FINAL STATUS SURVEY REPORT

Natick Soldier Center
Research Development and Engineering Command
Soldier Systems Center,

Natick, MA

USA Project 2005-030

Prepared for:

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ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
ARIEM	Army Research Institute of Environmental Medicine
^{14}C	Carbon-14
CABRERA	Cabrera Services, Inc.
CECOM	Communications-Electronics Command
CFR	Code of Federal Regulations
cm	centimeters
COC	chain of custody
cpm	counts per minute
DCGL	Derived Concentration Guideline Level
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
EMC	elevated measurement comparison
FR	Federal Register
FSS	Final Status Survey
FSSP	Final Status Survey Plan
^{3}H	tritium
HP	Health Physicist
HRA	Historical Radiological Assessment
JMC	Joint Munitions Command
LBGR	Lower Bound Gray Region
LSC	Liquid Scintillation Counting
LTR	License Termination Rule
m	meter
m/s	meters per second
m^2	square meter
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
µCI	microcurie
mrem/yr	millirem per year
NaI	sodium iodide
NRC	Nuclear Regulatory Commission
NSC	Natick Soldier Center
PM	Project Manager
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RDECOM	Research and Development Engineering Command
ROCs	radionuclides of concern
RSS	Radiological Safety Surveys
SOPs	Standard Operating Procedures
SOR	Sum of Ratios
SSC	Soldier Systems Center
SU	Survey unit
TEDE	Total Effective Dose Equivalent
^{232}Th	Thorium-232
µCi/ml	microcuries per milliliter
U.S.	United States
WRS	Wilcoxon Rank Sum

EXECUTIVE SUMMARY

Natick Soldier Center (NSC) - Research and Development Engineering Command (RDECOM) at Soldier Systems Center (SSC) in Natick, Massachusetts historically possessed and used quantities of radioactive materials licensed under the Atomic Energy Commission and the Nuclear Regulatory Commission (NRC). The use of these licensed materials has ceased and NSC, RDECOM wishes to terminate the license. To this end, Cabrera Services, Inc. (CABRERA) has been contracted to provide assistance to NSC, RDECOM in obtaining license termination from the NRC through the performance of a Final Status Survey and this report to assess the current radiological condition of the site and its suitability for free release from licensure.

The areas included in this survey were divided into 6 Survey Units. Each of those survey units were surveyed as MARSSIM Class 3 Units. Included in the survey were exposure rate measurements, beta scans, and fixed point survey measurements at systematic statistical survey locations. The fixed point survey measurements consisted of both open and closed window beta measurements, and removable beta (^{14}C and ^{3}H) samples for analytic analysis.

During the course of this survey, no exposure rate measurements elevated above background values were encountered and no fixed point static measurements or removable contamination analytic samples were found to exceed the project established DCGLs. Data collected in the survey and contained in this report meet the criteria derived in the Final Status Survey Plan design to support the unrestricted release of the facilities included in the plan.

1.0 INTRODUCTION

This *Final Status Survey (FSS) Report* presents results of the FSS conducted by Cabrera Services, Inc. (CABRERA) to support the radiological decommissioning of structures at the Natick Soldier Center (NSC) - Research and Development Engineering Command (RDECOM) at Soldier Systems Center (SSC) in Natick, Massachusetts. The impacted buildings included in the FSS included the Research Building (also known as Building 3), the Health Clinic Building (also known as Building 30), and the Low Level Radiation Storage Area (also known as Building 89). Activities described in this report were conducted in accordance with the *Final Status Survey Plan (FSSP) - U.S. Army Soldier Systems Center* (CABRERA, November 2006), which is presented in Appendix A. This report has been prepared by CABRERA for the United States (U.S.) Army Joint Munitions Command (JMC), under JMC Project Number *USA 2005-030*.

1.1 Site Description and Background

The SSC is a 76-acre facility located in Natick, Massachusetts. The SSC occupies a peninsula on the eastern shore of Lake Cochituate state park and recreational area and is bordered on the north and west by a residential area. The Army purchased the site in 1949 from the Metropolitan District Commission. At the time of purchase, the property was primarily used as a forested recreational area. The Army built the SSC in 1954 and has since used the area for industrial, laboratory, and storage activities for research and development in the areas of food science, aeromechanical, clothing, material, and equipment engineering. During its operation, the Army used a variety of substances including radioactive material. Radioactive materials were used for food irradiation, tracer studies and clothing absorption tests, respectively.

There was a research animal waste incinerator which began operation in 1973 in Building 30 and was retired in 1992. That unit also burned scintillation solvent waste that was contaminated with radioactive materials from various radiological procedures and tests.

The facility has a long history of radioactive material use. Early Atomic Energy Commission (AEC) licensing records indicate radioactive material use as early as 1955. Radioactive material work involved primarily radioisotopes commonly used for biological research and related sealed sources that support materials research such as detection, calibration, and irradiation.

The facility is a U.S. Army research and development facility. Radioactive material uses have dramatically been reduced over the last 10 years. The reduction in program scope has been archived by numerous license amendments documenting the reduction in the number, type and quantities of radioactive material. Over the past 5 to 10 years the number of authorized use locations within the facility have also been reduced. Current levels of activity consist of a small number of bioscience laboratories within ARIEM located in Building 42 under a separate NRC license. Radiation safety programmatic activities within Building 30 (Health Clinic) ceased with NRC's separate license authorization issued to ARIEM in 2004 and Building 89 is no longer used for radioactive waste storage.

A Historical Radiological Assessment (HRA) was conducted by CABRERA (CABRERA, 2004). The results of this assessment for the Research and Health Clinic Buildings identify two potential radiological contaminants of concern as listed in Section 1.2.

