range were 354 and 483 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross beta were 267 and 768 dpm/100cm^2; respectively.
- For MARSSIM required measurements, the average and maximum integrated direct measurements for gross alpha were 16 and 35 dpm/100cm^2; respectively
- The average floor scan results for gross beta and gross alpha were 422 and 34 dpm/100cm^2; respectively. There were no sustained elevated measurements that would indicate a small elevated area.
- The range of results of exposure rate measurements was between 8 and 16 µR/hour which was indicative of background levels for a small three sided brick structure.
- Results of smear measurements were less than MDA values of 8 dpm/100cm^2 for gross alpha and 20 dpm/100cm^2 for gross beta.

The conservative measurement results were less the DCGLs. Results from exposure rate, scan, static and smear measurements indicate the survey unit meets the criteria for unrestricted release by rejecting the null hypothesis which assumes contamination is present above the limit. As no individual result exceeded the release criteria, no additional statistical test was needed.

6.5 Recommendations

All impacted building surfaces were surveyed or evaluated for residual radioactivity and are recommended for delisting in license termination pursuant to Title 10, Code of Federal Regulations, Part 20, Standards for Protection Against Radiation, Subpart E-Radiological Criteria for License Termination.

This survey also included an evaluation of three clinical linear accelerator rooms (CLINAC) in Building 2, and two CLINACS were present at the time of survey. No residual surface contamination was identified in the rooms; however, an unquantifiable, potentially activated volume was identified in the heads of both LINACs. Disposition and control of the LINACs is beyond the scope of this survey. Army is currently planning removal of the CLINACS from the building.

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Appendix A

Supporting HSA Documents

(Supporting Interviews, Inventory Receipts, Leak Tests)

(Provided in attached electronic format.)

Appendix B

Computer Runs

(Microshield and RESRAD Printouts)

(Provided in attached electronic format.)

Appendix C

Building and Survey Unit Diagrams with Results

(Provided in attached electronic format.)

Appendix D

Procedure Listing

(Provided in attached electronic format.)

Appendix E

Calibration Sheets and Performance Checks

(Provided in attached electronic format.)

Appendix F

Laboratory Results

(Provided in attached electronic format.)

Appendix G

Evaluation of Varian CLINACs

(Provided in attached electronic format.)

Appendix H

Historical Site Assessment

(Provided in attached electronic format.)