US Army Corps
of Engineers
New York District

FINAL

FINAL STATUS SURVEY REPORT

FORT MONMOUTH
EATONTOWN, NEW JERSEY

15 August 2012

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (USACE) has developed this radiological Final Status Survey Report (FSSR) to support radiological closure of properties on Fort Monmouth in Eatontown and Tinton Falls, New Jersey. This FSSR reports the results of radiological surveys implemented in accordance with the USACE Radiological Scoping Survey Plan (RSSP), issued as final in June 2012 (USACE, 2012a). Radiological surveys were performed in June 2012 to secure unrestricted radiological release and facilitate transfer of real property as part of Base Realignment and Closure (BRAC).

The USACE RSSP and this final status survey (FSS) were designed based on information from the Final Phase I Historical Site Assessment (HSA) (CABRERA, 2007a), the Final Phase II Environmental Condition of Property Investigation (CABRERA, 2007b), and the HSA supplement developed by USACE in 2012 (USACE, 2012b). The FSS was designed using the approach outlined in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (U.S. Nuclear Regulatory Commission [NRC], 2000) and incorporates Department of the Army, Army Materiel Command (AMC) guidance (AMC, 2004), as applicable. The "scoping surveys" described in the USACE RSSP were designed in accordance with MARSSIM FSS requirements in order to generate sufficient information to release areas confirmed to be free of residual contamination for unrestricted use.

Approximately 25 buildings, building complexes, and/or open areas were identified in the HSA as areas where radioactive materials (RAM) were used or stored. Based on the information collected, the HSA classified four of the buildings as MARSSIM impacted. Information obtained subsequent to the HSA, and documented in the HSA Supplement (USACE, 2012b), resulted in classification of an additional building as MARSSIM impacted (total of five): Buildings 275, 283, 292, 2540 and 2541.

Radiological FSSs were performed in Buildings 275, 283, 292, 2540 and 2541. The surveys were designed in accordance with MARSSIM final status survey design criteria using conservative assumptions. Derived concentration guideline levels (DCGLs) applied to the surveys are the conservative NRC generic screening criteria. The sum of the ratios (SOR) rule was applied to all survey results to address the potential presence of multiple radionuclide contaminants. All SOR results in all buildings, including biased locations, are less than the limit of SOR = one. In addition, evaluations of building systems (drain and ventilation) for radioactive contaminants did not identify any radiological impacts to building systems. Based on historical research and the FSS field observations and supporting laboratory analytical data, all buildings surveyed are considered suitable for unrestricted release in accordance with Subpart E to 10 CFR 20, Radiological Criteria for License Termination.

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ACRONYMS

^{241}Am	Americium-241
^{252}Cf	Californium-252
^{14}C	Carbon-14
^{137}Cs	Cesium-137
^{36}Cl	Chlorine-36
^{57}Co	Cobalt-57
^{60}Co	Cobalt-60
^{154}Eu	Europium-154
^{63}Ni	Nickel-63
^{238}Pu	Plutonium-238
^{147}Pm	Promethium-147
^{226}Ra	Radium-226
^{90}Sr	Strontium-90
^{99}Tc	Technetium-99
^{230}Th	Thorium-230
^{232}Th	Thorium-232
^{3}H	Tritium
^{90}Y	Yttrium-90
AMC	Army Materiel Command
ARA	Army Radiation Authorizations
BRAC	Base Realignment and Closure
CABRERA	Cabrera Services, Inc.
CECOM	U.S. Army Communications-Electronics Command
CFR	U.S. Code of Federal Regulations
cm^2	Square Centimeter
COC	Chain of Custody
cpm	Counts per Minute
CQC	Contractor Quality Control
CSM	Conceptual Site Model
DCF	Dose Conversion Factor
DCGLor $DCGL_W$	Derived Concentration Guideline Level
DoD	Department of Defense
dpm/100 cm^2	Disintegrations per Minute per 100 Square Centimeters
DQCR	Daily Quality Control Report
ECP	Environmental Condition of Property
ELAP	Environmental Laboratory Accreditation Program
FSS	Final Status Survey
FSSR	Final Status Survey Report
ft	Foot
ft^2	Square feet
HEPA	High Efficiency Particulate Air
HP	Health Physicist
HSA	Historical Site Assessment
IDW	Investigation-derived waste
LBGR	Lower Bound of Gray Region
LCS	Laboratory Control Sample

LCSD	Laboratory Control Sample Duplicate
LSC	Liquid Scintillation Counter
m	meters
m^2	Square Meters
μR/hr	Micro-Roentgen per Hour
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC or MDC_{SCAN}	Minimum Detectable Concentration
MDA	Minimum detectable activity
MeV	Mega Electron Volts
min	minute
mrem/yr	Millirem Per Year
NAD	Normalized Absolute Difference
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
PCBs	Polychlorinated Biphenyls
PM	Project Manager
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
R&D	Research and Development
RAM	Radioactive materials
RCOPC	Radionuclide Contaminant of Potential Concern
RSC	Radiation Safety Committee
RSSP	Radiological Scoping Survey Plan
sec	Second
SOP	Standard Operating Procedure
SOR	Sum of the Ratios
SU	Survey Unit
U.S.	United States
USACE	U. S. Army Corps of Engineers

1.0 PROJECT DESCRIPTION

The U.S. Army Corps of Engineers (USACE) has developed this radiological Final Status Survey Report (FSSR) to support radiological closure of properties on Fort Monmouth in Eatontown and Tinton Falls, New Jersey. This FSSR reports the results of radiological surveys implemented in accordance with the USACE Radiological Scoping Survey Plan (RSSP), issued as final in June 2012 (USACE, 2012a). Radiological surveys were performed in June 2012 to secure unrestricted radiological release and facilitate transfer of real property as part of Base Realignment and Closure (BRAC). Figure 1 identifies the location of Fort Monmouth (figures are located at the end of this FSSR, after the References Section).

The USACE RSSP and this final status survey (FSS) were designed based on information from the Final Phase I Historical Site Assessment (HSA) (CABRERA, 2007a), the Final Phase II Environmental Condition of Property Investigation (CABRERA, 2007b), and the HSA supplement developed by USACE in 2012 (USACE, 2012b). The FSS was designed using the approach outlined in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (U.S. Nuclear Regulatory Commission [NRC], 2000) and incorporates Department of the Army, Army Materiel Command (AMC) guidance (AMC, 2004), as applicable. The “scoping surveys” described in the USACE RSSP were designed in accordance with MARSSIM FSS requirements in order to generate sufficient information to release areas confirmed to be free of residual contamination for unrestricted use.

The Army intends to release all facilities and areas at Fort Monmouth for unrestricted use. As part of the BRAC process, the type and location of potential hazards must be identified, and mitigated if necessary, prior to release. This FSSR demonstrates that all areas are suitable for unrestricted radiological release and that mitigation of radiological hazards is unnecessary.

This FSSR summarizes HSA findings, repeats substantive requirements of the RSSP, and presents the results of the radiological surveys performed with minimal information incorporated by reference. This minimizes the need to lookup information in supporting reference documents, facilitating primary review of a single document.

1.1 Background

Fort Monmouth was identified as one of the military installations slated for closure as part of BRAC 2005 (Public Law 101-510 as amended). BRAC is the process by which the nation reshapes its military installations to become more efficient and effective in supporting its forces. As part of this process, an Environmental Condition of Property (ECP) assessment was completed for Fort Monmouth. The ECP assists the Army in evaluation of the type and locations of potential radiological hazards at the facility and the surrounding environment. This FSSR presents the results of radiological surveys performed to specifically address areas identified in the HSA (as supplemented) that performed former operations involving radioactive materials (RAM) falling under NRC licenses, or under Department of the Army Radiation Authorizations (ARAs). The applicable NRC licenses and ARAs are summarized in the HSA.

The overall project intent is to plan, perform, and document radiological decommissioning efforts to allow release of facilities for "unrestricted release". This phase and previous phases include: 1) the identification of known sources/areas of radioactive contamination; 2) identification of areas that need further action; 3) assessment of the likelihood of contaminant migration; 4) identification of areas as impacted or non-impacted in accordance with MARSSIM; 5) identification of data gaps in impacted areas; 6) determination of the radiological status of the impacted areas through performance of final status surveys; and 7) demonstration that all areas are suitable for unrestricted radiological release.

1.2 Summary of Historical Site Assessment

A final HSA was prepared in support of the Environmental Condition of Property assessment based on document review, personal observation, and interviews with personnel at Fort Monmouth (CABRERA, 2007a). In addition, a supplement to the HSA was developed by USACE to summarize additional information (USACE, 2012b).

The HSA reviewed available information regarding Fort Monmouth, including operating history, survey results, and potential pathways for radioactive and hazardous material release. Information sources reviewed included:

- Fort Monmouth operating history, including RAM licenses, permits, and use authorizations and protocols;
- Minutes of the Fort Monmouth Radiation Safety Committee (RSC) for reference to any spills, releases of radioactive material to the environment surrounding the Site during facility operations, and onsite disposals of radioactive or hazardous materials;
- Surveys for RAM present at Fort Monmouth;
- Physical tours of the Fort Monmouth facilities expected to be impacted due to both current (then current) and former RAM usage;
- Off-installation document repositories including the NRC Public Document Room, U.S. Army Public Health Command, and U.S. Army Field Support Command.

As part for the HSA process, Interviews were conducted and documented with 35 personnel from varying groups, including:

- Facility Management
- Security
- Department of Public Works

- U.S. Army Communications-Electronics Command (CECOM) Radiation Analysis and Compliance Division and Laboratory/Research and Development (R&D) Operations
- Museum Operations
- Postal Operations
- Industrial Hygiene and Safety
- Supply Management

Approximately 25 buildings, building complexes, and/or open areas were identified in the HSA as areas where RAM were used or stored. Based on the information collected, the HSA classified four of the buildings as MARSSIM impacted. Information obtained subsequent to the HSA, and documented in the HSA Supplement, resulted in classification of an additional building as MARSSIM impacted (total of five buildings). The impacted buildings are discussed in Section 1.3 and shown in Figures 2 and 3.

1.2.1 Site History

Fort Monmouth is located 12 miles west of the Atlantic Ocean and 45 miles south of New York City, just north of Eatontown in Monmouth County, New Jersey (Figure 1). Military operations began at this installation in 1917. Documents gathered from various sources were reviewed and evaluated to extract information on the possession and use of RAM. These documents included licenses, permits, authorizations, inventory records, surveys, historical drawings, and floor plans. In addition, the HSA included a visual inspection of all buildings and areas where RAM was used or stored, and interviews with individuals knowledgeable of RAM handling, storage, and disposal. The use of RAM at Fort Monmouth was historically conducted in accordance with a number of NRC licenses and ARAs.

The presence of RAM at Fort Monmouth has been predominantly limited to certain areas and functions of the installation. Historically, laboratory R&D in the areas of radio and electronics use of vacuum tubes and radium dials, and military support equipment such as night vision goggles that contain radioactive commodities have been the most common uses of RAM at Fort Monmouth. Some of the past activities involving RAM were performed as part of the Signal Corps Laboratories, first housed in the Squier Building (Building 283) and then in the Myers Center. The majority of work with RAM was performed by CECOM under license with the NRC in Building 2540. Other work was performed in the Evans Area of the base, which was closed in the late 1990s due to BRAC 1993 activities, and the work then transferred to the CECOM office and laboratory in the Charles Wood Area.

At the time the HSA was finalized (in 2007), a research laboratory in Building 2540 in the Charles Wood Area was the only site to regularly use and store RAM as part of R&D activities. A designated storage area was set aside for drums containing material waiting for disposal, including tritium exit signs removed from Fort Monmouth buildings, smoke alarms containing

RAM, and other instruments with associated check sources. These items were periodically removed to Wright Patterson Air Force Base for disposal/recycling. At this time, all work involving RAM at Building 2540 has ceased and all RAM have been removed from the facility.

The administrative arm of the CECOM Safety Office was housed in the adjacent building, 2539, prior to relocating to Aberdeen Proving Ground in Maryland. The Safety Office maintains files pertaining to the use of any RAM on the installation as well as active and inactive NRC licenses and ARAs for Fort Monmouth. Documents indicate that radioactive material was used in chemical and explosives detectors operated by personnel working in security entrance areas, postal facilities, and shipping areas, and emergency responder personnel throughout the installation. Electron capture detectors containing ^{63}Ni were used in the Environmental Laboratory to analyze samples for pesticides and Polychlorinated Biphenyls (PCBs). All of this equipment involves the use of sealed sources rather than research-type dispersible materials. Leak test were performed regularly on sealed sources and no source ever failed a leak test.

1.2.2 Potential Radiological Contaminants

Radiological contaminants of potential concern (RCOPCs) were developed from research of Fort Monmouth's NRC RAM licenses and amendments and interviews with key personnel. Based on this research, the RCOPC list is shown in Table 1.

It should be noted that this list represents the primary radionuclides that were used at Fort Monmouth, but may not be all-inclusive since there were NRC licenses applicable to Fort Monmouth that permitted possession of any radionuclide with atomic numbers 1 through 95. The goal of developing a RCOPC list is to determine the instrumentation needs for the FSSs in order to ensure that all residual contamination will be detected and properly characterized. The list of RCOPCs dictated the requirement that instrumentation must be able to detect alpha, low energy to high energy beta, and gamma radiation.

The majority of the RCOPCs at Fort Monmouth are associated with the historic use and storage of radioactive commodities by the Garrison and current and former tenants. In addition, radioactive calibration sources and R&D commodities historically used by CECOM presented additional potential sources of radioactive material at Fort Monmouth.