1.2 Radionuclides of Concern

From the review of records of licensing, inventory, operations, and radiological safety in the HRA, it was evident that any significant contamination identified through routine operational Radiological Safety Surveys (RSS) was decontaminated at that time. Common good laboratory practices were used to remove and dispose of contamination as it was generated or discovered. With the use of radioactive material phasing out in the 1970s, the only radionuclides that had half-lives long enough to still be present at significant levels today are tritium (^{3}H) and Carbon-14 (^{14}C). The radionuclides of concern (ROCs) for this project are presented in Table 1-1 below.

Table 1-1: Radionuclides of Concern

NUCLIDE	NAME	HALF-LIFE	PRINCIPAL EMISSIONS	SOURCE OF RADIONUCLIDE
^{3}H	Hydrogen-3 (tritium)	**12.3 YR**	0.019 mega electron volts (MeV) beta	Radioisotope research
^{14}C	Carbon-14	**5730 YR**	**0.156 MEV BETA (RESEARCH)**	Radioisotope research

2.0 DERIVED CONCENTRATION GUIDELINE LEVELS

Decommissioning planning was conducted in accordance with guidance presented in NUREG-1757, *Consolidated NMSS Decommissioning Guidance, Volumes 1 and 2,* (NRC, 2003a and 2003b). This section describes the establishment of derived concentration guideline levels (DCGLs) that were used to guide site decommissioning activities. DCGLs, expressed for surface activity in disintegrations per minute per 100 square centimeters (dpm/100cm^2), represent the residual radioactivity concentrations (above background) on surfaces that correspond to the allowable radiation dose limit, considering the collective risks to human health associated with anticipated potential exposure scenarios and pathways to a potential future site population. Demonstrating that residual radioactivity remaining at the site is statistically within site-specific DCGLs maintains compliance with acceptable risk to a potential future site population.

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

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

Determination of ALARA levels must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from excavation and waste disposal activities.

The NRC standard of 25 mrem/yr is applicable to the decommissioning of the SSC structures and, therefore, has been used as the basis for demonstrating that the structures should be released for unrestricted use. Application of this DCGL ensures that the potential dose to the average member of the critical group will not exceed 25 mrem in any one year over a 1,000-year period.

The License Termination Rule (LTR) presented in 10 CFR 20, Subpart E, specifies an allowable dose limit of 25 mrem/yr. Supplemental information regarding the implementation of the LTR, including screening criteria for building surfaces and soil, has been published in the following Federal Register (FR) notices:

FR Volume 63, Number 222, November 18, 1998 (NRC, 1998);

FR Volume 64, Number 234, December 7, 1999 (NRC, 1999); and

FR Volume 65, Number 114, June 13, 2000 (NRC, 2000b).

These screening criteria were used to establish instrument/analysis sensitivity requirements for decommissioning activities.

The DCGLs used to support decommissioning of Natick SSC structures are presented in Table 2-1.

Table 2-1: Surface Activity DCGLs for Natick SSC Final Status Survey

Agency / Reference	Alpha		Beta/Gamma	
	Total (dpm/100cm^2)	Removable (dpm/100cm^2)	Total (dpm/100cm^2)	Removable (dpm/100cm^2)
NRC 10 CFR 20.1402	Total dose to the public after decommissioning of not more than 25 mrem/yr			
NRC NUREG 1757, Vol. 1 Building Surface Screening Values	N/A	N/A	H-3: 1.2 E+08 C-14: 3.6 E+06	10% of Total
Chosen DCGL For Natick SSC	***N/A***	***N/A***	***3,600,000***	***360,000***

Notes:
a. Averaged over 1 m^2
b. Measured at 1 centimeter (cm) from the surface
c. Screening values assumes removable surface contamination of 0.1%
d. Screening values derived using NUREG/CR-5512 Vol.3; Table 5.19 P_{crit} = 0.90 for building surfaces

3.0 FINAL STATUS SURVEY DESIGN

This section summarizes the design of final status surveys conducted at the Natick SSC, as described in the *FSSP* (CABRERA, 2006a). The survey design discussed below is based on the technical guidance and statistical methods presented in the *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC, 2000a), as required by *NUREG-1757, Consolidated NMSS Decommissioning Guidance, Vol. 2* (NRC, 2003b).

3.1 Determine Impacted and Non-Impacted Areas

In order to determine the scope of the FSS, a historical review of licensed radioactive material usage at the facility and a HRA was performed. The purpose of the review was to:

1. Identify radionuclides used, and which rooms/labs/areas were used or were potentially contaminated,
2. Identify areas that were previously released, and
3. Identify and quantify actual areas of contamination.

This information was then used to determine if certain areas were impacted by radionuclide usage. Specific areas covered under this FSS Plan include Building 89; Building 3, Rooms 131, 133, 134, 135, 136, 214, 307, 309; Building 30, Rooms 101, 103, 108, and the roof over Room 108, as described in the *FSSP*, which is attached as Appendix A.

3.2 Area Classification Based On Contamination Potential

Impacted areas were then classified based on contamination potential as per guidance in MARSSIM sections 2.2, 4.4, 5.5.2, and 5.5.3 (NRC, 2000). Namely,

- Class 1: The area had 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 the release criteria.

3.3 Statistical Tests

3.3.1 Sign Test

The Sign test is designed to detect uniform contamination above screening limits throughout a survey unit (SU). It draws direct comparisons between SU data and the chosen release criteria, i.e. DCGL. The Null Hypothesis is assumed to be true unless the statistical test indicates that it should be rejected in favor of the alternative. The null hypothesis states that the probability of a measurement less than the DCGL is less than one-half, i.e. the 50th percentile (or median) is greater than the DCGL. With this in mind, SUs may meet the release criteria even though some measurements may be greater than some reference area measurements. The result of the hypothesis test determines whether or not the SU as a whole meets the release criteria.

If all of the sample results are less than the DCGL then no Sign test statistical evaluation is required.