Table 1 lists RCOPCs and their primary charged particle emissions. It should be noted that other radionuclides were used at Fort Monmouth as part of CECOM operations. However, based on information documented in the HSA (as supplemented), these radionuclides are not considered RCOPCs for this survey. Such radionuclides were calibration or test standards in a sealed or electroplated physical form and were subjected to required routine leak tests. Documentation indicates that no source ever failed a leak tests at Fort Monmouth and that all sources performed as designed, containing their radioactive material and preventing dispersal. In addition, ^{232}Th, as an oxide in glass lenses, was demilitarized by CECOM (USACE, 2012b). However, ^{232}Th is not considered a RCOPC because it is non-dispersive and does not leach from thoriated lenses.

Table 1: Final Status Survey RCOPCs

ROC	Half-life	Principal Emission	Max Energy (MeV)	Average Energy (MeV)
^{3}H	12.3 y	Beta	0.02	0.01
^{63}Ni	100 y	Beta	0.07	0.02
^{57}Co	270.9 d	Electron	0.13	0.02
^{14}C	5700 y	Beta	0.16	0.05
^{147}Pm	2.62 y	Beta	0.22	0.06
^{99}Tc	2.13E5 y	Beta	0.29	0.08
^{60}Co	5.27 y	Beta	0.32	0.10
^{137}Cs	30.2 y	Beta	0.51	0.19
^{154}Eu	8.6 y	Beta	1.85	0.22
^{36}Cl	3.01E5 y	Beta	0.71	0.25
^{90}Sr/^{90}Y	29.12 y	Beta	2.28	0.56
^{226}Ra	1600 y	Alpha	4.78	NA
^{230}Th	7.54E4 y	Alpha	4.69	NA
^{241}Am	432.2 y	Alpha	5.49	NA

1.3 Summary of Impacted Areas

1.3.1 Building 275

Building 275 was a communications-electronics museum. Thoriated lenses (night vision lens), a Kodak camera, a radium-containing component on a radio, and vacuum tube were among several museum display items that gave off readings above background level during the HSA reconnaissance. These items and numerous other radioactive items have since been removed.

1.3.2 Building 283

Building 283 last housed administrative offices and previously housed research laboratories and signal school training classrooms. Evidence of radio communication work was found on shelves in the basement work area (radio manual, wire used in radio circuitry).

1.3.3 Building 292

Building 292 served as storage space for the museum. At the time of the HSA reconnaissance, this storage space contained a Chinese radio, a vacuum tube, suspected radioactive commodities, and radium-contaminated components in a posted radioactive storage locker (all with radiological readings above background levels). This storage space once contained 65 items containing RAM. All radioactive and other items have since been removed.

1.3.4 Building 2540

Building 2540 housed the CECOM Laboratory and Radiological testing facility. Inventory lists cite use of multiple radiological materials and many were in use at the time of the HSA. Radiation Safety Surveys were conducted regularly in Building 2540, specifically mentioning the calibration range (Room 108), radiological lab, prep lab (Room 102), calibration lab, radwaste storage, excess waste storage (Room 109), exposure room, irradiator room, and panoramic range (Room 106A). The portion of the building referred to as "Building 2540" was primarily used for sample analysis and instrument calibration. The northern portion, referred to as "Building 2540A", was primarily used for R&D.

Some historic surveys indicated radiation levels elevated beyond background in certain locations. The surveys note that a Mobile Laboratory, which was considered part of this building, had a closeout survey completed in August 2001. Minutes from RSC meetings discuss the disposal of low-level radioactive waste (drums containing tritium exit signs and smoke detectors) by shipping to Wright Patterson Air Force Base as well as an inventory of sources, smoke detectors, instruments, etc. Radiological Work Permits were issued for the use of x-ray machines, calibrator use of ^{137}Cs, ^{238}Pu, ^{99}Tc, and ^{60}Co, R&D use of ^{137}Cs, a radium-beryllium source, ^{252}Cf, and ^{60}Co, and demilitarization activities from excess storage of ^{232}Th (thoriated lenses), ^{226}Ra, and ^{3}H.

Radioactive materials were regulated under NRC licenses. R&D activities were performed in the northern portion of the building, Building 2540A; testing was performed in a low-level environmental lab (e.g., use of high-purity germanium detector, scintillator, etc.); a radioactive material storage area was established; the building contains a former irradiator room (Room 7) that used a 2000-curie ^{60}Co source (decayed) and produced a dose rate of 500 roentgens/hour; ^{252}Cf was used for calibration and instrument testing, along with various sealed sources. One of the laboratories had a fume hood, which was regularly surveyed. Some work involving liquid forms of ^{241}Am and ^{230}Th was performed in the fume hood in the nuclear counting laboratory and in Dr. Kronenberg's former office.

At the time of the HSA, the storage room adjacent to the building (Room 109) contained unused sealed sources/devices, including RADIAC meters (for training) and ten 55-gallon drums containing items such as smoke detectors and tritium compasses. These items have been removed and post-removal radiological safety surveys were performed prior to this FSS.

1.3.5 Building 2541

Building 2541 is a "Butler Building" located in close proximity to Building 2540. It was last used to store RADIAC equipment. Newly identified information, documented in the HSA Supplement, indicates that demilitarization of excess ^{232}Th (night vision lenses), ^{226}Ra, and tritium occurred in this building (USACE, 2012b). The initial HSA did not include Building 2541 as an impacted building because the demilitarization activities were thought to have occurred in Building 2540.

2.0 RESIDUAL RADIOACTIVITY SCREENING LEVELS – SURVEY DCGLS

The radionuclides potentially present at the site are numerous and varied with respect to radiation and unrestricted release criteria. NUREG-1757, Vol. 2, (NRC, 2003) provides 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. The look-up screening levels are found in Table H.1 of NUREG-1757, Vol. 2. When screening values were not available in the look-up tables, values were selected from NUREG/CR-5512, Vol. 3, (NRC, 1999a) Table 5.19, *Concentration (dpm/100 cm^2) equivalent to 25 mrem/y for the specified value of P_{crit}*. Values were selected at P_{crit} equal to 0.90 which is the same as those from DandD, Version 2.1 and those published in the lookup table. The screening levels and the "removable" radioactivity goal for each RCOPC are presented in Table 2. These screening levels are the derived concentration guideline levels (DCGLs) that are used for the design of this survey and for unrestricted release compliance testing of survey data.

Consistent with NRC modeling assumptions used to develop the screening levels, the survey is designed assuming that approximately 10% of total surface radioactivity is removable. This assumption was verified as part of the FSS and is discussed later in this FSSR.

Table 2: NRC Screening Criteria – FSS DCGLs

ROC	Half-life	Principal Emission	Screening Criteria (dpm/100 cm^2)	
			Total	Removable (1)
^{3}H	12.3 y	Beta	1.20E+08	1.20E+07
^{63}Ni	100 y	Beta	1.80E+06	1.80E+05
^{57}Co	270.9 d	Electron	2.11E+05	2.11E+04
^{14}C	5700 y	Beta	3.70E+06	3.70E+05
^{147}Pm	2.62 y	Beta	3.43E+05	3.43E+04
^{99}Tc	2.13E5 y	Beta	1.30E+06	1.30E+05
^{60}Co	5.27 y	Beta	7.10E+03	7.10E+02
^{137}Cs	30.2 y	Beta	2.80E+04	2.80E+03
^{154}Eu	8.6 y	Beta	1.15E+04	1.15E+03
^{36}Cl	3.01E5 y	Beta	5.00E+05	5.00E+04
^{90}Sr/^{90}Y	29.12 y	Beta	8.70E+03	8.70E+02
^{226}Ra	1600 y	Alpha	315	31.5
^{230}Th	7.54E4 y	Alpha	36.9	3.69
^{241}Am	432.6 y	Alpha	27.0	2.7

Note: (1) Removable fraction inferred from total assuming 10% is removable.

3.0 SURVEY DESIGN AND METHODOLOGY

3.1 Scope

FSSs were designed in accordance with MARSSIM (NRC, 2000) and AMC (2004) guidance. This survey specifically addresses the FSS of five buildings:

- Building 275, the Museum
- Building 292, the Museum storage facility
- Building 283, the Squier Building
- Building 2540, the CECOM Laboratory, and
- Building 2541, the CECOM Laboratory Butler building.

The surveying and sampling protocols and rationale are presented in sections to follow.

The overall objective of the FSS is to demonstrate that areas with little or no residual radioactivity are suitable for release for unrestricted use. This objective was achieved through completion of the following tasks.

- Direct alpha and beta radioactivity scan surveys
- Integrated direct surface alpha and beta radioactivity measurements
- Smear sample collection and analysis
- Biased smear sampling of suspect floor drains, sink traps, and hoods and ventilation systems

3.2 Conceptual Site Model

The radiological Conceptual Site Model (CSM), originally developed as part of the HSA, uses available information to provide potential contaminant pathways to support the determination of methods to assess the nature and extent of contamination, the determination of areas and media to be sampled, and the development of strategies for data collection. The Fort Monmouth CSM is presented in complete format in the project HSA (CABRERA, 2007a) and is summarized below.

Surface contamination of building materials (work surfaces, shelves, floors, walls, ceilings, hoods, ventilation systems, etc.) is considered a primary transport mechanism. A secondary mechanism shows contaminants leaching from soil or from leaky drain/sewer systems to soil and groundwater. Contaminant pathway scenarios are summarized as follows:

Scenario 1 - Leaks and/or spills: this possibility could result from sealed sources or storage containers that have been compromised, laboratory spill incidents, or the transfer of contamination from unsealed radiological sources/commodities.

Scenario 2 - Storage/disposal activities: materials that have been stored on the museum shelves or in the museum storage building (Buildings 275 and 292), any materials stored onsite awaiting offsite disposal, or any materials disposed of down laboratory sinks (either in Building 2540 – CECOM laboratory or in Building 283 old research facilities) could then contaminate areas apart from where they were in active use.

3.3 MARSSIM Compliance Testing

As stated previously, the RCOPCs are numerous with a variety of differing charged particle emissions. This FSS implements three primary quantification methods to determine whether or not a location or area meets the DCGLs listed in Table 2: 1) wet smear collection and off-site analysis, 2) direct beta measurements with handheld detectors, and 3) direct alpha measurements with handheld detectors.

3.3.1 Low Energy Beta RCOPCs – Wet Smear Analysis

Tritium, ^{57}Co, and ^{63}Ni emit low energy beta particles and cannot be reliably quantified using handheld instrumentation. As a result, these radionuclides were quantified through collection and analysis of wet smear samples. Wet smear samples were collected over an area of approximately 100 square centimeters (cm^2). These wet smears were analyzed off-site by liquid scintillation counting. The analysis was designed to measure all betas with energies less than 0.16 mega electron volts (MeV).

For all survey areas, the most restrictive low energy beta DCGL is associated with ^{57}Co. To be conservative, low energy beta smear sample results are compared to the removable ^{57}Co DCGL for compliance testing. This analysis is based on the assumption that 10% of the total radioactivity is removable.

It should be noted that this method will detect ^{14}C if it is present on a smear. This FSS uses direct measurements to quantify ^{14}C (see Section 3.3.2). As a result, it is possible that any ^{14}C present may be "double counted", being measured by both techniques. While conservative, this method is considered appropriate due to the low energy emission of ^{14}C and its effects on direct measurement efficiency.

3.3.2 Measureable Beta RCOPCs – Direct Measurement

RCOPCs with beta endpoint energies greater than 0.15 MeV can be reliably measured using handheld detectors. These RCOPCs were quantified using a gas proportional detector.

For all survey areas, the most restrictive DCGL for measureable betas is associated with ^{60}Co. To be conservative, gross beta results are compared to the total ^{60}Co DCGL for compliance testing.

3.3.3 Alpha RCOPCs – Direct Measurement

The alpha emitting RCOPCs can be reliably measured using handheld detectors. These RCOPCs were quantified using a gas proportional detector.

For survey areas where ^{230}Th and ^{241}Am are RCOPCs, the most restrictive DCGL for alpha is associated with ^{241}Am. To be conservative, gross alpha results are compared to the total ^{241}Am DCGL for compliance testing.

For survey areas where ^{230}Th and ^{241}Am are not RCOPCs, the DCGL for alpha is associated with ^{226}Ra. Gross alpha results are compared to the total ^{226}Ra DCGL for compliance testing.

3.3.4 Sum of the Ratios (SOR)

The low energy beta, measureable beta, and alpha results must be evaluated collectively for compliance testing. This is accomplished through use of the unity rule, also called the "sum of ratios" (SOR). At each measurement location, radiological conditions are evaluated using the sum of ratios which must not exceed "1" (i.e., "unity"). The concentrations are limited as follows (MARSSIM equation 4-3):

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

Where: C = concentration, and

DCGL = guideline value for each individual radionuclide (1, 2, ..., n)

The low energy beta smear and direct alpha and beta measurement results are compared to the most restrictive DCGLs for the survey unit. These comparisons or ratios are summed and the SOR determined from the following equations. It should be noted that negative ratios are set to zero during summing to ensure SOR results are not inappropriately biased low. Through application of the SOR approach, the DCGL for the survey becomes SOR equal to one.

<u>Areas Where ^{230}Th and ^{241}Am are RCOPCs</u>

$$\mathrm{SOR} = \frac{\text{low energy beta result}}{\text{removable DCGL}_{\text{Co-57}}} + \frac{\text{measureable beta result}}{\text{total DCGL}_{\text{Co-60}}} + \frac{\text{alpha result}}{\text{total DCGL}_{\text{Am-241}}}$$

Areas Where ^{230}Th and ^{241}Am are not RCOPCs

$$\text{SOR} = \frac{\text{low energy beta result}}{\text{removable DCGL}_{\text{Co-57}}} + \frac{\text{measureable beta result}}{\text{total DCGL}_{\text{Co-60}}} + \frac{\text{alpha result}}{\text{total DCGL}_{\text{Ra-226}}}$$

It should be noted that any stated "low energy beta activity" is conservatively assumed to be entirely due to low energy betas. However, a portion of the gross residual count rate may be attributable to other radionuclides of concern. For the sake of evaluating potential contamination, this conservative assumption was deemed appropriate.

3.4 Impacted Building MARSSIM Classifications and Area-Specific RCOPCs

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

- 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 are based on MARSSIM guidance on classifying areas per the potential level of residual radioactive material contamination relative to the established release criteria (i.e., DCGLs).

In the following building descriptions, the restrictive RCOPC (i.e., lowest) is identified with its respective DCGL for each quantification method: 1) low energy beta emitters, which include ^{3}H, ^{57}Co, and ^{63}Ni; 2) readily detectable beta emitters which include ^{14}C and other beta emitters with maximum beta energies greater than 0.15 MeV; and 3) alpha emitters.

3.4.1 Building 275

Building 275 was surveyed as a MARSSIM Class 3 area. Building 275 is the former Communications-Electronics Museum, which contained various historical displays including demilitarized artifacts. During the site observation conducted for the HSA, several displays with radioactive material were identified: the AN/PRC-10 Radio Miniaturization Display, the Vacuum Tube Development Display, the Night Vision Equipment Display, and the Combat

Photography Display. Since the physical form of RAM associated with these artifacts are of robust construction, spread of contamination was unlikely to occur, but contaminant pathway Scenario 2 from the CSM was considered applicable in Building 275.

To be conservative, all radionuclides listed in Table 1 are considered RCOPCs in Building 275, with the exception of ^{230}Th and ^{241}Am (radionuclides associated only with Building 2540 operations). Specific DCGLs for surveys in Building 275 are as follows:

- Low energy beta emitter: ^{57}Co with DCGL of 21,000 disintegrations per minute per 100 square centimeters (dpm/100 cm^2) (removable)
- Directly measured beta emitter: ^{60}Co with DCGL of 7,100 dpm/100 cm^2
- Directly measured alpha emitter: ^{226}Ra with DCGL of 315 dpm/100 cm^2

Building 275 includes a single Class 3 survey unit. The building layout and measurement/ sample locations are shown in Appendix A, Figure A-1.

3.4.2 Building 283

Building 283 was surveyed as a MARSSIM Class 3 area. Building 283 was utilized as a laboratory with wet labs. Limited evidence was found of radio communication work that was performed in the basement of the building. Laboratory drains lines were covered over, but original janitorial sinks remain. Contaminant pathway Scenarios 1 and 2 from the CSM were considered applicable in Building 283.

To be conservative, all radionuclides listed in Table 1 are considered RCOPCs in Building 283, with the exception of ^{230}Th and ^{241}Am (radionuclides associated only with Building 2540 operations). Specific DCGLs for surveys in Building 283 are as follows:

- Low energy beta emitter: ^{57}Co with DCGL of 21,000 dpm/100 cm^2 (removable)
- Directly measured beta emitter: ^{60}Co with DCGL of 7,100 dpm/100 cm^2
- Directly measured alpha emitter: ^{226}Ra with DCGL of 315 dpm/100 cm^2

Building 283 includes two Class 3 survey units. The building layout and measurement/sample locations are identified on Figures A-2 through A-4 in Appendix A.

3.4.3 Building 292

Building 292 was surveyed as a MARSSIM Class 3 area. Building 292 was used for storage of museum artifacts containing RAM inside three locked and posted cabinets in one area of the building. A foreign radio with radioluminescent backlight components and an electron tube were found in the main storage area of the building during the HSA reconnaissance. The main storage area, located in the northwest portion of the building, had 6-8 moveable storage shelves containing hundreds to thousands of artifacts. Additional shelf storage was present in a back (north) area of the building. Contaminant pathway Scenario 2 from the CSM was considered applicable in Building 292.

To be conservative, all radionuclides listed in Table 1 are considered RCOPCs in Building 292, with the exception of ^{230}Th and ^{241}Am (radionuclides associated only with Building 2540 operations). Specific DCGLs for surveys in Building 292 are as follows:

- Low energy beta emitter: ^{57}Co with DCGL of 21,000 dpm/100 cm^2 (removable)
- Directly measured beta emitter: ^{60}Co with DCGL of 7,100 dpm/100 cm^2
- Directly measured alpha emitter: ^{226}Ra with DCGL of 315 dpm/100 cm^2

Building 292 includes a single Class 3 survey unit. The building layout and measurement/ sample locations are identified on Figure A-5 in Appendix A.

3.4.4 Building 2540

Building 2540 was surveyed as a MARSSIM Class 1 area, with the exception of the administrative areas of the building, which were surveyed as a single Class 3 area. Building 2540 housed the CECOM Laboratory and radiological testing facility. The building housed a gamma irradiator, RADIAC calibrators, a storage room for low-level radioactive material with multiple radioactive sources from the demilitarization of commodities, a nuclear counting laboratory, and several health physics laboratories. Radioactive sources consisted of alpha, beta, gamma, and low fluence neutron emitters. Sample testing work was performed with liquid forms of low-activity ^{230}Th and ^{241}Am in the nuclear counting laboratory and in Dr. Kronenberg's office. Contaminant pathway Scenarios 1 and 2 from the CSM were considered applicable in Building 2540. The building layout is shown if Figure 5 at the end of this FSSR. Measurement/sample locations are identified on Figures A-6 through A-13 in Appendix A.

To be conservative, all radionuclides listed in Table 1 are considered RCOPCs in Building 2540. However, ^{230}Th and ^{241}Am are only RCOPCs in the nuclear counting laboratory (SU's 8 and 9) and in Survey Units 6 and 7 where Dr. Kronenberg's office was located, not in other portions of the building. Specific DCGLs for surveys in Building 2540 are as follows:

<u>Nuclear Counting Laboratory and Dr. Kronenberg's Office Environs (SUs 6 through 9):</u>

- Low energy beta emitter: ^{57}Co with DCGL of 21,000 dpm/100 cm^2 (removable)
- Directly measured beta emitter: ^{60}Co with DCGL of 7,100 dpm/100 cm^2
- Directly measured alpha emitter: ^{241}Am with DCGL of 27 dpm/100 cm^2

All Areas in Building 2450 Except Nuclear Counting Laboratory and Dr. Kronenberg's Office Environs:

- Low energy beta emitter: ^{57}Co with DCGL of 21,000 dpm/100 cm^2 (removable)
- Directly measured beta emitter: ^{60}Co with DCGL of 7,100 dpm/100 cm^2
- Directly measured alpha emitter: ^{226}Ra with DCGL of 315 dpm/100 cm^2

Building 2540 includes 14 Class 1 survey units and one Class 3 survey unit. The building layout is shown in Figure 5. Measurement/sample locations are identified on maps in Appendix A.

3.4.5 Building 2541

Building 2541 was surveyed as a MARSSIM Class 1 area. Building 2541 was, in part, used for demilitarization of excess ^{232}Th (night vision lenses), ^{226}Ra, and ^{3}H.

To be conservative, all radionuclides listed in Table 1 are considered RCOPCs in Building 2541, with the exception of ^{230}Th and ^{241}Am (radionuclides associated only with Building 2540 operations). Specific DCGLs for surveys in Building 2541 are as follows:

- Low energy beta emitter: ^{57}Co with DCGL of 21,000 dpm/100 cm^2 (removable)
- Directly measured beta emitter: ^{60}Co with DCGL of 7,100 dpm/100 cm^2
- Directly measured alpha emitter: ^{226}Ra with DCGL of 315 dpm/100 cm^2

Building 2541 includes 2 Class 1 survey units. Measurement/sample locations are identified on Figure A-14 Appendix A.

3.5 Survey Design

The FSSs were performed to demonstrate that residual radioactivity in each survey unit satisfied the predetermined criteria for release for unrestricted use. The FSSs provide data to demonstrate that all radiological parameters do not exceed the established DCGLs and that collectively, they meet the annual dose criteria. For the FSS, the survey units represent the fundamental elements for compliance demonstration using the statistical tests.

The design of this 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 RCOPs. Due to very low energy beta emissions, ^{3}H, ^{57}Co, and ^{63}Ni are problematic because they cannot reliably be scanned for or quantified using handheld instrumentation. These radionuclides were measured through smear sample collection and laboratory analysis. To account for scanning weaknesses of these radionuclides, the sample density per survey unit is set considerably higher than that required by MARSSIM.

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 attempt to reject the null hypothesis.

Characteristics of selected instrumentation are provided in detail in Section 4. However, the integrated count times, minimum detectable concentrations (MDCs), and fraction of DCGL achieved with the stated count times are provided in Table 3 here for reference.

The survey plan consists 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 in the survey design. Activities (organized units of work needed to complete a function) have been defined and tasks (specific work assignments within a specific activity) were assigned. Table 4 provides a listing of specific survey activities and tasks.

Table 3: Instrument Count Times, MDCs, and Fraction of DCGL Achieved

Type	RCOPC	Isotopic DCGL (dpm/100cm^2)	Count Time (min)	Nominal MDC (dpm/100cm^2)	DCGL Fraction
Low energy Beta	^{57}Co	2.11E+04 (removable)	Not measured directly (smears performed)		
Beta	^{60}Co	7,100	1	624	9%
Alpha	^{226}Ra	315	1	27.8	9%
	^{241}Am	27	5	11.4	42%

Table 4: Overview of Major Activities and Tasks

Activities	Tasks
Evaluate contamination potential	1. Review radiological data from HSA.
	2. Identify radionuclides of concern and determine DCGLs.
	3. Identify boundaries of survey units and MARSSIM Classes.
Establish reference system	1. Determine frequency and locations of measurements to meet criteria.
	2. Prepare facility survey maps and work packages.
Determine background levels	1. Measure indoor gamma levels in similar non-impacted building.
	2. Measure alpha and beta levels on various materials.
Perform measurements	1. Perform surface scans.
	2. Perform static measurements and smears for low energy betas.
	3. Perform exposure rate measurements.
	4. Collect gross alpha/beta smears at locations with SOR > 0.2 to confirm dose modeling assumptions.
	5. Collect volumetric samples as necessary identify RCOPCs in building systems.
Analyze samples	1. Analyze smears and volumetric samples.
Interpret data	1. Convert data to standard units and calculate SOR.
	2. Calculate average, sigma, maximum, and minimum levels.
	3. Compare data with Sign test criteria.
Prepare report (This FSSR)	1. Construct data tables.
	2. Develop graphics.
	3. Prepare text.
	4. Submit report.

3.5.1 MARSSIM-required 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. As no scoping measurements had been collected, all calculations presented in this section were verified before survey completion of individual survey units.

Reviews were made during the initial scanning/static measurement phase to confirm survey unit classifications were appropriate. Reviews include for example, if 20% of any DCGL is detected in a Class 3 survey unit, the classification of the survey unit was evaluated. (The 20% value is an acceptable industry practice published by ORISE (ORISE, undated).) This process assures that ultimately all surveys have conservatism built into the design. No survey unit classifications were modified during these reviews as part of this FSS. Based on the FSS results in Building 2540 survey units, it appears the Class 1 survey unit classification was very conservative (Class 2 would have been appropriate). However, the decision to Classify Building 2540 areas as Class 1 during survey planning was appropriate based on the limited characterization data that existed before the FSS.

Section 5.5.2.2 of MARSSIM describes the process for determining the number of survey measurements necessary to ensure a data set is sufficient for statistical analysis. The method for determining the number of data points (N) for the survey unit is based on the expected contaminant variability and the predetermined acceptable Type I and Type II error rates. The project data quality objectives 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.

The relative shift is calculated as follows:

$$\Delta/\sigma = \frac{DCGL_w - LBGR}{\sigma}$$

Where: $DCGL_w$ = Derived Concentration Guideline Level

LBGR = concentration at the Lower Bound of the Gray Region (LBGR). The LBGR is the concentration at which the survey unit has an acceptable probability of passing the statistical tests.

σ = an estimate of the standard deviation of the concentration of residual radioactivity in the survey unit (which includes real spatial variability in the concentration as well as the precision of the measurement system).

DCGLs for RCOPCs are listed in Table 2. Because multiple radionuclides may be present in each survey unit, compliance testing is based on SORs. By definition, an SOR of 1.0 is equivalent to the release criteria and can represent the $DCGL_w$ in the above equation.

The standard deviation (sigma) associated with the surface concentration of any residual radioactivity in the survey units was estimated to be low during development of the RSSP since significant contamination was not expected to be encountered. In addition, the standard deviation was not expected to be adversely affected by measurement precision, as selected instrumentation and laboratory measurement methods have adequate precision at excepted concentrations. The standard deviation (sigma) was estimated at approximately 15% of an SOR of 1.0, or 0.15. Setting the LBGR equal to one-half of the DCGL, the relative shift was calculated as follows:

$$\Delta/\sigma = \frac{DCGL_w - LBGR}{\sigma}$$

Or, substituting values

$$\Delta/\sigma = \frac{1.0 - 0.5}{0.15} = 3.3$$

Using the parameters discussed above, the relative shift was calculated to be 3.3, or, conservatively, rounded to 3. The number of suggested measurement locations per SU is 14 per MARSSIM (NRC, 2000, Table 5.5) given a relative shift of 3 and an error rate for both Type I and Type II errors of five percent (i.e., $\alpha = \beta = 0.05$). However, for prudent conservatism the number of systematic measurement/sample locations for each survey unit was increased to approximately 30. This is consistent with AMC guidance (AMC, 2004) for Class 3 areas. In addition, the increased density helps in identification and quantification of low energy beta RCOPCs that cannot be reliably scanned for with handheld instruments.

The relative shift was calculated for each survey unit based on the actual FSS results and is presented in Section 6 of this report along with FSS survey results. For each survey unit, the actual relative shift was in excess of 3.3 indicating that sufficient sampling density was achieved.

3.5.2 Reference Area and Reference Materials

A reference area building was established for quantifying radioactivity in “background,” non-impacted conditions. A reference area is a geographical area from which representative measurements of background conditions are selected for comparison with measurements collected in specific survey units. The background reference area has similar physical, chemical, radiological, and biological characteristics to the impacted area being surveyed, but is not contaminated by site activities. The distribution of measurements in the reference area is similar to the distribution of measurements in the survey units where residual radioactivity is not present. The reference area was selected as Building 1205, West Point Cadet Training building, based on field observations and professional judgment.