3.3.2 Application of Sign Test for Multiple Surfaces

The typical approach for evaluating internal building surfaces using the MARSSIM protocol involves the Wilcoxon Rank Sum (WRS) test. The WRS test requires that an appropriate background (reference) unit be surveyed for each material type in a SU such that gross measurements may be used for evaluating survey results. However, application of the WRS test for complex buildings with many structural surfaces can be cumbersome, as a single SU may require several background reference areas for proper evaluation. To address situations like this, a method for applying the Sign test to multiple surfaces was developed. The procedures for this are described in Chapter 12 of NUREG-1505. (NRC 1998)

NUREG-1505 states " …the Sign test may be more appropriate when there are many different materials within what would otherwise logically be a single SU. As indicated at the beginning of this chapter (Chapter 12), to divide such a SU into separate parts, each requiring its own reference area is not only impractical, but may be inconsistent with the dose models used to determine the DCGLs." "Fortunately, there is a third option - to use the Sign test with paired observations. Each measurement in the SU is paired with an observation on a suitable reference material. The Sign test is then performed on the difference. The tradeoff is the higher variability of the differences compared to a single measurement."

To account for this potential increased variability in measurement standard deviation from multiple surfaces, the planning sigma values used in the determination of the number of sample points per SU were doubled from their observed values during the Scoping Survey. Details of the SU design are provided in Section 3.8.

Representative background values to be used in the paired observations were collected in unimpacted areas of the buildings on similar building materials. The selection and measurement of the background reference areas were done prior to the execution of the field work so they could be applied directly. A minimum of five (5) 1-minute fixed-point measurements were collected with the average used for subtraction from each systematic measurement location prior to evaluation using the Sign test.

3.3.3 Performing the Sign Test

The Sign test is applied as outlined in the following five steps from Section 8.3.2 of the MARSSIM. Each measurement had the appropriate background reading subtracted and the difference would be subject to the Sign test, outlined in the steps below:

Step 1: List the SU measurements, X_i, $i = 1, 2, 3, \ldots, N$.

Step 2: Subtract each measurement, X_i, from the DCGL to obtain the differences:

$$D_i = DCGL - X_i,\ i = 1, 2, 3, \ldots, N.$$

Step 3: Discard each difference that is exactly zero and reduce the sample size, N, by the number of such zero measurements.

Step 4: Count the number of positive differences. The result is the test statistic (S+). Note that a positive difference corresponds to a measurement below the DCGL and contributes evidence that the SU meets the release criterion.

Step 5: Large values of S+ indicate that the null hypothesis (that the SU exceeds the release criterion) is false. The value of S+ is compared to the critical values in MARSSIM Appendix I, Table I.3. If S+ is greater than the critical value, *k*, the null hypothesis is rejected.

3.4 Elevated Measurement Comparison

If a measurement showed a location of elevated activity greater than the DCGL and further decontamination is not possible, then the area around the location would need to be surveyed per the elevated measurement comparison (EMC) procedure. The EMC is performed for both measurements obtained on the systematic/random sampling grid and for locations flagged by scanning measurements. Any measurement from the SU that was equal to or greater than an investigation level indicated an area of relatively high concentrations that should be investigated, regardless of the outcome of the nonparametric statistical tests.

Radiological contamination above the DCGL levels would require a breakup of the SU with reclassification to Class 1 of at least certain sections. The EMC consists of comparing each measurement from the SU to investigation levels (the DCGL for this survey). If such a situation arose, then the EMC procedure as specified in MARSSIM, Section 8.5.1 and/or decontamination would need to be performed. Surveys of Class 1 areas were beyond the scope of this FSS effort.

3.5 SU Breakdown

For this FSS, the impacted areas were assigned six SUs designations based on the classification and physical location of each area.

- 3-1W Building 3, First Floor West, Rooms 131, 133, 134, 135, 136
- 2-3W Building 3, Second Floor West, Room 214
- 3-3E Building 3, Third Floor East, Rooms 307, 309
- 30-1 Building 30, Rooms 101, 103, 108
- 30-roof Building 30, Roof over Room 108
- 89-1 Building 89, all

Graphical representations of these areas are provided in the *FSSP*, attached as Appendix A.

3.6 SU Coverage

The coverage of beta and gamma measurements in each SU is dependent upon the survey class and the types of ROCs. General specifications for each SU class are provided below. Note that

"Fixtures" includes features such as countertops, drawers, cabinets, and hoods.

<u>Class 1</u>

Floors, Lower Walls (< 2 meters [m]) and Fixtures)

Perform a 100% beta scan survey of surfaces. Collect fixed-point measurements at systematic locations using a triangular grid pattern. Floor areas limited to 100 square meters (m^2), where practical. Collect additional fixed-point measurements at biased locations using scan described in 3.10.1 or professional judgment.

Upper Walls (> 2m) and Ceilings

Perform a minimum 25% scan survey on walls above 2 m and 10% scan survey on accessible ceiling surfaces. Collect fixed-point measurements at biased locations using professional judgment.

<u>Class 2</u>

Floors, Lower Walls (< 2m and Fixtures)

Perform a minimum 25% scan survey of surfaces. Collect fixed-point measurements at systematic locations using a triangular grid pattern. Floor area limit of 1,000 m^2 applied. Collect additional fixed-point measurements at biased locations using professional judgment.

Upper Walls and Ceilings

Perform a minimum 10% scan on walls above 2 m and accessible ceiling surfaces. Collect fixed-point measurements at biased locations using scan described in 3.10.1 or professional judgment.

<u>Class 3</u>

All Surfaces and Fixtures

Perform a minimum 10% scan survey of all surfaces. Collect fixed-point measurements at biased locations using professional judgment. No floor area size limit enforced.