Fourteen background measurements were performed and recorded for each survey instrument to establish “background radioactivity” for different types of surface material being surveyed. (e.g., concrete, floor tile, concrete block wall, etc.). Section 6.1 provides the results of reference area measurements. The average gross count rate in the reference materials is subtracted from the gross count rate in the survey units to determine activity concentration.

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

- Integrated direct surface alpha radioactivity measurements
- Integrated direct surface beta radioactivity measurements
- General area exposure rate measurements

As permitted by NUREG-1757, Vol. 2, A.3.3, measured backgrounds for different materials are subtracted from individual measurement points and the Sign test applied to the background corrected data set. Chapter 2 of NUREG-1505 (NRC, 1999b) 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.” During this FSS, the Sign test was not performed for any survey units because all SOR values were less than one for all measurement locations.

3.5.3 Determination of Survey Point Locations

Before the surveys were conducted within a survey unit, a fixed reproducible starting point was selected in the southwestern corner of the survey unit at ground level. The survey unit points are based on an X-Y reference-coordinate system that is provided with the work maps. Tape measures and building layout maps were used in the measurement of the survey units for the survey. Visual aids such as grease marker writing and removable tape can were used to mark survey point locations within the survey units.

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

For Class 1 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 feet from a reference point (0, 0). Locations of the remaining survey points are gridded from that location.

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

The (0, 0) point was set as the southwest 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. Survey unit maps have been developed as part of this USACE FSSR (see Appendix A).

3.5.4 Selection of Area Size for Survey Units

Suggested survey unit sizes from MARSSIM are listed in Table 5. Survey units used in this FSS conform to the MARSSIM suggestions. These areas are suggested in MARSSIM because they give a reasonable sampling density and they are consistent with most commonly used dose modeling codes. To facilitate survey design and ensure that the number of survey data points is 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 are 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 as necessary. MARSSIM suggests that a survey unit have a minimum floor area of 10 m^2 (108 ft^2) so smaller rooms were sometimes combined with similar nearby areas.

Table 5: 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

3.5.5 Surface Scan Requirements

Scanning was used to identify areas of elevated radioactivity within the survey. These locations are marked and receive additional investigations to determine the concentration, area, and extent of contamination, if confirmed to be present.

The required area covered by scan measurement is based on the survey unit classification as derived from MARSSIM Table 5.9. For the Class 1 Survey Units in Buildings 2540 and 2541, a 100% scan of the reasonably accessible portions of floors and lower walls was performed. For Class 3 Survey Units scanning was performed on areas based on the potential for contamination and the judgment of the radiation survey staff; there was no set percentage. Scanning for ^{3}H, ^{57}Co, and ^{63}Ni is not technically feasible with available technology and very low yields for the low energy beta emitters such as ^{14}C.

Sensitivity for scanning techniques used in Class 2 and 3 areas is 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. A comparison of DCGLs and MDCs is presented in Section 4.1.

3.5.5.1 Class 1 Scan Requirements

For Class 1 areas, MARSSIM specifies scan sensitivity requirements. The required scan sensitivity is defined in MARSSIM equation 5.3, as follows:

$$\text{Scan MDC}_{\text{required}} = \text{DCGL}_{\text{w}} * \text{Area Factor}$$

The estimated scan sensitivity for ^{230}Th and ^{241}Am exceeds their DCGLs. Thus, it was necessary to derive area factors for these radionuclides to confirm scan sensitivity is adequate for the Class 1 survey units in Building 2540.

The area factor is based on the size of the survey unit and the spacing of systematic samples.

Area factors for ^{230}Th and ^{241}Am were derived using the DandD Version 2.1 dose modeling program developed by NRC. For each radionuclide, the program was executed assuming surface contamination was distributed over an infinite area. The program was then executed using the contamination was distributed over a 3.33 m^2 area, which was established based on the MARSSIM maximum recommended size for Class 1 survey units of 100 m^2 and the established sampling density of 30 measurements per survey unit. The output of DandD provided dose conversion factors (DCFs). The area factors were calculated as the ratio of the infinite area DCF to the 3.33 m^2 area DCF. Required scan sensitivities were calculated using these area factors and are shown in Table 6. DandD output reports are included in Appendix A of the RSSP.

Table 6: Area Factors and Required Class 1 Scan Sensitivity

Nuclide	Dose Conversion Factor (mrem/yr per dpm/100 cm^2)		Area Factor	DCGL (dpm/100 cm^2)	Required Scan MDC (dpm/100 cm^2)
	Infinite Area	3.33 m^2	3.33 m^2		
^{230}Th	0.681	0.227	3.0	36.9	111
^{241}Am	0.931	0.31	3.0	27.0	81.1

The estimated scan sensitivities for ^{230}Th and ^{241}Am presented in Section 4.1.2 meet the MARSSIM requirement based on this analysis. This was confirmed based on actual instrument efficiencies and observed backgrounds.

3.5.6 Interpretation of Results

Data of a specific quality and quantity are needed to test the null hypothesis. This sampling plan is designed to provide these data.

3.5.6.1 Basic Statistics and Range

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

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

3.5.6.2 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, by manual computation, input of data for computer processing, and direct computer output, was performed and is documented in this FSSR.

3.5.7 Decision Rules

The following decision rules are adapted from MARSSIM Table 8.2 "Summary of Statistical Tests" for radionuclides in background. These decision rules are applied to SORs calculated based on:

- Wet smear samples collected and analyzed off site for low energy gross beta
- Direct surface alpha radioactivity measurements performed within buildings/indoor areas
- Direct surface beta radioactivity measurements performed within buildings/indoor areas.

Table 7: Decision Rules

Survey Results	Conclusion
All measurements less than DCGL	Survey unit meets release criterion for Class 1, 2, and 3
Average greater than DCGL	Survey unit does not meet release criterion. Evaluate to determine if surveys units are appropriately classified and attempt to bound elevated area
Any measurement greater than DCGL and the average less than DCGL	For Class 1 survey units – Conduct Sign test and elevated measurement comparison. For Class 2 and 3 – evaluate to determine if survey units are appropriately classified.

3.5.8 Performing the Sign Test

The Sign test would have been applied if any measurement in a survey unit is greater than DCGL and the average of all measurements is less than DCGL. However, all measurements with background subtracted in all survey units are less than the DCGL of SOR = 1. Thus, based on the decision rules in Table 7, it was unnecessary to perform the Sign test; all survey units meet the release criteria.

4.0 SAMPLING APPARATUS AND FIELD INSTRUMENTATION

This section describes the survey instruments and methodologies used during implementation of the FSSs. Specific measurement/ sampling frequencies and approaches are discussed in Section 3. The FSS field investigation was a MARSSIM graded approach requiring a combination of field screening methods and 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 could not be detected at desired levels by direct measurement, the portion of the survey dealing with measurements at discrete locations is designed to rely primarily on smear or sampling and laboratory analysis. Survey instrumentation used during the FSS is shown below in Table 8. The selected instrumentation suite was capable of quantifying alpha, beta and gamma radiation.

- For building surfaces, scanning, direct measurements, exposure rate measurements, and surface smears were performed to measure surface radioactivity concentrations of site RCOPCs. These measurements are based on gamma, alpha or beta emissions, depending upon the RCOPC of interest.

- Wet smears collected for low energy betas were analyzed for low energy beta radioactivity by liquid scintillation at an offsite laboratory. These smears were collected to determine total activity concentration of ^{3}H, ^{57}Co, and ^{63}Ni for compliance testing (using the assumption that the observed smear activity represents 10% of the total activity).

- Dry smears were analyzed off-site for alpha and beta radioactivity. These smears are used to verify the NRC screening dose modeling assumption that 10% of the total radioactivity is removable.

- Both wet and dry smears were collected in building systems to determine if there were any radiological impacts to ventilation systems in Building 2540 and sinks and drains in Buildings 2540 and 283.

Ludlum gas proportional detectors, Model 43-37 and 43-37-1, were used with Ludlum Model 2360 data loggers utilizing P-10 counting gas (10% methane, 90% argon). The 43-37 and 43-37-1 probes were calibrated with ^{99}Tc to determine beta efficiency and ^{230}Th to determine alpha efficiency. Certificates of calibration are included as Appendix E to this FSSR. Table 9 provides the observed efficiencies for the three probes used during the FSS.

Table 8: Selected Instrumentation

Measurement Type	Detector Type	Detector Area	Instrument Model	Detector Model
Alpha/Beta Scan	P-10 gas proportional	821 cm^2 active	Ludlum 2360	Ludlum 43-37-1
Alpha/Beta Scan & Directs	P-10 gas proportional	582 cm^2 active	Ludlum 2360	Ludlum 43-37
Gamma Exposure Rate	Sodium iodide scintillator	Not applicable	Ludlum 19	Internal

Table 9: FSS Detector Efficiencies

Instrument / Probe	Serial Number	Isotope	ε_i	$\varepsilon_{Surface}$	ε_{total}
2360 / 43-37	275724 / 092501	Th-230	0.38	0.25	0.096
		Tc-99	0.36	0.25	0.091
2360 / 43-37	275713 / 093966	Th-230	0.39	0.25	0.098
		Tc-99	0.37	0.25	0.091
2360 / 43-37-1	138251 / 136631	Th-230	0.43	0.25	0.11
		Tc-99	0.34	0.25	0.084

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 exposure rates were measured at one meter above the floor surface and recorded over all floor area measurement locations. Exposure rate measurements were also performed at each wall measurement location with the detector held in close proximately to the wall surface.

Alpha and beta radioactivity direct scan surveys were performed on floors and lower walls using a Ludlum Model 43-37-1 gas flow proportional detector floor monitor (active area of 821 cm^2).

In Building 275 some scan surveys were performed with a Ludlum Model 43-37 due to size limitations (active area of 584 cm^2). All direct static measurements were performed with the 43-37 detectors. Both the 43-37-1 and 43-37 detectors were coupled to Ludlum 2360 Alpha-Beta Data Loggers. The 43-37-1 and the 43-37 probes were calibrated to measure both alpha and beta surface activity simultaneously (i.e., dual channel analysis). Alpha and beta measurement results were recorded separately. The Ludlum 2360 data logger allows for recording of both alpha and beta channels simultaneously at a set interval, allowing for a high density of data points. During scan surveys, the instantaneous rolling average alpha and beta count rates were recorded at one or two second intervals (Appendix H provides a large table with all scan data, in excess of 30,000 total data points).

The 43-37-1 and 43-37 detectors are not sensitive to relatively low-energy alpha/beta radioactivity due to the presence of their Mylar® entrance windows. ^{3}H, ^{57}Co, and ^{63}Ni are considered low energy (hard-to-detect) beta emitters and are RCOPCs in all survey units. In order to quantify these radionuclides, wet smear sample collection and off-site analyses was performed in lieu of direct measurements. This off-site analysis was performed via liquid scintillation counting. The upper window of the analysis was set at approximately 0.16 MeV, reducing the undesired detection of higher energy beta emitters, which were directly measured. Low energy beta smear results are considered representative of 10% of the total radioactivity concentration of the low energy beta RCOPCs for compliance testing purposes.

The concept of material specific background radioactivity measurements was previously introduced. Fourteen gross alpha and beta background measurements were performed and recorded for each detector for different types of surface materials that were suspected to contribute significantly to instrument response. Reference areas were not established for some material types that were not expected to significantly impact instrument response, such as metal and drywall. For these materials a survey unit specific instrument background was established by positioning the detector face away from any surface in the survey unit and performing an integrated count.

The primary purpose of the background measurements is to correct the instrument for ambient gamma dose and material specific beta/alpha emissions that can result in additional beta or alpha counts. Instrument net count rate was determined as the difference between the measurement count rate and the instrument-specific, material-specific, average background count rate measured or the survey unit specific ambient background (for materials with no significant natural background impact on instrument response).

Analysis count times for integrated alpha/beta measurements were dependent upon the alpha DCGL applicable to the survey unit. As illustrated in Table 3, the count time was either one minute or five minutes.

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 MDC. The MDC equations and example values for both static measurements and swipe analysis are presented in this section. The following is an *a priori* analysis and actual MDCs will be determined with background and calibration data for instruments to be used. Per the MARSSIM "Roadmap" For direct measurements and sample analyses, minimum detectable concentrations less than 10% of the DCGL are preferable while MDCs up to 50% of the DCGL are acceptable.

The most restrictive DCGL is for ^{241}Am at 27 dpm/100 cm^2 and to obtain an alpha MDC of 50% of the DCGL, the length of the count was five minutes. When ^{241}Am was not potentially present, ^{226}Ra and ^{60}Co drive the count duration requirements and the count time was decreased to one minute. 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 = active probe area in cm^2

Determining the MDC in counts per minute (cpm) requires knowledge of the survey instrument efficiency, the material source efficiency and the background rates. The count time for the actual MDCs was verified immediately prior to the survey and remained as either one or five minutes.

4.1.2 Alpha and Beta Scan Minimum Detectable Concentrations

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. Scanning surveys are performed to locate radiation anomalies indicating residual gross activity that may require further investigation or action.

4.1.2.1 Beta Scan MDC

For beta scanning, the time interval over an area is typically one to two seconds. The following equation is 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 0.6 false positives;

b_i = Background counts during the observation interval;

i = Observation interval in seconds; and

√0.5 = MARSSIM determined level of performance for the surveyor.

There is no scanning capability for low energy (hard-to-detect) beta emissions. Results for detectable betas for all RCOPCs are tabulated in Table 10.

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 (Abelquist, 2001) 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; 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 pages 193-197: 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

Approximate MDCs for RCOPCs are presented in Table 10. The time interval for scanning was one second, equivalent to a scan speed of one detector width per second in areas where ^{230}Th and ^{241}Am were not RCOPCs. In areas were ^{230}Th and ^{241}Am were RCOPCs, the scan speed was one-half detector width per second.