The SUs are defined in this manner in order to simplify administration of the survey and handling of the data. Surveys of upper walls and ceilings are being administered as part of the survey of the lower floors and walls.

NOTE: All areas of the facility addressed in this FSS were classified as MARSSIM Class 3 SUs.

3.7 Release Criteria

3.7.1 Surface Contamination DCGLs

Screening values used were the DCGLs shown in Table 2-1. If these values were exceeded during the survey, an evaluation would need to be performed to ensure that the prospective dose due to residual radioactivity did not exceed 25 millirem per year (mrem/yr).

3.8 Sampling Grid Layout

3.8.1 Relative Shift

The relative shift describes the relationship of site residual radionuclide concentrations to the DCGL and is calculated using the following equation, found in Section 5.5.2.2 of MARSSIM (NRC, 2000):

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

where:

σ	=	An estimate of the standard deviation of the concentration of residual radioactivity in the SU (which includes real spatial variability in the concentration as well as the precision of the measurement system). σ is estimated as 0.3 times the DCGL.
Δ	=	The width of the gray region, i.e., DCGL minus the lower bound of the gray region (LBGR)
DCGL	=	The derived concentration guideline level (i.e., release limit)
LBGR	=	Concentration at the LBGR. The LBGR effectively becomes the survey's action level. For conservatism, the LBGR was set to 0.5 times the DCGL for this FSS.

3.8.2 Number of Sampling Points

The *FSSP* established the acceptable decision errors $\alpha=\beta=0.05$. Based on these acceptable decision errors and the relative shift, the minimum number of measurement locations in each SU was calculated per MARSSIM Section 5. This calculation includes the MARSSIM recommended

20% additional samples to protect against the possibility of lost or unusable data (Table 5.5 from the MARSSIM document).

Table 3-1 shows the MARSSIM-based statistical parameters used in a calculation of the target number of samples per survey area.

Table 3-1: Summary of MARSSIM Design Parameters for the Site FSS

MARSSIM Parameter	Static Measurement[1] (cpm)	Tritium Smear Test (dpm/100 cm^2)
σ	30,240[2,3]	108,000[2]
DCGL	100,800[3]	360,000
LGBR	50,400	180,000
Relative Shift (Δ/σ)	1.67	1.67
Pr (from MARSSIM Tbl. 5.1)	0.95	0.95
N	14	14
N (including 20% overage)[4]	*17*	*17*

Notes:

1. Static counts to be performed with Ludlum 43-68 proportional detector. Count time = 30 sec.
2. Sigma values for static measurements and tritium smear tests were set at 0.3 times the DCGL to account for potential added variability (see Section 3.3.2)
3. 100,800 counts per minute (cpm) is equivalent to the beta DCGL of 3,600,000 disintegrations per minute per 100 centimeters squared (dpm/100 cm^2) assuming 2.8% ^{14}C efficiency for the Ludlum 43-68 probe.
4. MARSSIM Sec. 5.5.2.1 recommends that the calculated number of samples per SU (N) be increased by 20% to account for potentially lost or unusable data. Final N rounded up to nearest whole number.

The LGBR was chosen as one-half of the DCGL as per guidance provided in the MARSSIM. The standard deviation static measurements and the tritium smear analysis were set at 30% of the DCGL as per MARRSIM recommendation when site-specific standard deviation data is not available.

The results show that all of the measurements are sufficiently sensitive to allow a relatively small number of MARSSIM-type systematic measurements to be performed in each SU (i.e., 17). Scans and biased measurements are also important in demonstrating that the residual radioactivity levels are less than the DCGLs.

3.8.3 SU Grid Spacing

Grid spacing and placement of fixed-point measurement locations within each SU was based on a relative coordinate system.

Locations of measurement locations in Class 3 SUs were determined by multiplying the east-west (Y) and the north-south (X) dimensions of each SU by a randomly generated number between 0 and 1 for each dimension. For consistency, the southwest corner of each SU was used the origin for each SU. Sample locations were calculated using a computer to determine random numbers and plot data point locations on a survey map. To facilitate field measurements, the calculated coordinates were rounded to the nearest whole number of meters.

3.9 Background Survey Areas

Determination of background values is of the utmost importance in building decommissioning projects. Since 'net' residual contamination values, or the difference between a sample count rate and background, are used to assert whether a particular SU satisfies the criteria for unrestricted release, application of accurate and applicable background values is crucial to proper decision-making. In this light, background measurements must be made in non-impacted areas on building surfaces expected during the FSS. The selection and measurement of the background reference areas was done before the execution of fieldwork. Representative measurements of various flooring and wall materials were collected with each detector used so an applicable background could be applied before direct comparison with a DCGL value or application of the Sign test. In order to account for instrument response to ambient background, which can change from location to location, instrument background measurements were performed on each material encountered.

3.10 Survey Methods and Instrumentation

The purpose of this section is to describe direct radiation measurement and sample collection and analysis techniques that were implemented during the Site FSS. Physical and performance characteristics of each detector probe are provided in Table 3-2.

Table 3-2: FSS Detector Probe Characteristics

Detector	Application	Detector Type	Radiation Sensitivity	Active Area (cm^2)
Ludlum 44-9	Building, system, equipment surfaces; personnel frisking	Geiger-Mueller	Beta, Gamma	15
Ludlum 43-68	Large area surfaces (floor, walls, bench tops, drawers)	Gas Proportional	Alpha, Beta	126
Ludlum 43-37 Floor Monitor (239-1F)	Smooth floor surfaces	Gas Proportional	Alpha, Beta	582
Ludlum 44-110 Gas Proportional Tritium Detector	Direct Static Measurements Only – no scans	Window-less Gas Proportional	19 keV Beta	126
Ludlum Model 19	Gamma radiation scans and counts	Micro-R Exposure Rate (1-inch by 1-inch Sodium Iodide [NaI])	Gamma	N/A
LSC	Removable beta contamination measurements	Liquid scintillation	beta	N/A

3.10.1 Surface Beta Radioactivity Scans

Applicability:

Impacted areas that had the potential for beta-emitting radionuclide surface contamination were scanned as described in this section. For the Natick SSC survey, this includes all impacted areas. Floors, walls, bench tops, and cabinet interiors were scanned.

Instrumentation:

The following detectors, which had the ability to detect ^{14}C and higher-energy beta particles, were used per the judgment of the survey supervisor:

- Gas proportional detector (Ludlum 43-68 and Ludlum 43-37) for any large surfaces

Scan measurement sensitivities are presented in the *FSSP*, attached as Appendix A.

Technique:

The surfaces were scanned for ^{14}C by moving the probe in straight paths with spacing that ensured that the minimum surface area was covered as required by the SU classification. The ratemeter was set to alarm at a preset level indicating that contamination approaching a screening value was being detected.

The scan survey action level was a sustained instrument response above the ambient level. Action levels were calculated in "gross counts per minute (cpm)" for a given area with an asserted background level. If a survey resulted in locations above the action level, the following additional data was also collected:

- A 30 second static measurement at the location ("biased count") for beta/alpha;
- A 30 second static measurement with a window-less detector for tritium; and
- A "biased" smear sample to be analyzed with Liquid Scintillation Counting (LSC) for potential nuclides of interest.

Data Recording:

Any biased measurements resulting from an elevated scan reading were recorded, including location, count or count rate reading, and a description of the object of interest.

A field scan sheet was completed for each area of the survey unit recording maximum and average count rates.

3.10.2 Fixed-Point Measurements

Applicability:

Fixed-point measurements (for both beta/alpha and low-energy beta/tritium) were defined as static counts performed with a portable instrument. They were performed as part of the statistical survey or as biased measurements to investigate elevated scan readings. Since the instrument used for static counts is capable of simultaneous alpha and beta radiation detection and quantification, alpha static counts were recorded for completeness even though non of the ROCs are alpha emitting radionuclides. No significant elevated alpha activity was noted during the survey and no alpha statistical analysis was performed.

Instrumentation:

Ludlum 43-68 and 44-110 probes were used to perform and document fixed-point measurements.

Technique:

Fixed-point measurements were 30 seconds in duration with the instrument placed in scaler mode. The highest indicated 30-second scaler count was recorded as the result of the fixed-point measurement.

The fixed-point (static) survey action level was the DCGL plus the average background specific to the material type being evaluated.

Data Recording:

Fixed point measurements were recorded, including location (grid point or recognizable object), count rate (or exposure rate) reading, distance from the object of interest (if gamma reading), and a description of the object of interest as applicable.

3.10.3 Smear Sample Collection and Analysis

Applicability:

Selected building surfaces had LSC smear samples taken to assess the presence of removable contamination. These smears were taken at every location that a fixed-point measurement was taken and at any other locations deemed necessary based on visual inspections and professional judgment.

Technique:

Smear samples were collected by moistening the smear, performing the sample over a surface area of 100 cm^2, and placing the smear in LSC vials provided by the offsite laboratory.

Smear samples were sent offsite and analyzed using LSC for site ROCs ^{3}H and ^{14}C.

Data Recording:

Smear samples were recorded, including location (grid point or recognizable object), and a description of the object of interest as applicable. A chain of custody (COC) form was completed and included with smears sent off-site for analysis.

3.10.4 Exposure Rate Surveys

Prior to conducting the beta scan surveys in each SU, an exposure rate survey was performed. No exposure rates elevated above background were encountered during the course of the project.

4.0 FINAL STATUS SURVEY RESULTS

This section presents the results of survey and sampling activities conducted as part of the FSS for the Natick SSC buildings.

4.1 Building Survey Results

Class 3 scan surveys were performed in each of 6 impacted areas. A total of 17 integrated measurements and smears were also collected in each SU at computer-generated random locations for the statistical survey as presented in Table 3-1. Biased survey locations were also placed in accordance with the guidance in the FSSP. Survey forms and data are presented in Appendix B. Smears were sent offsite to Paragon Analytics, Inc. for LSC analysis. Analytical results are presented in Appendix C. A summary of the beta static survey results is presented in Table 4-1. A summary of removable beta and removable low energy beta results (via LSC) is presented in

Table 4-2.

Table 4-1: Fixed Contamination Survey Summary

Direct Static Count Result								
	Beta Result				Low Energy Beta Result			
SU[1]	Average (dpm/ 100cm^2)	Median (dpm/ 100cm^2)	Range (dpm/ 100cm^2)	Standard Deviation (dpm/ 100cm^2)	Average (dpm/ 100cm^2)	(Median) (dpm/ 100cm^2)	Range (dpm/ 100cm^2)	Standard Deviation (dpm/ 100cm^2)
3-1W	-28.82	-280.00	2240.00	672.35	171.33	-67.40	4336.74	1066.52
3-2W	-401.88	-350.00	4466.00	1145.09	-300.61	-210.98	1963.26	456.60
3-3E	-131.76	490.00	4340.00	1343.72	-689.64	-770.65	3150.00	796.44
30-1	859.76	595.00	6608.00	1652.32	-383.17	-553.81	2845.26	1015.58
30-roof	-2860.94	-3528.00	6090.00	1709.48	N/A[2]	N/A[2]	N/A[2]	N/A[2]
89	-567.41	-728.00	9870.00	2355.91	-536.40	-603.63	1289.30	331.76
NOTES:1)	SU=Survey Unit. 3-1W= Building 3, First Floor West, Rooms 131, 133, 134, 135, 136. 3-2W= Building 3, Second Floor West, Room 214. 3-3E= Building 3, Third Floor East, Rooms 307 and 309. 30-1= Building 30, Rooms 101, 103, 108. 30-roof= Building 30, Roof over Room 108. 89= Building 89							
2)	N/A= Scan not performed. Data Not Available							