4.1.3 Gamma Exposure Rate Measurements

General area gamma dose rate measurements were qualitatively performed during the survey activities to ensure worker health and safety and to document exposure rates in survey units. Measurements were performed using Ludlum Model 19 exposure rate detectors. The measurements were performed one meter above each measurement/sample location on a SU floor surface. Exposure rate measurements were also performed at wall measurement locations with the instrument held in close proximity to the wall surface.

Table 10: Direct Alpha Beta Measurement Nominal Sensitivities

ROC	Half-life	Principal Emission	Max Energy (MeV)	Average Energy (MeV)	Particles per decay	DCGL (dpm/100 cm^2)	Es	Ei	Background Scan (cpm)	Background Static (cpm)	Scan Speed (inch/sec)	Static Count Time (min)	Net Count Rate at DCGL (cpm)	Scan MDC (dpm/100 cm^2)	Static MDC (dpm/100 cm^2)
^{3}H	12.3 y	Beta	0.02	0.01	1.0	1.20E+08	Radionuclide not measured Directly								
^{63}Ni	100 y	Beta	0.07	0.02	1.0	1.80E+06									
^{57}Co	270.9 d	Electron	0.13	0.02	1.0	2.11E+05									
^{14}C	5700 y	Beta	0.16	0.05	1.0	3.70E+06	0.25	0.06	1700	1200	6	1	3.24E+05	5.06E+03	1.87E+03
^{147}Pm	2.62 y	Beta	0.22	0.06	1.0	3.43E+05	0.25	0.10	1700	1200	6	1	5.01E+04	3.04E+03	1.12E+03
^{99}Tc	2.13E5 y	Beta	0.29	0.08	1.0	1.30E+06	0.25	0.16	1700	1200	6	1	3.04E+05	1.90E+03	7.02E+02
^{60}Co	5.27 y	Beta	0.32	0.10	1.0	7.10E+03	0.25	0.18	1700	1200	6	1	1.87E+03	1.69E+03	6.24E+02
^{137}Cs	30.2 y	Beta	0.51	0.19	1.0	2.80E+04	0.50	0.31	1700	1200	6	1	2.53E+04	4.90E+02	1.81E+02
^{154}Eu	8.6 y	Beta	1.85	0.22	1.0	1.15E+04	0.50	0.34	1700	1200	6	1	1.14E+04	4.47E+02	1.65E+02
^{36}Cl	3.01E5 y	Beta	0.71	0.25	0.98	5.00E+05	0.50	0.36	1700	1200	6	1	5.15E+05	4.30E+02	1.59E+02
^{90}Sr/^{90}Y	29.12 y	Beta	2.28	0.56	2.0	8.70E+03	0.50	0.51	1700	1200	6	1	2.59E+04	1.49E+02	5.51E+01
^{226}Ra	1600 y	Alpha	4.78	NA	1.0	315	0.25	0.47	17	12	6	1	2.16E+02	1.43E+02	2.78E+01
^{230}Th	7.54E4 y	Alpha	4.69	NA	1.0	36.9	0.25	0.47	17	12	3	5	2.53E+01	7.16E+01	1.14E+01
^{241}Am	432.6 y	Alpha	5.49	NA	1.0	27	0.25	0.47	17	12	3	5	1.85E+01	7.16E+01	1.14E+01

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 could not be made reliably, (i.e., ^{3}H, ^{57}Co, and ^{63}Ni quantification), which was quantified based on wet smear evaluations.

The off-site laboratory, Pace Analytical Services, Inc. of Greensburg Pennsylvania, is a Department of Defense (DoD) Environmental Laboratory Accreditation Program (ELAP) certified.

The analysis procedure for low energy beta wet smear analysis is summarized as follows:

- Smears were wet in the field with deionized water, collected over an approximate 100 cm^2 area, and placed into a 20-mL glass vial containing 5-10 mL of deionized water. Wet smears were analyzed for low energy beta activity using off-site liquid scintillation counting. A Packard Tri-Carb 3100 liquid scintillation counter (LSC) (or similar equipment) was used for the analysis.

- Each sample was combined with scintillation counting cocktail in the 20-mL glass vial and counted. The system was calibrated to measure beta particles with energies up to 0.16 MeV (the upper level discriminator was set at approximately 0.16 MeV). The system did not discriminate specific radionuclides and all gross counts are assumed to result from the most restrictive RCOPC, ^{57}Co.

- The gross beta efficiency was determined using a commercially available ^{63}Ni standard traceable to the National Institute of Standards and Technology (NIST). The Tri-Carb 3100 is maintained under a routine service program and quench curves as appropriate established annually. Daily control charts (performance checks) are maintained of counts of background and unquenched ^{3}H and ^{14}C NIST traceable beta standards.

- Results are transferred from the LSC data printout or file in units of cpm or counts, background is subtracted and the net count-rate is converted to activity using the determined efficiency based on instrument response to a ^{63}Ni source. The activity is reported is gross alpha and gross beta activity per sample.

NUREG-1757 requires that residual radioactivity on surfaces must be mostly fixed (not loose), with the fraction of loose (removable) residual radioactivity no greater than 10% of the total surface activity.

As an attempt to confirm the removable fraction for other higher energy beta and alpha emitters, dry smears were collected at direct measurement locations with results indicating greater than 20% of a DCGL. Smear samples were analyzed for alpha and beta radioactivity by the Pace Analytical Laboratory. The gross alpha and gross beta MDCs were less than 1 dpm/100 cm^2.

4.3 Volumetric Sample Collection and Analysis

Volumetric building system samples were not collected. Instead wet and/or dry smear samples were collected to determine whether or not building systems were impacted by RAM. Results are discussed in Section 6.

5.0 DATA QUALITY ASSESSMENT

A quality assessment of the data collected during the Final Status Surveys 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 RSSP.
- Basic (i.e. minimum, maximum, mean) Statistical Analysis of the data set
- Quality Assurance (QA)/Quality Control (QC) records for instrumentation

5.1 Data Completeness

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

5.2 Statistical Analysis

Basic statistical analysis was performed on the data collected during implementation of the RSSP requirements. The analysis included quantities such as the minimum, maximum, and mean of static alpha/beta measurements, 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 Appendix C to this report. Statistics for SOR values in all survey units are provided in Table 12. Statistics for static alpha and beta measurements area provided in Table 13.

5.3 Instrument QA/QC

Ludlum Model 19 exposure rate meters were used to assess ambient gamma exposure rate. Large areas gas proportional detectors were used to quantify alpha and beta surface radioactivity for MARSSIM compliance testing. These instruments were operated in accordance with standard operating procedures and the manufacturer user's manuals. Quality control measures were implemented on days the instruments were used, at a minimum, to ensure their proper operation.

Initial Gas Proportional Detector Efficiency Calibration and Operating Test

Prior to use, thirty one minute counts were performed on each of the Model 43-37 and 43-37-1 gas proportional detectors using ^{230}Th (alpha) and ^{99}Tc (beta) NIST-traceable sources. The reduced chi-square statistic was calculated for the thirty alpha counts and thirty beta counts and compared to 0.05 and 0.95 acceptance criteria for each instrument. After establishing that each of the instruments passed the chi-square test, the intrinsic efficiency of each detector for alpha and beta was determined. These efficiencies were compared to efficiencies established during instrument calibration to ensure they were approximately the same as the calibration facility determined. Each of the comparisons was favorable, and the efficiencies established were used for reduction of FSS data. Appendix F provides the initial setup information for each detector used.

General Instrument Conditions

During daily QA/QC checks instruments were inspected for physical damage, battery voltage levels, current calibration, and erroneous readings, in accordance with standard operating procedures (SOPs). The gas flow rate for gas proportional detectors was evaluated routinely throughout the day to ensure adequate P-10 counting gas concentrations were present in the active volume of the detectors; Mylar windows on the gas flow proportional detectors were also evaluated for rips or tears throughout the day for the same purpose.

Instrument Response Checks

Model 19 exposure rate meters were response checked daily by comparing response to a designated ^{137}Cs NIST traceable source. The acceptance criteria for these instrument response checks were ± 20% of the mean response generated using thirty initial source checks. Results were plotted on control charts. Ambient background was also recorded at the time of the daily checks. Control charts and results of daily QC measurements are provided in Appendix F.

Model 43-37 and 43-37-1 gas proportional detectors were checked daily by comparing response to designated ^{230}Th (alpha) and ^{99}Tc (beta) NIST-traceable sources and to ambient background. The acceptance criteria for these instrument response checks were ± 20% of the mean response generated using thirty initial source checks. Results were plotted on control charts. The graphs also include two and three sigma indicators based on the initial thirty counts for information purposes. Control charts and results of daily QC measurements are provided in Appendix F.

There were no QA/QC issues identified with the radiological instrumentation used during implementation of the FSS at Fort Monmouth.

5.4 Off-Site Laboratory Sample Analysis

Gross alpha/beta gas proportional and low energy beta liquid scintillation analysis of the of smear samples was performed by the off-site laboratory, Pace Analytical.

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, USACE reviewed the results of the quality control samples. The following sections provide a summary of those reviews. All off-site laboratory data reports and case narratives are included in Appendix J.

5.4.1 Method Blank

Method blanks consisted of unused smears, known to be free of the contaminants of interest. The method blanks were 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 method blank provides assurances that an analyte of interest was not inadvertently added to the samples through a reagent or analytical operation and that the detector is not contaminated or compromised. A method blank analysis was performed at a rate of one per batch of 20 or fewer samples.

5.4.1.1 Gross Alpha/Beta

Pace analyzed 25 method blanks for the gross alpha/beta smear analyses. Two of the alpha results were slightly above the minimum detectable activity (MDA) for the analysis. All other blanks were less than MDA for alpha and all were less than MDA for beta. As a result, some sample results in batches RADC12468 and RADC12470 were qualified with a "B" flag. This is considered acceptable for the FSS, as it indicates that the results may be slightly overly conservative for these batches (resulting in possible false positives). No results were rejected as a result of method blank analyses.

5.4.1.2 Low Energy Beta

Pace analyzed 42 method blanks for the low energy beta smear analyses. All results were less than the MDA for the analysis. No results were rejected or qualified as a result of method blank analyses.

5.4.2 Laboratory Control Sample / Laboratory Control Sample Duplicate

Laboratory control samples (LCSs) and laboratory control sample duplicates (LCSDs) were prepared and analyzed by Pace. 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 (for low energy beta), or counting a NIST traceable source(s) for gross alpha/beta. 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. Pace analyzed one LCS and one LCSD with each batch of 20 or fewer samples.

5.4.2.1 Gross Alpha/Beta

Pace performed 25 LCS and 25 LCSD analyses for the gross alpha/beta analyses. In each batch at least one LCS and/or LCSD failed the laboratory acceptance criteria, exceeding the upper control limit. This indicates that the gross alpha/beta results may be biased slightly high and may explain why two method blanks exceeded the MDA. As a result of these LCS/LCDS evaluations, some samples were reported with a narrative notation that the results may be biased high. No sample results were rejected based on the results of their evaluations.

While there is potential bias, the results are considered acceptable for the FSS because if a bias does exist it would result in conservative interpretation of survey results.

5.4.2.2 Low Energy Beta

Pace performed 42 LCS and 42 LCSD analyses for the low energy beta analyses. All LCS and LCSD results were within laboratory acceptance criteria. No sample results were rejected or qualified based on the results of their evaluations.

5.4.3 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. For this FSS, the MDCs were set at well below any project DCGL.

The laboratory met the MDA requirements of less than 1 dpm alpha and 5 dpm beta for all gross alpha/beta analyses (all alpha and beta MDAs were less than 1 dpm). No data were qualified because of a failure to meet the requested MDAs.

The laboratory met the MDA goal of less than 10 dpm for the vast majority of the low energy beta analyses. Two percent of the analyses (19 of 823) have MDAs slightly in excess of 10 dpm, with the maximum MDA being 33 dpm. This was considered acceptable because the maximum observed MDA is only 0.2% of the applicable DCGL. No data were qualified because of a failure to meet the requested MDAs.

5.4.4 Method Performance and Summary Assessment

Overall, the performance of the laboratory analyses was adequate. 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 verification by Pace personnel and appropriate qualifiers applied to the data. In addition, USACE independently reviewed the data for the QC samples: LCS, LCSD, and method blanks. The results of the QC samples were generally acceptable, although an apparent high bias was identified in the gross alpha/beta data. None of the data was rejected during the data validation and review process. All data reported by the laboratory is of appropriate quality for FSS decision making.

5.5 Duplicate Measurements and Field Duplicate Smears

Duplicate static alpha/beta measurements were performed and duplicate smears were collected and analyzed to provide an evaluation of the precision of the measurement processes. Duplicate results were compared to initial results by calculating the normalized absolute difference (NAD).

$$\text{NAD} = \frac{|\text{initial result - duplicate result}|}{\sqrt{\sigma^2_{\text{initial}} + \sigma^2_{\text{duplicate}}}}$$

NAD values were compared to an acceptance criteria of less than or equal to 2.58. The following subsections present the results of duplicate analyses.

5.5.1 Static Gross Alpha/Beta Duplicates

During performance of the FSS, 83 duplicate static alpha/beta measurements were performed. The NAD equation was applied to gross alpha counts and gross beta counts for each analysis. The variance of each result (σ^2) was assumed to be the gross counts, based on the applicability of Poisson statistics. All alpha results were within the NAD acceptance criteria of 2.58 or less. Two beta results were slightly in excess of the criteria with NAD values of 3.3 and 3.4. Considering that the vast majority of the results were within the acceptance criteria, the gross alpha/beta static measurement results are deemed to exhibit acceptable levels of precision. Appendix I provides a table with the results of each duplicate evaluation.