Table 4-2: Removable Contamination Survey Summary

	Smear Count Result									
	Beta Result					Low Energy Beta Result				
SU[1]	Number of Samples	Average (dpm/ 100cm^2)	Standard Deviation	Max (dpm/ 100cm^2)	# exceed SL[2]	Number of Samples	Average (dpm/ 100cm^2)	Standard Deviation	Max (dpm/ 100cm^2)	# exceed SL[2]
3-1W	17	-1.04	2.5	3.1	0	17	-5.7	3.2	0.22	0
3-2W	19	-0.50	1.92	3.6	0	19	-2.10	3.9	6.4	0
3-3E	17	-0.16	1.28	2.2	0	17	3.8	2.9	8.4	0
30-1	20	297	1267	5,372	0	20	265	1136	4,817	0
30-roof	18	-0.63	1.60	4.0	0	18	1.15	3.1	5.6	0
89	17	3.2	3.9	10.4	0	17	7.5	10.5	30.2	0

NOTES:1) SU=Survey Unit. 3-1W= Building 3, First Floor West, Rooms 131, 133, 134, 135, 136. 3-2W= Building 3, Second Floor West, Room 214. 3-3E= Building 3, Third Floor East, Rooms 307 and 309. 30-1= Building 30, Rooms 101, 103, 108. 30-roof= Building 30, Roof over Room 108. 89= Building 89

2) Number of Net Sample Results Exceeding NRC Default Screening Limit(SL):
Beta = 360,000 dpm / 100cm^2
19 keV Beta = 12,000,000 dpm / 100cm^2

4.1.1 Building 3, First Floor West, Rooms 131, 133, 134, 135, 136

A surface scan was performed over at least 10% of floors and walls in Building 3, Rooms 131, 133, 134, 135, and 136. No significant areas of elevated activity were identified during scan surveys.

The integrated measurement fixed alpha results averaged 7.24 dpm/100 cm^2 with a standard deviation of 26.8 dpm/100 cm^2 and a maximum of 90.8 dpm/100 cm^2. The integrated measurement fixed beta results averaged -28.8 dpm/100 cm^2 with a standard deviation of 672 dpm/100 cm^2 and a maximum of 1400 dpm/100 cm^2. Surface screening limits were not exceeded. Complete results are presented in Appendix B.

Integrated low-energy beta activity measurements were also performed at each measurement location. The low-energy beta screening limit was not exceeded in any measurement location, and no survey areas were identified as exhibiting elevated low-energy beta activity.

The integrated measurement low-energy beta activity results averaged 171 dpm/100 cm^2 with a maximum of 3110 dpm/100 cm^2 and a standard deviation of 1067 dpm/100 cm^2. The low-energy beta activity measurement results are presented in Appendix B.

Smears were collected at each integrated measurement location, sent offsite to Paragon Analytics, and analyzed for project ROCs ^3H and ^{14}C. The maximum ^3H smear result was 0.2 dpm/100 cm^2. The maximum ^{14}C smear result was 3.1 dpm/100 cm^2. Transferable activity screening limits were not exceeded for smear results. Smear data results are presented in Appendix C.

4.1.2 Building 3, Second Floor West, Room 214

A surface scan was performed over at least 10% of floors and walls in Building 3, Room 214. No significant areas of elevated activity were identified during scan surveys.

The integrated measurement fixed alpha results averaged 7.15 dpm/100 cm^2 with a standard deviation of 14.4 dpm/100 cm^2 and a maximum of 55.7 dpm/100 cm^2. The integrated measurement fixed beta results averaged -411 dpm/100 cm^2 with a standard deviation of 1150dpm/100 cm^2 and a maximum of 1950 dpm/100 cm^2. Surface screening limits were not exceeded. Complete results are presented in Appendix B.

Integrated low-energy beta activity measurements were also performed at each measurement location. The low-energy beta screening limit was not exceeded in any measurement location, and no survey areas were identified as exhibiting elevated low-energy beta activity.

The integrated measurement low-energy beta activity results averaged -301 dpm/100 cm^2 with a maximum of 610 dpm/100 cm^2 and a standard deviation of 457 dpm/100 cm^2. The low-energy beta activity measurement results are presented in Appendix B.

Smears were collected at each integrated measurement location, sent offsite to Paragon Analytics, and analyzed for project ROCs ^3H and ^{14}C. The maximum ^3H smear result was 6.4 dpm/100 cm^2. The maximum ^{14}C smear result was 3.6 dpm/100 cm^2. Transferable activity screening limits were not exceeded for smear results. Smear data results are presented in Appendix C.

4.1.3 Building 3, Third Floor East, Rooms 307 and 309

A surface scan was performed over at least 10% of floors and walls in Building 3, Rooms 307 and 309. No significant areas of elevated activity were identified during scan surveys.

The integrated measurement fixed alpha results averaged 2.07 dpm/100 cm^2 with a standard deviation of 14.2 dpm/100 cm^2 and a maximum of 32.2 dpm/100 cm^2. The integrated measurement fixed beta results averaged -132 dpm/100 cm^2 with a standard deviation of 1344 dpm/100 cm^2 and a maximum of 1610 dpm/100 cm^2. Surface screening limits were not exceeded. Complete results are presented in Appendix B.

Integrated low-energy beta activity measurements were also performed at each measurement location. The low-energy beta screening limit was not exceeded in any measurement location, and no survey areas were identified as exhibiting elevated low-energy beta activity.

The integrated measurement low-energy beta activity results averaged -690 dpm/100 cm^2 with a maximum of 519 dpm/100 cm^2 and a standard deviation of 769 dpm/100 cm^2. The low-energy beta activity measurement results are presented in Appendix B.

Smears were collected at each integrated measurement location, sent offsite to Paragon Analytics, and analyzed for project ROCs ^{3}H and ^{14}C. The maximum ^{3}H smear result was 8.4 dpm/100 cm^2. The maximum ^{14}C smear result was 2.2 dpm/100 cm^2. Transferable activity screening limits were not exceeded for smear results. Smear data results are presented in Appendix C.

4.1.4 Building 30, Rooms 101, 103, 108

A surface scan was performed over at least 10% of floors and walls in Building 30, Rooms 101, 103, and 108. No significant areas of elevated activity were identified during scan surveys.

The integrated measurement fixed alpha results averaged 13 dpm/100 cm^2 with a standard deviation of 13.6 dpm/100 cm^2 and a maximum of 41 dpm/100 cm^2. The integrated measurement fixed beta results averaged 860 dpm/100 cm^2 with a standard deviation of 1650 dpm/100 cm^2 and a maximum of 4960 dpm/100 cm^2. Surface screening limits were not exceeded. Complete results are presented in Appendix B.

Integrated low-energy beta activity measurements were also performed at each measurement location. The low-energy beta screening limit was not exceeded in any measurement location, and no survey areas were identified as exhibiting elevated low-energy beta activity.

The integrated measurement low-energy beta activity results averaged -383 dpm/100 cm^2 with a maximum of 1210 dpm/100 cm^2 and a standard deviation of 1020 dpm/100 cm^2. The low-energy beta activity measurement results are presented in Appendix B.

Smears were collected at each integrated measurement location, sent offsite to Paragon Analytics, and analyzed for project ROCs ^{3}H and ^{14}C. The maximum ^{3}H smear result was 4817 dpm/100 cm^2. The maximum ^{14}C smear result was 5372 dpm/100 cm^2. Transferable activity screening limits were not exceeded for smear results. Smear data results are presented in Appendix C.

4.1.5 Building 30, Roof over Room 108

A surface scan was performed on the outside and top of the stack roof on the roof above room 108 in Building 30. No significant areas of elevated activity were identified during scan surveys.

The integrated measurement fixed alpha results averaged -4.48 dpm/100 cm^2 with a standard deviation of 13.5 dpm/100 cm^2 and a maximum of 20.5 dpm/100 cm^2. The integrated measurement fixed beta results averaged -2860 dpm/100 cm^2 with a standard deviation of 1710dpm/100 cm^2 and a maximum of 1930 dpm/100 cm^2. Surface screening limits were not exceeded. Complete results are presented in Appendix B.

Smears were collected at each integrated measurement location, sent offsite to Paragon Analytics, and analyzed for project ROCs ^{3}H and ^{14}C. The maximum ^{3}H smear result was 5.6 dpm/100 cm^2. The maximum ^{14}C smear result was 4.0 dpm/100 cm^2. Transferable activity screening limits were not exceeded for smear results. Smear data results are presented in Appendix C.

4.1.6 Building 89

A surface scan was performed over at least 10% of floors and walls in Building 89. No significant areas of elevated activity were identified during scan surveys.

The integrated measurement fixed alpha results averaged -6.21 dpm/100 cm^2 with a standard deviation of 13.9 dpm/100 cm^2 and a maximum of 35.2 dpm/100 cm^2. The integrated measurement fixed beta results averaged -567 dpm/100 cm^2 with a standard deviation of 2360 dpm/100 cm^2 and a maximum of 4310 dpm/100 cm^2. Surface screening limits were not exceeded. Complete results are presented in Appendix B.

Integrated low-energy beta activity measurements were also performed at each measurement location. The low-energy beta screening limit was not exceeded in any measurement location, and no survey areas were identified as exhibiting elevated low-energy beta activity.

The integrated measurement low-energy beta activity results averaged –536 dpm/100 cm^2 with a maximum of 114 dpm/100 cm^2 and a standard deviation of 332 dpm/100 cm^2. The low-energy beta activity measurement results are presented in Appendix B.

Smears were collected at each integrated measurement location, sent offsite to Paragon Analytics, and analyzed for project ROCs ^{3}H and ^{14}C. The maximum ^{3}H smear result was 30.2 dpm/100 cm^2. The maximum ^{14}C smear result was 10.4 dpm/100 cm^2. Transferable activity screening limits were not exceeded for smear results. Smear data results are presented in Appendix C.

4.1.7 Biased Surveys

During the course of the FSS, biased surveys were performed in areas of elevated activity identified during the beta/gamma scans and suspect areas per professional judgment of surveyors. One area of these biased surveys identified fixed and removable beta activity clearly distinguishable from background – a small area (about 100 cm^2) on a wall surface located in Room 103 of Building 30. Both fixed and removable beta activity measurements were well below project DCGLs, so there was no impact on the FSS design as provided in the FSSP. However, a decontamination effort was later performed on the area by RDECOM personnel for ALARA purposes. CABRERA personnel later returned to resurvey the cleaned area. The original and post-decontamination measurement data is presented in the Table 4-3.

Table 4-3: Room 103 Biased Survey Results

Original Condition				
ID	C-14		H-3	
	Fixed	Removable	Fixed	Removable
	dpm/100 cm^2	dpm/100 cm^2	dpm/100 cm^2	dpm/100 cm^2
30-1-18	4,129.20	5,372.4	17,239.60	4817.4
Post-Decontamination				
ID	C-14		H-3	
	Fixed	Removable	Fixed	Removable
	dpm/100 cm^2	dpm/100 cm^2	dpm/100 cm^2	dpm/100 cm^2
30-1-19	4,099.20	6.2	7,861.60	4.0
30-1-20		6.2		8.2
Average		6.2		6.2

4.2 MARSSIM-Based Evaluation of FSS Results

FSS results were evaluated in accordance with MARSSIM guidance. No net sample result exceeded the $DCGL_w$ for each ROC and therefore comparison to the DCGL elevated measurement criteria, $DCGL_{EMC}$, is not required.