5.5.2 Off-site Gross Alpha/Beta Analyses

During performance of the FSS, 23 duplicate gross alpha/beta smear samples were collected and submitted to Pace for analysis. The NAD equation was applied to each analysis. The variance of each result (σ^2) was assumed to be the half the laboratory-reported uncertainty squared. The value of one half was used because the lab reported data at the 95% confidence level. Evaluations were not performed on negative results. All alpha and beta results are within the NAD acceptance criteria of 2.58 or less. Thus, the gross alpha/beta smear analysis results are deemed to exhibit acceptable levels of precision. Appendix I provides a table with the results of each duplicate evaluation.

5.5.3 Off-site Low Energy Beta Analyses

During performance of the FSS, 50 duplicate low energy beta smears were collected using identical smears and glass vials and submitted to Pace for analysis. The NAD equation was applied to each analysis. The variance of each result (σ^2) was assumed to be the half the laboratory-reported uncertainty squared. The value of one half was used because the lab reported data at the 95% confidence level. Evaluations were not performed on negative results; approximately half of the duplicate analyses cannot be compared because one or more results are negative.

All low energy beta results are within the NAD acceptance criteria of 2.58 or less. Thus, the low energy beta smear analysis results are deemed to exhibit acceptable levels of precision. Appendix I provides a table with the results of each duplicate evaluation.

6.0 INTERPRETATION OF FINAL STATUS SURVEY RESULTS

Final status surveys and sampling of potentially impacted building structures at Fort Monmouth has been completed in accordance with the requirements specified in the RSSP. Field Changes from the RSSP requirements are noted in this section, as applicable.

In accordance with MARSSIM, measurement 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 Reference Material Background

Site specific background values were determined for four different materials for each detector: laminate tile, poured concrete, concrete block, and ceramic tile. Background reference areas for each material were established in Building 1205, the West Point Cadet Training building, which had no known or suspected historic use of RAM. The building is of similar age and construction of the impacted site buildings.

Each background reference material was surveyed using 14 random static alpha and beta measurements for each material. Count times were one minute. Reference area measurements were applied to multiple survey units as long as the material being surveyed was similar to that in the reference area. When materials in survey units differed from the four material-specific background materials (e.g., wood, metal, drywall), the ambient background in the survey unit was determined by performance of an integrated count with the detector facing upward (away from any surface) to determine net count rate.

A summary of the results of reference area/material background data is provided in Table 11. Individual results of background measurements are included as Appendix D to this RSSP.

Table 11: Gas Proportional Detector Material Backgrounds

Probe / SN	Material	Alpha (cpm)				Beta (cpm)			
		min	max	stdev	Average	min	max	stdev	Average
Ludlum 43-37 (SN 092501)	Ceramic Tile	12	23	3.0	17.7	1193	1341	41	1275
Ludlum 43-37 (SN 093966)	Ceramic Tile	5	18	4.6	11.6	963	1073	28	1026
Ludlum 43-37-1 (SN 136361)	Ceramic Tile	20	40	6.0	29.5	1470	1669	52	1587
Ludlum 43-37 (SN 092501)	Concrete Block	4	17	3.9	8.93	388	720	140	555
Ludlum 43-37 (SN 093966)	Concrete Block	0	7	1.8	2.50	287	679	152	459
Ludlum 43-37-1 (SN 136361)	Concrete Block	2	15	3.4	10.9	455	931	194	705
Ludlum 43-37 (SN 092501)	Laminate Tile	2	14	3.1	8.64	366	497	36	404
Ludlum 43-37 (SN 093966)	Laminate Tile	1	6	1.4	2.64	234	350	31	270
Ludlum 43-37-1 (SN 136361)	Laminate Tile	2	12	2.6	7.64	358	538	43	430
Ludlum 43-37 (SN 092501)	Poured Concrete	3	14	3.2	8.64	426	534	28	467
Ludlum 43-37 (SN 093966)	Poured Concrete	1	9	2.7	4.21	305	390	24	344
Ludlum 43-37-1 (SN 136361)	Poured Concrete	4	14	2.9	9.21	453	622	51	543

6.2 Confirmation of Assumed 10% Removable Fraction

Gross alpha/beta smears were collected and analyzed at locations with SOR values greater than 0.20 and at many other locations to confirm the assumption that 10% (or less) of the total radioactivity is removable. This assumption is inherent in the NRC screening criteria. This comparison could not be performed because none of the measurements confirmed the presence of contamination. In addition, the vast majority of the gross alpha and beta results are less than the minimum detectable activity of one dpm or less. The highest alpha and beta smear results are 2.6 and 2.6 dpm/100 cm^2, respectively. Individual smear results are provided in the Appendix J laboratory reports.

While the data collected could not be used to mathematically prove the 10% removable assumption is accurate, the very low results indicate that removable radioactive contaminants are not present in significant quantities. On this basis, the NRC screening criteria are considered appropriate DCGLs for this survey.

Table 12: Summary of Survey Unit SOR Results

Building Number	Survey Unit ID	Number of Measurements		SOR Statistics (non-biased)				Relative Shift
		Systematic/ Random	Biased	Average	Standard Deviation	Min.	Max.	
275 (Museum)	1	30	0	0.04	0.032	0.000	0.11	30
283 (Squier)	1	40	0	0.06	0.040	0.00	0.16	24
283 (Squier)	2	17	10	0.14	0.051	0.05	0.24	17
292 (Museum Storage)	1	30	0	0.09	0.035	0.03	0.14	26
2540 (CECOM)	1	32	1	0.24	0.047	0.18	0.33	16
2540 (CECOM)	2	21	1	0.36	0.062	0.26	0.46	10
2540 (CECOM)	3	47	1	0.33	0.042	0.24	0.41	16
2540 (CECOM)	4	30	1	0.12	0.015	0.09	0.17	60
2540 (CECOM)	5	36	1	0.02	0.048	0.00	0.18	20
2540 (CECOM)	6	32	2	0.27	0.12	0.08	0.54	6.2
2540 (CECOM)	7	49	2	0.02	0.042	0.00	0.20	23
2540 (CECOM)	8	30	3	0.04	0.043	0.000	0.16	22
2540 (CECOM)	9	80	2	0.23	0.14	0.000	0.64	5.5
2540 (CECOM)	10	24	1	0.10	0.020	0.06	0.13	45
2540 (CECOM)	11	42	1	0.01	0.012	0.00	0.04	82
2540 (CECOM)	12	32	2	0.06	0.023	0.00	0.11	40
2540 (CECOM)	13	40	1	0.03	0.024	0.00	0.07	41
2540 (CECOM)	14	27	1	0.13	0.15	0.00	0.47	5.7
2540 (CECOM)	15	30	1	0.07	0.046	0.01	0.19	20
2541 (CECOM Demil)	1	30	1	0.17	0.053	0.10	0.33	16
2541 (CECOM Demil)	2	30	1	0.03	0.026	0.00	0.08	38

6.3 FSS Results by Building

This section presents the results of FSSs performed in each of the buildings and survey units. Results are presented by building. Table 12 provides a summary of the survey unit SOR results for all survey units. Table 13 provides a summary of static alpha and static beta results for each survey unit. Low energy beta results are not summarized in Table 13 because over 99% of the results are less than MDA and the maximum result is 8.7 dpm/100 cm^2, an extremely small fraction of the DCGL of 21,000 dpm/100 cm^2. Appendix C provides the individual results for each measurement location in each survey unit.

All locations in all survey units have SOR values less than one, indicating all survey units and buildings are suitable for release for unrestricted use. All relative shifts (delta over sigma values), which were calculated based on actual SOR average and standard deviation, are greater than the survey design specification in the RSSP of 3 indicating that a sufficient number of measurement locations were established in each survey unit.

Biased measurement locations were established based on scanning information, requirements for the RSSP, and professional judgment. Some biased measurements were performed to evaluate building drainage and ventilation systems. All biased measurements produced SOR values less than one.

Table 13: Summary of Survey Unit Alpha/Beta Results

Building Number	SU ID	Direct Alpha Statistics (non-biased) dpm/100 cm^2				Direct Beta Statistics (non-biased) dpm/100 cm^2			
		Avg.	Std. Dev.	Min.	Max.	Average	Std. Dev.	Min.	Max.
275 (Museum)	1	5	4	-2	12	141	202	-169	598
283 (Squier)	1	13	10	-8	43	82	294	-508	737
283 (Squier)	2	32	10	16	50	223	280	-250	709
292 (Museum Storage)	1	8	7	-2	21	414	181	-55	714
2540 (CECOM)	1	25	7	13	39	1155	250	726	1649
2540 (CECOM)	2	52	12	31	69	1420	208	1119	1749
2540 (CECOM)	3	59	13	35	83	1047	183	709	1552
2540 (CECOM)	4	1	5	-6	17	817	78	667	1059
2540 (CECOM)	5	-2	5	-10	8	-98	391	-574	1166
2540 (CECOM)	6	5	3	0	11	616	353	-99	1025
2540 (CECOM)	7	-1	2	-6	5	-156	173	-388	604
2540 (CECOM)	8	-1	2	-7	3	174	163	-182	673
2540 (CECOM)	9	6	4	0	17	74	109	-107	436
2540 (CECOM)	10	5	4	-2	12	571	95	406	805
2540 (CECOM)	11	2	5	-11	11	-38	103	-269	271
2540 (CECOM)	12	1	5	-10	15	380	148	13	563
2540 (CECOM)	13	3	6	-9	18	68	184	-203	500
2540 (CECOM)	14	28	36	-3	113	282	310	-177	795
2540 (CECOM)	15	-4	13	-32	19	425	283	103	1128
2541 (CECOM Demil)	1	24	14	7	64	668	81	554	908
2541 (CECOM Demil)	2	10	8	-2	27	-201	37	-265	-120

6.3.1 Building 275 - Museum

Building 275 is the Communications-Electronics Museum, which contains various historical displays that formerly displayed demilitarized artifacts. The building was surveyed as a MARSSIM Class 3 area. The highest potential for contamination in this building was in the display cases where radioactive artifacts were displayed. Figure A-1 in Appendix A identifies the building layout.

Deviations from RSSP

The RSSP indicated that display case shelves would be scanned at a rate of 5% of the surface area for residual contamination. Instead 100% of the bottom surfaces of all display cases were scanned. This was deemed appropriate, as the most likely locations for contamination would be in the display cases.

No other deviations from the RSSP occurred.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of the bottom surfaces of all display cases. The scans did not indicate the presence of contamination and there were no sustained elevated measurements that would indicate a small elevated area. Instantaneous rolling average alpha and beta count rates were recorded at two second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Building 275 consisted of a single Class 3 Survey unit with 30 randomly established measurement locations. Figure A-1 identifies the survey unit layout and the sample locations. All SOR values were less than one, ranging from 0.0 to 0.11 and averaging 0.04. Figure B-1 (in Appendix B) is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 6 to 14 µR/hr, averaging 9.4 µR/hr.

There were no discernible indications that residual radioactivity was present.

Biased Measurements

In accordance with the RSSP biased gross alpha/beta and low energy beta smear samples were collected in the following display cases: AN/PRC-10 Radio Miniaturization Display, Vacuum Tube Development Display, Night Vision Equipment Display, and the Combat Photography Display. Analysis results for these samples were all less than the gross alpha and beta MDAs (MDAs less than 1 dpm/100 cm^2). The maximum alpha and beta smear results were 0.52 and 0.11 dpm/100cm^2, respectively. All low energy beta results were less than the MDA of approximately 10 dpm/100 cm^2.

6.3.2 Building 283 – Squier Hall

Building 283 was historically utilized as a laboratory with wet labs. Evidence was found of radio communication work performed in the basement of the building. Approximately 20 years ago the building was completely remodeled and converted into office space. As a result, laboratory drain lines were covered over by carpet, but original janitorial sinks remain in the building. During performance of the survey, three floor drains covered by carpet were identified. The building was surveyed as a MARSSIM Class 3 area. Based on information documented in the HSA, the most likely location for potential contamination was the radio room in the basement. Figure A-2 identifies the building layout.

Deviations from RSSP

The RSSP included performance of an alpha/beta scan over approximately 5% of the total floor area of former wet lab rooms. The location of wet lab rooms could not be limited to certain areas as no prints are available that identify their location. With the exception of bathrooms, janitor closets, the auditorium, and utility areas, all portions of the building have renovated and carpeted. Based on these facts, scanning of potential wet labs was not performed. Instead, a second survey unit was established (Survey Unit 2). This survey unit included all locations in the initial survey unit (Survey Unit 1) that were carpeted. Survey Unit 1 measurements were performed on top of carpet when it was present. Survey Unit 2 measurements where performed beneath the carpet by cutting and removing the carpet.

The RSSP indicated that the radio room would be scanned at a rate of approximately 5% of its floor area. Instead 100% of the reasonably accessible floor area was scanned (approximately 70% of the total floor area due to the presence of fixed shelving and stored metal conduit). This was deemed appropriate, as the most likely location for contamination in Squier Hall was in the radio room.

The RSSP included the collection of one sludge sample from drains within each of the janitor's closet sinks. It also included collection of sludge samples from covered floor drains (if identified). There was insufficient material in the janitor closet sink traps and the floor drains identified to support collection of a volumetric sample. Instead, smear samples were collected.

Biased smear samples were collected from two basement sumps. This was performed prior to identification of the covered floor drains as a possible substitute for sampling floor drains. Collection of smears in the sumps was not included in the RSSP.

No other deviations from the RSSP occurred.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of the reasonably accessible floor area in the radio room. Due to the presence of fixed shelving and stored metal conduit along the wall, this resulted in scan coverage of approximately 70% of the total floor (the middle portion of the room). In addition, scans were performed over floor areas in the general vicinity of janitor sinks. The scans did not indicate the presence of contamination and there were no sustained elevated measurements that would indicate a small elevated area. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Building 283 consisted of two Class 3 Survey units. Survey Unit 1 was defined in the RSSP and has 30 randomly established measurement locations (see Figure A-2). Survey Unit 2 was added during performance of the survey work to address the potential for contamination under renovated areas with carpet. In Survey Unit 2 locations, measurements were performed beneath the carpet with the carpet removed. Survey Unit 2 includes all 17 Survey Unit 1 locations that were carpeted (see Figure A-3).