4.2.1 Sign Test

As described in Section 3.3, the Sign Test is used to statistically evaluate whether a SU meets release criteria when one or more samples exceed the $DCGL_w$, but the average does not, and the $DCGL_{EMC}$ is not exceeded. Since no survey measurement in the FSS exceeded the $DCGL_{W,}$ accounting for material-specific background, Sign Tests were not required. Therefore, building survey areas included in the field efforts at the Natick SSC are suitable for unrestricted release.

5.0 QUALITY ASSURANCE/QUALITY CONTROL

Field activities conducted as part of the decommissioning effort were performed in accordance with written procedures and/or protocols in order to ensure consistent, repeatable results. Data generated during the FSS met the Quality Assurance (QA)/Quality Control (QC) requirements outlined in the *FSSP* (CABRERA, 2006a).

5.1 Survey Instrumentation Quality Control

The CABRERA Project Health Physicist (HP) was responsible for determining the instrumentation required to complete the requirements of this FSS. Only instrumentation approved by the CABRERA Project HP was used to collect radiological data. The CABRERA Project HP was responsible for ensuring individuals were appropriately trained to use project instrumentation and other equipment, and that instrumentation met the required detection sensitivities. Instrumentation were operated in accordance with either a written procedure or manufacturers' manual, as determined by the CABRERA Project HP. The procedure and/or manual provided guidance to field personnel on the proper use and limitations of the instrument.

5.1.1 Calibration Requirements

Instruments used during project performance had current calibration and maintenance records on site for review and inspection. The records included the following:

- name of the equipment
- equipment identification (model and serial number)
- manufacturer
- date of calibration
- calibration due date

Instrumentation was maintained and calibrated to manufacturers' specifications to ensure that required traceability, sensitivity, accuracy and precision of the equipment/instruments were maintained. Instruments were under current calibration. The calibration records for each instrument used during this characterization survey are presented in Appendix E.

5.1.2 Instrument QC Source Checks

Prior to daily use, project instrumentation was QC checked by comparing instrument response to a benchmark response. Prior to the commencement of field operations, site reference locations were selected for performance of these checks; subsequent QC checks were performed at these locations. QC source checks consisted of a one-minute integrated count with the designated source positioned in a reproducible geometry performed at the reference location. Prior to the start of initial surveys, this procedure was repeated at least ten times to establish average instrument response. The QC results for each instrument used during this characterization survey are presented in Appendix E.

5.1.2.1 Direct Radiation Measurement Instrumentation QC

Instrument responses to designated QC check sources were recorded and evaluated against the average established at the start of the field activities. An acceptance criterion of ± 20% was required for direct measurement detectors. A QC count outside the respective screening limit would require informing the Project Manager (PM), or designee, a detector evaluation, and could have resulted in the detection system being removed from service for corrective action. Direct measurement detectors that were used during field activities passed QC evaluations daily. The QC results for each instrument used during this characterization survey are presented in Appendix E.

6.0 HEALTH AND SAFETY

Health and safety measures were employed during conduct of FSS activities, in accordance with the project Site Safety and Health Plan (CABRERA, 2005b).

6.1 General Health and Safety Measures

Daily health and safety activities were performed in accordance with the project Health and Safety Plan, including conducting Daily Tailgate Safety meetings, prior to the performance of survey activities each day. These daily safety meetings allowed for discussion of daily safety measures required based on the activities planned for each day. Daily Safety Tailgate Meeting records are provided in Appendix F. The Site Safety and Health Plan was reviewed by CABRERA project personnel prior to the performance of characterization survey activities. No reported injuries took place during the characterization survey field effort.

6.2 Radiological Health and Safety Measures

General radiological health and safety measures were performed in accordance with the project Site Safety and Health Plan (CABRERA, 2005b) and CABRERA Standard Operating Procedures (SOPs).

7.0 SUMMARY OF RESULTS AND CONCLUSIONS

Final Status Surveys were conducted at the Natick SSC in accordance with MARSSIM guidance. Surveys were performed in 6 different SUs that had a history of radiological use. Survey areas were separated into six distinct Class 3 SUs. None of the FSS analytical sample results, as presented in Appendix D, exceeded the $DCGL_w$. Data obtained from this FSS effort support the release of this site for unrestricted use.

8.0 REFERENCES

CABRERA, 2006a. *Final Status Survey Plan: U.S. Army Soldier Systems Center – Natick, Massachusetts*. Cabrera Services, Inc. November 2006.

CABRERA, 2006b. *Health and Safety Plan: U.S. Army Soldier Systems Center – Natick, Massachusetts*. Cabrera Services, Inc. November 2006.

NRC, 1998. *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions.* NUREG-1507. Nuclear Regulatory Commission. June 1998.

NRC, 1999. *Residual Radioactive Contamination from Decommissioning, Parameter Analysis*. NUREG-CR-5512, Volume 3. U.S. Nuclear Regulatory Commission. October 1999.

NRC, 2000a. *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM), NUREG-1575. U.S. Nuclear Regulatory Commission, U.S. Department of Defense, U.S. Environmental Protection Agency, and U.S. Department of Energy. August 2000.

NRC, 2003a. *Consolidated NMSS Decommissioning Guidance: Characterization, Survey, and Determination of Radiological Criteria*. NUREG-1757, Vol. 1. U.S. Nuclear Regulatory Commission. September 2003.

NRC, 2003b. *Consolidated NMSS Decommissioning Guidance: Characterization, Survey, and Determination of Radiological Criteria*. NUREG-1757, Vol. 2. U.S. Nuclear Regulatory Commission. September 2003.