Figure A-2 identifies the Survey Unit 1 layout and sample locations. All SOR values were less than one, ranging from 0.0 to 0.16 and averaging 0.06. Figure B-2 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 4 to 15 µR/hr, averaging 8.2 µR/hr.

Figure A-3 identifies the Survey Unit 2 layout and sample locations. All SOR values were less than one, ranging from 0.05 to 0.24 and averaging 0.14. Figure B-3 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 4 to 14 µR/hr, averaging 9.0 µR/hr.

There were no discernible indications that residual radioactivity was present in either survey unit.

Biased Measurements

Figure A-4 identifies the six biased measurement locations performed in the basement radio room. All SOR values were less than one, ranging from 0.06 to 0.11 and averaging 0.09. Figure B-4 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 10 to 16 µR/hr, averaging 12.7 µR/hr. There were no discernible indications that residual radioactivity was present in the radio room.

Biased gross alpha/beta and low energy beta smear samples were collected in the four janitor sinks, the four sink traps, and in two basement sumps. The maximum gross alpha and beta results for these smears were from the smear collected in the basement sump and are 2.6 and 1.1 dpm/100cm^2, respectively. All low energy beta results were less than the MDC of approximately 10 dpm/100 cm^2. Based on the very low results of these smear analyses it is concluded that these building systems were not impacted by RAM.

Biased gross alpha/beta and low energy beta smear samples were collected in two floor drains, from Room 102 and 214A. The maximum alpha and beta results for these smears are 0.319 (less than MDC) and 1.8 dpm/100cm^2, respectively. All low energy beta results were less than the MDC of approximately 10 dpm/100 cm^2. Based on the very low results of these smear analyses it is concluded that these building systems were not impacted by RAM.

6.3.3 Building 292 - Museum Storage

Building 292 was the Museum storage facility, where museum artifacts containing RAM were stored. The building was surveyed as a MARSSIM Class 3 area. Artifacts containing RAM were stored in one area of the building inside three locked cabinets, with a radioactive material posting. A foreign radio with radioluminescent backlight components and an electron tube were also found in the main storage area during HSA reconnaissance. The main storage area had 6-8 moveable storage shelves containing hundreds to thousands of artifacts, which were removed at the time of the FSS. Additional shelf storage was present in a back area of the building. However, the majority of the shelf storage was removed at the time of the survey. The highest potential for contamination in this building was in the area where the storage cabinets were located. Figure A-5 identifies the building layout. The storage cabinets were located in the vicinity of sample point 10 on Figure A-5.

Deviations from RSSP

No deviations from the RSSP occurred during FSS activities in Building 292.

Alpha Beta Scan

Alpha/beta scans were performed in floor areas surrounding the storage cabinets, the former location of the movable storage cabinets and the back area shelf storage locations. Scans were also performed over the shelves in the storage cabinets. Figure A-5 identifies the areas that were scanned. The scans did not indicate the presence of contamination and there were no sustained elevated measurements that would indicate a small elevated area. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Building 292 consisted of a single Class 3 Survey unit with 30 randomly established measurement locations. Figure A-5 identifies the survey unit layout and the sample locations. All SOR values were less than one, ranging from 0.03 to 0.14 and averaging 0.09. Figure B-5 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 3 to 7 µR/hr, averaging 4.7 µR/hr.

There were no discernible indications that residual radioactivity was present. Differences in SOR values were primarily driven by beta count variability. This slight variability was likely due to changes in beta background as a result of geometry and building materials.

Biased Measurements

In accordance with the RSSP biased gross alpha/beta and low energy beta smear samples were collected in the three storage cabinets. The maximum alpha and beta results for these smears are 0.65 and 2.4 dpm/100cm^2, respectively. All other smear results were less than the MDC (MDCs less than 1 dpm/100 cm^2). All low energy beta results were less than the MDC of approximately 10 dpm/100 cm^2.

6.3.4 Building 2540 – CECOM Laboratory

Building 2540 housed the CECOM Laboratory and radiological testing facility. The building housed a gamma irradiator and several RADIAC calibrators, and contained a low-level storage room with multiple radioactive sources from the demilitarization of commodities, a nuclear counting laboratory, and several health physics laboratories. Radioactive sources consisted of alpha, beta, gamma, and neutron emitters. All areas in Building 2540 were surveyed as MARSSIM Class 1, with the exception of the administrative area, which was surveyed as a Class 3 area. Figure 5 of this FSSR identifies the building layout and survey unit layout. Figures A-6 through A-14 identify the measurement locations in each survey unit.

Deviations from RSSP

The RSSP did not include measurement locations on interior walls of the Class 1 survey units. Instead, it only included wall measurement locations on the outer walls of each survey unit. A substantial quantity of additional points was established during the FSS to ensure all Class 1 survey unit walls were surveyed with the same measurement density. This was accomplished by continuing the measurement location grid along interior walls.

Measurement location coordinates presented in the original RSSP (developed by a contractor in 2007) were carried forward in the revised USACE RSSP used to perform this FSS. In some survey units the coordinates did not match the actual building/room dimensions. In such cases, new sample locations were determined in the field using a triangular grid and a random start point. All sample locations maps in this FSSR identify the actual sample locations where FSS data was collected.

The RSSP did not include survey of the administrative area in Building 2540. During performance of the FSS it was decided that this area should be surveyed. As a result, Survey Unit 15 was established as a Class 3 survey unit. This area was surveyed last, after all data was collected in other survey units. The Class 3 designation was considered appropriate based on the results of measurements in the Class 1 areas; considering that all results in the Class 1 areas had SOR values less than one indicating that a Class 2 designation may have been appropriate for those areas.

6.3.4.1 Survey Units 1, 2, and 3

Survey Units 1, 2, and 3 are located in the “mural room” in the northwest corner of the building. This area (a single larger room) was used for R&D activities. Figure A-6 identifies measurement locations in the survey units. Survey Unit 1 is the floor of the western portion of the room, Survey unit 2 is the floor of the eastern portion, and Survey Unit 3 is the lower walls (up to 2 meters) of the room.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of floor areas and over 100% of lower walls, up to 2 meters. It was noted that in general, count rates (and exposure rates) in this room were slightly higher than most other areas of the building. However, there were no sustained elevated measurements that would indicate a small elevated area of radioactivity. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Appendix C provides results for each measurement location in each survey unit. The following paragraphs summarize the results.

Survey Unit 1 is the western portion of the room floor. All SOR values are less than one, ranging from 0.15 to 0.33 and averaging 0.24. Figure B-6 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 10 to 16 μR/hr, averaging 14 μR/hr.

Survey Unit 2 is the eastern portion of the room floor. All SOR values are less than one, ranging from 0.26 to 0.46 and averaging 0.36. Figure B-6 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 12 to 19 μR/hr, averaging 15 μR/hr.

While no small areas of elevated radioactivity were identified in this survey unit, it was noted that radioactivity levels were generally slightly higher than the western portion of the room.

Survey Unit 3 is the lower walls of the room. All SOR values are less than one, ranging from 0.24 to 0.41 and averaging 0.33. Figure B-6 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 10 to 20 μR/hr, averaging 14 μR/hr.

While measurement results in these survey units were slightly greater than other portions of the building, SOR values are considerably less than the limit of one indicating the survey units are suitable for release for unrestricted use.

Biased Measurements

Alpha/beta scan surveys did not identify any areas of elevated radioactivity. However, the scan surveyor flagged the area in each survey unit exhibiting the highest count rate for performance of a biased static measurement. The SOR results of these biased measurements are 0.30, 0.31, and 0.27, in Survey Units 1, 2, and 3, respectively.

6.3.4.2 Survey Units 4 and 5

Survey Units 4 and 5 are located south of the "mural room". This area, a single room, was used as a support area for R&D activities. Figure A-7 identifies measurement locations in the survey units. Survey Unit 4 is the floor and Survey Unit 5 is the lower walls of the room.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of floor areas and over 100% of lower walls, up to 2 meters. There were no sustained elevated measurements that would indicate a small elevated area of radioactivity. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Appendix C provides results for each measurement location in each survey unit. The following paragraphs summarize the results.

Survey Unit 4 is the floor of the room. All SOR values are less than one, ranging from 0.09 to 0.17 and averaging 0.12. Figure B-7 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 8 to 14 μR/hr, averaging 9.9 μR/hr.

Survey Unit 5 is the lower walls of the room. All SOR values are less than one, ranging from 0.0 to 0.18 and averaging 0.02. Figure B-7 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 7 to 15 μR/hr, averaging 10 μR/hr.

SOR values in these survey units are considerably less than the limit of one indicating the survey units are suitable for release for unrestricted use.

Biased Measurements

Alpha/beta scan surveys did not identify any areas of elevated radioactivity. However, the scan surveyor flagged the area in each survey unit exhibiting the highest count rate for performance of a biased static measurement. The SOR results of these biased measurements are 0.11 and 0.0, in Survey Units 4 and 5, respectively.

6.3.4.3 Survey Units 6 and 7

Survey Units 6 and 7 include the machine shop, a small storage room supporting the machine shop, and Dr. Kronenberg's Office. Dr. Kronenberg stored samples spiked with liquid forms of ^{230}Th and ^{241}Am in his office. As a result, ^{230}Th and ^{241}Am were considered RCOPCs in these survey units. The alpha DCGL for the survey units is 27 dpm/100 cm^2 (compared to 315 dpm/100 cm^2 in most other survey units) resulting in slower scan speeds and longer static count times. Figure A-8 identifies measurement locations in the survey units. Survey Unit 6 is the floors of the rooms and Survey Unit 7 is the lower walls of the rooms.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of floor areas and over 100% of lower walls, up to 2 meters. Scan speed was reduced to one half detector width per second to meet the requirements for the lower alpha DCGL. There were no sustained elevated measurements that would indicate a small elevated area of radioactivity. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Appendix C provides results for each measurement location in each survey unit. Count times for static measurements were five minutes to meet the MDC requirement for the lower alpha DCGL. The following paragraphs summarize the results.

Survey Unit 6 is the floor of the rooms. All SOR values are less than one, ranging from 0.08 to 0.54 and averaging 0.27. Figure B-8 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 6 to 10 µR/hr, averaging 7.5 µR/hr.

Survey Unit 7 is the lower walls of the room. All SOR values are less than one, ranging from 0.0 to 0.20 and averaging 0.02. Figure B-8 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 5 to 11 µR/hr, averaging 7.6 µR/hr.

SOR values in these survey units are less than the limit of one indicating the survey units are suitable for release for unrestricted use.

Biased Measurements

Alpha/beta scan surveys did not identify any areas of elevated radioactivity. However, the scan surveyor flagged the areas in the office and the machine shop exhibiting the highest count rate for performance of biased static measurements. The SOR results of these biased measurements in Survey Unit 6 are 0.18 and 0.21. The SOR results of these biased measurements in Survey Unit 7 are 0.03 and 0.02.

A gross alpha/beta smear was also collected in the sink trap in the machine shop. Its alpha and beta results are 0.99 and 0.72 dpm/100 cm^2, both slightly greater than MDC. Based on these very low results it is concluded that the drain system was not impacted by RAM.

6.3.4.4 Survey Units 8 and 9

Survey Units 8 and 9 include the counting laboratory and health physics offices. Samples were prepared in the counting laboratory fume hood by spiking them with liquid forms of ^{230}Th and ^{241}Am. As a result, ^{230}Th and ^{241}Am were considered RCOPCs in these survey units. The alpha DCGL for the survey units is 27 dpm/100 cm^2 (compared to 315 dpm/100 cm^2 in most other survey units) resulting in slower scan speeds and longer static count times. Figure A-9 identifies measurement locations in the survey units. Survey Unit 8 is the floors of the rooms and Survey Unit 9 is the lower walls of the rooms.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of floor areas and over 100% of lower walls, up to 2 meters. Scan speed was reduced to one half detector width per second to meet the requirements for the lower alpha DCGL. Scans were also performed on and in fixed laboratory benches and countertops and in the fume hood. There were no sustained elevated measurements that would indicate a small elevated area of radioactivity. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Appendix C provides results for each measurement location in each survey unit. Count times for static measurements were five minutes to meet the MDC requirement for the lower alpha DCGL. The following paragraphs summarize the results.

Survey Unit 8 is the floor of the rooms. All SOR values are less than one, ranging from 0.0 to 0.16 and averaging 0.04. Figure B-9 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 3 to 5 µR/hr, averaging 3.9 µR/hr.

Survey Unit 9 is the lower walls of the room. All SOR values are less than one, ranging from 0.0 to 0.64 and averaging 0.23. Figure B-9 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 3 to 5 µR/hr, averaging 4.0 µR/hr.

SOR values in these survey units are less than the limit of one indicating the survey units are suitable for release for unrestricted use.

Biased Measurements

Alpha/beta scan surveys did not identify any areas of elevated radioactivity. However, the scan surveyor flagged areas for performance of biased static measurements. The SOR results of these biased measurements in Survey Unit 8 are 0.04, 0.22, and 0.03. The SOR results of these biased measurements in Survey Unit 9 are 0.44 and 0.30.

In accordance with the RSSP, biased measurements were performed and smears were collected in the fume hood and the exhaust outlet for the fume hood. Survey Unit 9 location 33 was inside on the wall of the fume hood as well, with an SOR result of 0.0. A measurement was performed in the exhaust vent pipe with an SOR result of 0.0. Gross alpha/beta smear results in the fume hood base and the exhaust vent are less than the MDCs for alpha and beta (MDCs less than 1 dpm/100 cm^2). Low energy beta smear results are less than the MDC of approximately 10 dpm/100 cm^2. Based on these results, it is concluded that the exhaust outlet and ductwork was not impacted by RAM.

A gross alpha/beta smear was also collected in the sink trap in the counting laboratory. Its results are less than the MDCs for alpha and beta (MDCs less than 1 dpm/100 cm^2).

6.3.4.5 Survey Units 10 and 11

Survey Units 10 and 11 include the storage room/utility room. Figure A-10 identifies measurement locations in the survey units. Survey Unit 10 is the floors of the room and Survey Unit 11 is the lower walls of the room.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of floor areas and over 100% of lower walls, up to 2 meters. There were no sustained elevated measurements that would indicate a small elevated area of radioactivity. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Appendix C provides results for each measurement location in each survey unit. The following paragraphs summarize the results.

Survey Unit 10 is the floor of the room. All SOR values are less than one, ranging from 0.06 to 0.13 and averaging 0.10. Figure B-10 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 3 to 6 μR/hr, averaging 4.8 μR/hr.

Survey Unit 11 is the lower walls of the room. All SOR values are less than one, ranging from 0.0 to 0.04 and averaging 0.01. Figure B-10 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 3 to 6 μR/hr, averaging 4.5 μR/hr.

SOR values in these survey units are less than the limit of one indicating the survey units are suitable for release for unrestricted use.

Biased Measurements

Alpha/beta scan surveys did not identify any areas of elevated radioactivity. However, the scan surveyor flagged areas for performance of biased static measurements. The SOR results of these biased measurements in Survey Unit 10 and 11 are 0.10 and 0.02, respectively.

6.3.4.6 Survey Units 12 and 13

Survey Units 12 and 13 are the calibration range room. Figure A-11 identifies measurement locations in the survey units. Survey Unit 12 is the floors of the room and Survey Unit 13 is the lower walls of the room.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of floor areas and over 100% of lower walls, up to 2 meters. There were no sustained elevated measurements that would indicate a small elevated area of radioactivity. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Appendix C provides results for each measurement location in each survey unit. The following paragraphs summarize the results.

Survey Unit 12 is the floor of the room. All SOR values are less than one, ranging from 0.0 to 0.11 and averaging 0.06. Figure B-11 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 3 to 5 μR/hr, averaging 4.3 μR/hr.

Survey Unit 13 is the lower walls of the room. All SOR values are less than one, ranging from 0.0 to 0.07 and averaging 0.02. Figure B-11 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 3 to 6 μR/hr, averaging 4.3 μR/hr.

SOR values in these survey units are less than the limit of one indicating the survey units are suitable for release for unrestricted use.

Biased Measurements

Alpha/beta scan surveys did not identify any areas of elevated radioactivity. However, the scan surveyor flagged areas for performance of biased static measurements. The SOR results of these biased measurements in Survey Unit 12 are 0.04 and 0.07. The SOR result in Survey Unit 13 is 0.0.

6.3.4.7 Survey Unit 14

Survey Unit 14 is the former radioactive waste storage room (Room 109) and the outdoor pad leading to the storage room. Due to the small area of the survey unit, walls and floors are included in the single survey unit. Figure A-12 identifies measurement locations in the survey unit.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of floor areas and over 100% of lower walls, up to 2 meters. There were no sustained elevated measurements that would indicate a small elevated area of radioactivity. It was noted that the outdoor pad uniformly exhibited higher alpha and beta count rates than most portions of the building. Considering the uniformity of the results, the higher radioactivity is attributed to natural background in the concrete. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Appendix C provides results for each measurement location.

All SOR values in Survey unit 14 are less than one, ranging from 0.0 to 0.47 and averaging 0.13. Figure B-12 is a posting plot of SOR data. As can be seen in the figure, the pad at the southern portion of the survey unit exhibited higher SOR values attributable to natural radioactivity. Exposure rate measurements performed at each location ranged from 3 to 6 μR/hr, averaging 4.2 μR/hr.

SOR values in this survey unit are less than the limit of one indicating the survey unit is suitable for release for unrestricted use.

Biased Measurements

Alpha/beta scan surveys did not identify any areas of elevated radioactivity. However, the scan surveyor flagged one floor area for performance of a biased static measurement. The SOR result of this biased measurement is 0.09.

6.3.4.8 Survey Unit 15

Survey Unit 15 is a Class 3 survey unit including a portion of the hallways in the building, the administrative office area, and the bathroom. Figure A-13 identifies measurement locations in the survey unit.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of floor areas in the hallways and approximately 30% of the floor areas in the office areas. There were no sustained elevated measurements that would indicate a small elevated area of radioactivity. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Random Measurement Location Results

Appendix C provides results for each measurement location.

All SOR values in Survey unit 15 are less than one, ranging from 0.01 to 0.19 and averaging 0.07. Figure B-13 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 4 to 15 µR/hr, averaging 11 µR/hr.

SOR values in this survey unit are less than the limit of one indicating the survey unit is suitable for release for unrestricted use.

Biased Measurements

Alpha/beta scan surveys did not identify any areas of elevated radioactivity. However, the scan surveyor flagged one floor area for performance of a biased static measurement. The SOR result of this biased measurement is 0.03.

6.3.5 Building 2541 – CECOM Butler Building

Building 2541 was surveyed as a MARSSIM Class 1 area. Building 2541 was historically used, in part, for demilitarization of excess ^{232}Th (night vision lenses), ^{226}Ra, and ^{3}H. Two survey units were established in Building 2541 in accordance the RSSP. Survey Unit 1 is the floors and

Survey Unit 2 is the lower walls. Figure A-14 identifies the building layout and measurement locations.

Deviations from RSSP

No deviations from the RSSP occurred during FSS activities in Building 2541.

Alpha Beta Scan

Alpha/beta scans were performed over 100% of floor areas and the lower walls. There were no sustained elevated measurements that would indicate a small elevated area of radioactivity. Instantaneous rolling average alpha and beta count rates were recorded at one second intervals and are included in Appendix H to this FSSR.

MARSSIM Measurement Location Results

Appendix C provides results for each measurement location in each survey unit. The following paragraphs summarize the results.

Survey Unit 1 is the floor of the building. All SOR values are less than one, ranging from 0.10 to 0.33 and averaging 0.17. Figure B-14 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 3 to 5 µR/hr, averaging 3.9 µR/hr.

Survey Unit 2 is the lower walls of the building. All SOR values are less than one, ranging from 0.0 to 0.08 and averaging 0.03. Figure B-14 is a posting plot of SOR data. Exposure rate measurements performed at each location ranged from 3 to 5 µR/hr, averaging 3.8 µR/hr.

SOR values in these survey units are less than the limit of one indicating the survey units are suitable for release for unrestricted use.

Biased Measurements

Alpha/beta scan surveys did not identify any areas of elevated radioactivity. However, the scan surveyor flagged one floor area and one wall area for performance of biased static measurements. The SOR result of these biased measurements is 0.13 and 0.04 in Survey Units 1 and 2, respectively.

7.0 CONCLUSION

Radiological FSSs were performed in Buildings 275, 283, 292, 2540 and 2541 at Fort Monmouth, New Jersey. The surveys were designed in accordance with MARSSIM final status survey design criteria using conservative assumptions. DCGLs applied to the surveys are the conservative NRC generic screening criteria. The sum of the ratios rule was applied to all survey results to address the potential presence of multiple radionuclide contaminants. All SOR results in all buildings, including biased locations, are less than the limit of one. In addition, evaluations of building systems (drain and ventilation) for radioactive contaminants did not identify any radiological impacts to building systems. Based on historical research and the FSS field observations and supporting laboratory analytical data, all buildings surveyed are considered suitable for unrestricted release in accordance with Subpart E to 10 CFR 20, Radiological Criteria for License Termination.

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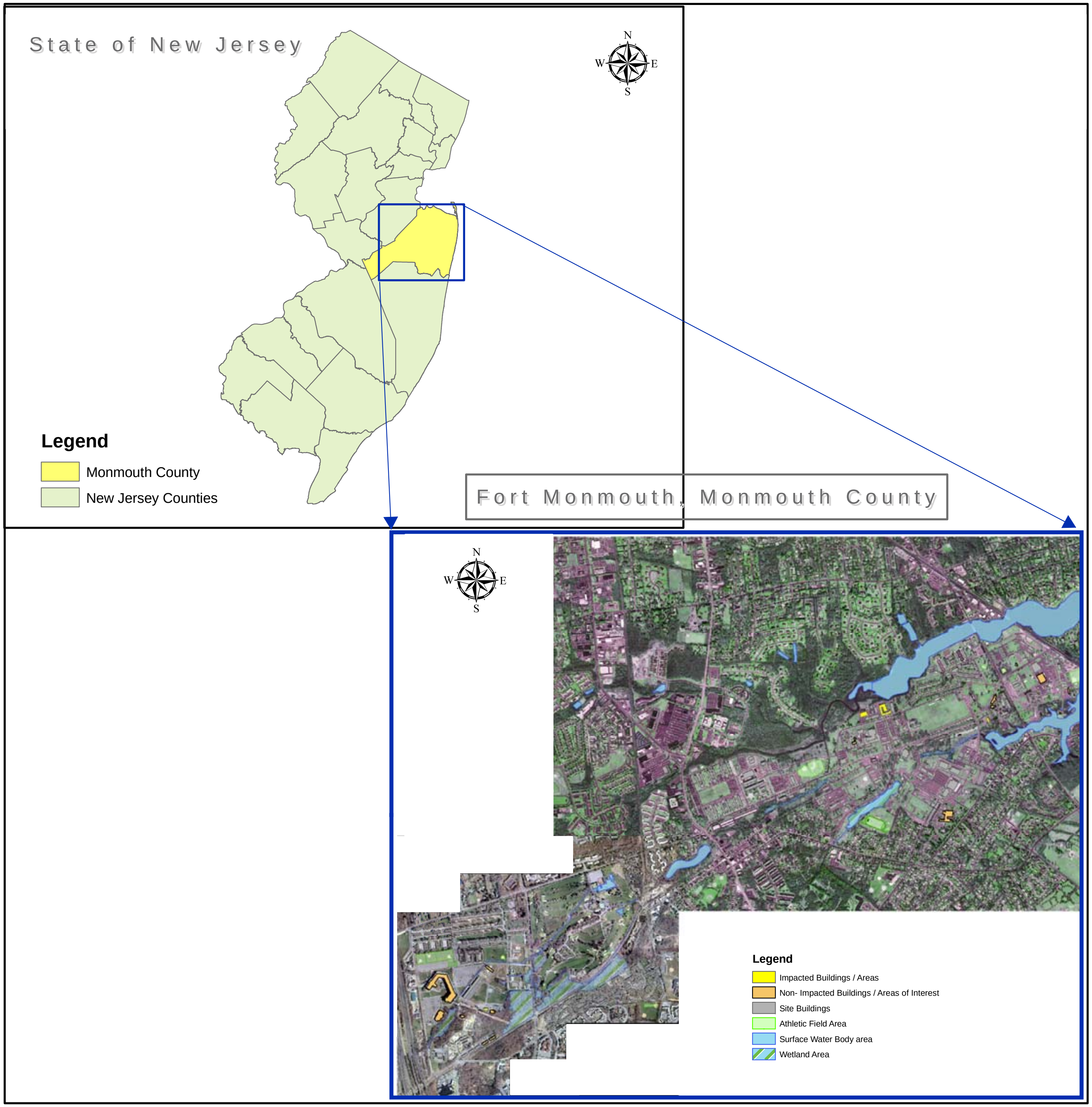
FIGURES



FORT MONMOUTH

MONMOUTH COUNTY
NEW JERSEY

Date: April, 2007 Project #: 05-3132.01 File Name: Figure 1 Prepared By: B.Pangelova	Figure 1

CABRERA SERVICES
RADIOLOGICAL · ENVIRONMENTAL · REMEDIATION

N
W E
S

Legend

- Impacted Buildings / Areas
- Non- Impacted Buildings / Areas of Interest
- Site Buildings
- Athletic Field Area
- Surface Water Body area
- Wetland Area

0 1,900 3,800
Feet

FORT MONMOUTH
OVERVIEW MAP

Fort MONMOUTH,
NEW JERSEY

Date: April, 2007

Project #: 05-3132.01

File Name: Figure 2

Prepared By: B.Pangelova

Figure 2

CABRERA SERVICES
RADIOLOGICAL · ENVIRONMENTAL · REMEDIATION

FORT MONMOUTH, MAIN POST

Fort Monmouth, Main Post
NEW JERSEY

Date: April, 2007
Project #: 05-3132.04
File Name: Figure 3
Prepared By: B.Pangelova

Figure 3

CABRERA SERVICES
RADIOLOGICAL · ENVIRONMENTAL · REMEDIATION

N
W E
S

Legend

- Impacted Buildings / Areas
- Non- Impacted Buildings / Areas of Interest
- Site Buildings
- Athletic Field Area
- Surface Water Body area
- Wetland Area

0 520 1,040 Feet

FORT MONMOUTH, CHARLES WOOD AREA

Fort Monmouth, Charles Wood Area
NEW JERSEY

Date: April, 2007 Project #: 05-3132.04 File Name: Figure 4 Prepared By: B.Pangelova	Figure 4

CABRERA SERVICES
RADIOLOGICAL · ENVIRONMENTAL · REMEDIATION

Legend

- SU1 (Radiation Facillity)
- SU2 (Radiation Facillity)
- SU4 (Work Area)
- SU6 (Machine Shop)
- SU8
- SU10
- SU12
- SU14
- SU15 (Class 3)

BUILDING 2540
FLOOR PLAN and
CLASS 1 SURVEY UNITS

FORT MONMOUTH
NEW JERSEY

Date: September, 2006
Project #: 05-3132.04
File Name: Figure 8
Prepared By: B.Pangelova

Figure 5

CABRERA SERVICES
RADIOLOGICAL · ENVIRONMENTAL · REMEDIATION

MODIFIED: Original Contractor Figure Modified by USACE on 26 July 2012